Department of Energy
Washington, DC 20585

March 2, 2016

Attention: Document Control Desk
Steve Ruffin, Acting Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Storage and Transportation,
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Dear Steve Ruffin:

The U.S. Department of Energy (DOE) is requesting renewal and amendment of U. S. Nuclear Regulatory Commission Certificate of Compliance (CoC) Number 9315, for the Model ES-3100 package (NRC Docket 71-9315). The current certificate, Revision 12, expires April 30, 2016 and DOE has a continued programmatic need for this package. This request meets the "timely renewal" requirements of 10 CFR 71.38(b).

There were no changes to the packaging design since the last revision of the CoC. However, this request includes a minor content change to increase the mass of Teflon bottles used for shipping highly enriched uranium (HEU) crystals. The package continues to meet the requirements of 10 CFR Part 71.

This application submission includes one paper copy and one electronic copy on CD media of the following documents:

- This Transmittal Letter
- Enclosure 1 – List of Page Changes from Safety Analysis Report (SAR) Revision 4 to Revision 5, with a description and basis for each change
- Enclosure 2 – Mark-up of the Certificate of Compliance Revision 12 proposed for Revision 13
- Enclosure 3 - *Safety Analysis Report, Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents*, Y/LF-717, Revision 5, which incorporates:
  - the supplement dated October 15, 2014,
  - updates to implement administrative changes to the license drawings and change of the Y-12 contractor preparing the SAR from B&W-Y12, LLC to Consolidated Nuclear Security, LLC, and
  - Increasing the mass of Teflon bottles allowed for shipping HEU crystals.

Note – SAR Rev 5 is a clean copy, that is, with no change bars in the page margins.

One CD will also be mailed directly to Project Manager, Pierre Saverot.

NMSS24

DOE also requests NRC, for the benefit of the package users, to include on the CoC in the References section the "SAR document number and revision" corresponding to the application date in block 3.b., page one, of the CoC.

If you have any questions or need more details please call at 301-903-5513 or james.shuler@em.doe.gov.

James M. Shuler
Manager, DOE Packaging Certification Program
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Office of Packaging and Transportation
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Applicant Mark-up 3/30/2016

2. PREAMBLE

a. This certificate is issued to certify that the package (packaging and contents) described in Item 5 below meets the applicable safety standards set forth in Title 10, Code of Federal Regulations, Part 71, "Packaging and Transportation of Radioactive Material."

b. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. THIS CERTIFICATE IS ISSUED ON THE BASIS OF A SAFETY ANALYSIS REPORT OF THE PACKAGE DESIGN OR APPLICATION

a. ISSUED TO *(Name and Address)*

U.S. Department of Energy
Washington, DC 20585

b. TITLE AND IDENTIFICATION OF REPORT OR APPLICATION

~~BWXT Y-12, L.L.C., application dated March 3, 2011~~; as ~~supplemented.~~ Consolidated Nuclear Security, L.L.C., application dated March 24, 2016

4. CONDITIONS

This certificate is conditional upon fulfilling the requirements of 10 CFR Part 71, as applicable, and the conditions specified below.

5.

(a) Packaging

(1) Model No.: ES-3100

(2) Description

The ES-3100 package is a cylindrical container that is approximately 110 cm (43 in) in overall height and 49 cm (19 in) in overall diameter and is composed of an outer drum assembly and an inner containment vessel. The containment vessel is placed inside the drum and surrounded by a cement based borated neutron absorber, Catalog 277-4. The purpose of the ES-3100 is to transport bulk high enriched uranium in various forms.

The outer drum assembly consists of a reinforced stainless steel, standard mil spec 30-gal drum with an increased length. The volume formed between the drum and the attached inner liner is filled with an inorganic, castable refractory material, Kaolite 1600™, which is comprised of concrete and vermiculite. The Kaolite 1600™ acts as both a thermal insulating and an impact limiting material.

The containment vessel is approximately 82 cm (32 in) in overall height and 13 cm (5 in) in overall diameter and is constructed of 304L stainless steel. The containment boundary consists of the 0.1 in thick containment vessel body and the lid assembly. The lid assembly consists of a sealing lid, a closure nut, and external retaining ring, which holds both the assembly and closure nut together. The double ethylene-propylene elastomer O-rings in the top flange of the containment vessel permit leak testing of the containment vessel. The maximum gross weight of the package, including contents, is 190.5 kg (420 lb).

5.(a) Packaging (continued)

(3) Drawings

The Model No. ES-3100 package is constructed and assembled in accordance with:

(i) ~~BWXT Y-12, L.L.C.,~~ Drawing No. M2E801580A037, sheets 1 through 6, Rev. C, "Consolidated Assembly Drawing."

(ii) BWXT Y-12, L.L.C., Drawing No. M2E801580A026, Rev. C, "Heavy Can Spacer Assembly."

(ii) ~~(iii)~~ Equipment Specification JS-YMN3-801580-A001, Rev. ~~F~~ G, "ES-3100 Containment Vessel."

(iii) ~~(iv)~~ Equipment Specification JS-YMN3-801580-A002, Rev. D, "ES-3100 Drum Assembly."

(iv) ~~(v)~~ Equipment Specification JS-YMN3-801580-A003, Rev. C, "Manufacturing Process Specification for Casting Kaolite 1600™ into the ES-3100 Shipping Package."

(v) ~~(vi)~~ Equipment Specification JS-YMN3-801580-A005, Rev. G, "Casting Catalog No. 277-4 Neutron Absorber for the ES-3100 Shipping Package."

(vi) ~~(vii)~~ ~~BWXT Y-12, L.L.C.,~~ Drawing No. M2E801580-A043, Rev. ~~0~~ B, "Heavy Can Spacer Assembly (SST)."

5.(b) Contents (Type and form of material, maximum quantity of material per package, and Criticality Safety Index (CSI)).

The weight of the radioactive contents, convenience containers, can lift attachments, polyethylene bags, spacers, and other material in the containment vessel shall not exceed 90 lb. The maximum mass of off-gassing packaging materials in the containment vessel (e.g., polyethylene containers or bagging, silicone rubber pads, nylon bags, etc.) shall not exceed 500 grams. The maximum content decay heat load shall not exceed 0.4 watts.

With the use of Teflon bottles as convenience containers, an additional ~~990~~ 1200 g of off-gassing material is authorized in the containment vessel. The additional ~~990~~ 1200 g must be Teflon (e.g., three Teflon bottles weighing ~~330~~ 400 g each). With Teflon bottles, the maximum mass of off-gassing materials is ~~1490~~ 1600 g: ~~990~~ 1200 g Teflon and ~~500~~ 400 g of any type of ~~hydrogenous~~ off-gassing packaging material. ~~except in the case of shipping uranium in the form of broken metal, in which case the hydrogenous material must have a hydrogen atom density less than or equal to that of water.~~

New ¶ In the case of shipping uranium in the form of broken metal, hydrogenous materials used in the containment vessel must have a hydrogen atom density less than or equal to that of water.

5.(b) Contents (continued)

The concentration limits of uranium and transuranic constituents shall be the following:

Isotope	Maximum Concentration
U-232	0.040 μg/gU[a]
U-233	0.006 g/gU[b]
U-234	0.02 g/gU
U-235	1.00 g/gU
U-236	0.40 g/gU
Transuranics (except Np)	40.0 μg/gU
Np-237	0.025 g/gU

[a] μg/gU = 10^{-6} grams per gram of total uranium
[b] g/gU = grams per gram of total uranium

(1) Uranium as solid metal or alloy, packaged in stainless-steel or tin-plated carbon steel convenience cans. Alloys of uranium include uranium-aluminum, uranium-molybdenum, and uranium-zirconium. Mass of the non-uranium portion of the alloy shall be assumed to be uranium-235.

The maximum uranium enrichment is 100 weight percent U-235.

For contents that must be shipped with spacers, the spacers must be in accordance with BWXT Y-12, L.L.C., Drawing No. M2E801580A026 or M2E801580A043, and Equipment Specification JS-YMN3-801580-A005, as specified in Condition No. 5.(a)(3). The quantity of fissile material in any convenience can shall not exceed one third of the mass loading limit per package for that content. Spacers must be positioned between every two convenience cans, or in the case of shipping one convenience can only, the spacer must be positioned on top of the single can.

(i) For metal and alloy in the form of solid geometric shapes, meeting the following restrictions, mass limits are listed in Table 1. Contents not meeting the following restrictions must be shipped as broken metal (see Condition No. 5.(b)(1)(ii)).

(A) Cylinders having a diameter no larger than 4.25 in (maximum of one cylinder per convenience can)

(B) Square bars having a cross section no larger than 2.29 in × 2.29 in (maximum of one bar per convenience can)

(C) Slugs having dimensions of 1.5 in diameter × 2 in tall (maximum of 10 slugs per convenience can)

5.(b)(1) Contents (continued)

Table 1: Loading Limits for Metal and Alloy in Solid Geometric Shapes

Solid uranium metal or alloy (specified geometric shapes)	Uranium Enrichment (weight percent U-235)	CSI	With Spacers Maximum Mass U-235 (kg)		No Spacers Maximum Mass U-235 Per Package (kg)
			Per Convenience Can	Per Package	
Cylinders (3.24 in.< diameter ≤ 4.25 in.)	≤ 100	0.0	8.333	25.000	15.000
Cylinders (diameter ≤ 3.24 in.)	≤ 100	0.0	10.000	30.000	18.000
Square Bars	≤ 100	0.0	11.733	35.200	30.000
Slugs	≤ 95	0.0	–		17.374
Slugs	> 80 and ≤ 95	0.0	8.108	24.324	Spacer req'd
Slugs	> 80 and ≤ 95	0.4	11.583	34.749	Spacer req'd
Slugs	≤ 80	0.0	9.773	29.318	Spacer req'd

(ii) For metal and alloy defined as broken metal, mass limits are specified in Table 2. Uranium metal and alloy pieces must have a surface-area-to-mass ratio of not greater than 1.00 cm^2/g or must not pass freely through a 3/8-inch (0.0095m) mesh sieve. The uranium metal must also have had no more than a limited contact with water and been subsequently dried. Particles and small shapes that do not pass this size restriction, as well as powders, foils, turnings, and wires, are not permitted, unless they are in a sealed container under an inert cover gas. Uranium material or alloy which has been stored in water or is visibly wet at the time of packaging is not authorized to be shipped in this package.

5.(b)(1) Contents (continued)

Table 2: Loading Limits for Solid Metal or Alloy in the Form Defined as Broken Metal

Uranium Enrichment (weight percent U-235)	CSI	With Spacers Maximum Mass U-235 (kg)[a]		No Spacers Maximum Mass U-235 Per Package (kg)[a]
		Per Convenience Can	Per Package	
> 95 and ≤ 100	0.0	0.925	2.774	Spacer req'd
	0.4	1.850	5.549	Spacer req'd
	0.8	3.083	9.248	Spacer req'd
	2.0	4.624	13.872	Spacer req'd
	3.2	8.323	24.969	Spacer req'd
> 90 and ≤ 95	0.0	1.172	3.516	Spacer req'd
	0.4	2.051	6.154	Spacer req'd
	0.8	3.516	10.549	Spacer req'd
	2.0	6.154	18.461	Spacer req'd
	3.2	8.791	26.373	Spacer req'd
> 80 and ≤ 90	0.0	1.111	3.333	Spacer req'd
	0.4	2.500	7.500	Spacer req'd
	0.8	4.167	12.500	Spacer req'd
	2.0	6.667	20.000	Spacer req'd
	3.2	9.445	28.334	Spacer req'd
> 70 and ≤ 80	00	1.483	4.450	2.967
	0.4	2.967	8.900	5.192
	0.8	5.439	16.317	8.900
	2.0	8.406	25.218	17.059
	3.2	9.395	28.184	~~27.692~~ 27.443

Uranium Enrichment (weight percent U-235)	CSI	With Spacers Maximum Mass U-235 (kg)[a]		No Spacers Maximum Mass U-235 Per Package (kg)[a]
		Per Convenience Can	Per Package	
> 60 and ≤ 70	0.0	1.733	5.198	3.249
	0.4	4.332	12.996	5.848
	0.8	6.931	20.793	13.646
	2.0	8.231	24.692	21.444
	3.2	8.231	24.692	24.692
≤ 60	0.0	3.718 kgU	11.154 kgU	5.576 kgU
	0.4	9.604 kgU	28.813 kgU	14.872 kgU
	0.8	11.733 kgU	35.200 kgU	28.814 kgU
	2.0	11.733 kgU	35.200 kgU	35.200 kgU
	3.2	11.733 kgU	35.200 kgU	35.200 kgU

[a] All limits are expressed in kg U-235 unless specified as kgU, which means kilograms of total uranium.

(2) Uranium as oxide, which may include UO_2, UO_3, and U_3O_8, packaged in stainless-steel, tin-plated carbon steel, or nickel-alloy convenience cans, or polyethylene bottles. The physical form of all contents is dense, loose powder which may contain clumps and pellets. Moisture content in oxide is limited to 3 weight percent water. Carbide compounds are not authorized. Two types of loading are authorized:

(i) A mass limit of 15.13 kg of oxide, with a maximum mass of 9.682 kg U-235 and 921 g carbon, with a CSI of 0.0.
(ii) A mass limit of 15.13 kg oxide, with a maximum mass of 12.32 kg U-235 and no carbon, with a CSI of 0.4.

The maximum uranium enrichment is 100 weight percent U-235. No spacers are required in the containment vessel. Shipments of oxide must be complete within 12 months of sealing the containment vessel.

(3) Solid uranyl nitrate in the form of uranyl nitrate crystals, UN_x, and $[UO_2(NO_3)_2 \cdot xH_2O$, where x is ≤ 6]. Uranyl nitrate crystals must be contained in a non-metallic convenience container (such as Teflon bottles). The mass limits are specified in Table 3. The maximum uranium enrichment is 100 weight percent U-235. No spacers are required in the containment vessel.

5.(b)(3) Contents (continued)

Table 3: Loading Limits for Solid Uranyl Nitrate Crystals

UNx (X value)	Seal Time[a] (months)	CSI	UNx loading limit (kg)	U Content (wt %)
> 0 and ≤3	2	0.4	11.90	> 52 and ≤ 61
	4	0.4	6.70	> 52 and ≤ 61
> 3 and ≤ 6	2	0.4	9.17	> 46 and ≤ 52
	4	0.0	4.75	> 46 and ≤ 52

a. Seal time is the length of time after the containment vessel is sealed that the shipment must be complete.

(4) Unirradiated TRIGA fuel elements and pellets (sections). The fuel is composed of uranium zirconium hydride (UZrH). The uranium concentration in the fuel is a nominal 8.5 weight percent, and the maximum H to Zr ratio in the fuel is 2.0. The maximum uranium enrichment is 70 weight percent U-235. The fuel sections may be from any of three types of fuel elements: standard fuel elements, instrumented standard fuel elements, and fuel follower control rods. The U-235 mass for standard and instrumented fuel elements is a nominal 136 grams per element, and the U-235 mass for fuel follower control rods is a nominal 112 grams per element. Each fuel element contains three fuel sections, either stainless steel or aluminum clad or unclad. The fuel elements are approximately 15 inches in length, with sections approximately 5 inches in length; the approximate diameter of the fuel is 1.44 inches for the standard and instrumented fuel elements, and 1.31 inches for the fuel follower control rods. The fuel elements and sections are packaged within stainless steel or tin-plated carbon steel convenience cans. Disassembled fuel elements are to be packaged with a maximum of three fuel sections, or three fuel elements, per convenience can. Fuel sections from different fuel elements may not be mixed within a single convenience can. A maximum of three convenience cans with disassembled fuel elements may be loaded into a single package. Three stainless steel or aluminum clad elements with crimped ends are to be packaged in a single convenience can with a maximum of one can per package. No spacers are required. The maximum quantity of fissile material per package is 408 grams U-235. The CSI is 0.0.

6. The vent holes on the outer steel drum shall be capped closed during transport and storage to preclude entry of rain water into the insulation cavity of the drum.

7. Content forms may not be mixed in a single ES-3100 containment vessel.

8. Any combination of convenience can sizes is allowed in a single package, as long as the total height of the can stack (including silicone rubber pads and spacers, if required) does not exceed the inside working height of the containment vessel (31 in). Any closure on the convenience can is allowed.

9. Empty convenience cans, spacers, silicone rubber pads, and/or stainless-steel scrubbers (i.e., stainless steel trimmings that act as dunnage) may be used to fill the void space in the containment vessel. Empty convenience cans must have a minimum 0.125 in diameter hole through the lid.

10. The contents and the convenience cans may be bagged or wrapped in polyethylene or nylon for contamination control provided the limits of Condition No. 5.(b) are met.

11. The mass of unidentified constituents in the content to be shipped shall be counted against the fissile mass loading limit. Content shall not contain unevaluated moderating materials.

12. Transport by air is not authorized, except for shipment of unirradiated TRIGA fuel pellets, as described and limited in Condition No. 5(b)(4).

13. In addition to the requirements of Subpart G of 10 CFR Part 71:

    (a) The package shall be prepared for shipment and operated in accordance with the Package Operations in Section 7 of the application (with the exception of the uranyl nitrate shipping times in Section 7.1.3.3 of the SAR). The uranyl nitrate shipping times shall be in accordance with Condition 5.(b)(3).

    (b) Each package must meet the Acceptance Tests and Maintenance Program of Section 8 of the application.

    (c) Either one or two Tamper Indicating Devices (TIDs) may be used for compliance with 10 CFR 71.43(b), as long as the TID(s) attach through both TID lugs.

14. The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.

15. Expiration date: April 30, 20~~16~~ 21.

16. Revision 12 of this certificate may be used until April 30, 2017.

REFERENCES

Consolidated Nuclear Security ~~BWXT Y-12~~, L.L.C., application dated March ~~3, 2011~~ 24, 2016.
U.S. Department of Energy letter dated ~~May 14, 2012~~ March 2, 2016.

~~As supplemented: October 15, 2014.~~

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

/RA/

Michele Sampson, Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

Date: December 8, 2014

Enclosure 1

List of Changes

Y/LF-717, *Safety Analysis Report, Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents*

Revision 5

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List of Changes, ES-3100 HEU SAR (Y/LF-717, Rev. 5)

Page	Description of Change
	Front Matter
Front covers	Reformatted front covers to reflect the new contractor report cover, document date, and contractor name change.
i	Revised title page to reflect the revised document date and contractor name change.
iii	Updated Approvals page
v	Revised Table of Contents for Apps. 1.4.9, 1.4.10, and 1.4.11.
xxvii	Added Rev. 5 information to the Revision Log.
xxviii	Added blank page.
	Section 1
1-1	Deleted occurrence of B&W in Sect. 1.1.
1-4	Corrected thickness of the third tier height in Sect. 1.2.1.1 from "5.99 cm (2.36 in.)" to "3.00 cm (1.18 in.)."
1-6	Updated the contract number and contractor name in Sect. 1.2.1.2.
1-15	Corrected mass limit in Table 1.3 for broken HEU metal or alloy (>70, ≤80% enrichment, CSI=3.2) from 27.692 kg to 27.443 kg ^{235}U to be consistent with the results presented in Tables 6.1c and 6.9.1.1 for Case ncf5bmt11_35_1_5_3.
1-16	Removed the reference to the carbon-steel can spacer Drawing M2E801580A026 in Footnote d of Table 1.3. Revised the seal times presented in Table 1.3a to be consistent with U.S. NRC Certificate of Compliance 9315, Rev. 12. Revised Footnote c in Table 1.3a to indicate the seal times have been reduced for additional conservatism compared to the calculated values shown in Table 3.6.7.1.
1-22	Revised Sect. 1.2.3.4 to remove the carbon-steel can spacer option. Increased the total mass of offgassing material from 1490 g to 1600 g in Sect. 1.2.3.4 when Teflon bottles are used as convenience containers.
1-23	Revised the mass of each Teflon bottle from 330 g to 400 g and decreased the polyethylene bagging mass from 500 g to 400 g in Sect. 1.2.3.4. Updated the maximum normal operating pressure from "198.98 kPa (28.859 psia)" to "98.84 kPa (14.336 psig) [200.20 kPa (29.036 psia)]" in Sect. 1.2.3.5.
1-24	Revised loading restriction (8) in Sect. 1.2.3.8 to increase the total mass of offgassing material from 1490 g to 1600 g when Teflon bottles are used as convenience containers.
1-27	Revised Appendices listing to include App. 1.4.11, Equipment Specification SPC M801580-0002, *ES-3100 Ethylene Propylene Diene Monomer (EPDM) Containment Vessel (CV) O-rings.*
1-55–1-66	Updated Equipment Specification JS-YMN3-801580-A001, *ES-3100 Containment Vessel,* from Rev. E to Rev. G.

List of Changes, ES-3100 HEU SAR (Y/LF-717, Rev. 5)

Page	Description of Change
1-137	Revised the engineering drawing listing to update the revisions for Drawings M2E801580A001, M2E801580A005, M2E801580A009, M2E801580A013, M2E801580A024, and M2E801580A043. Deleted the listing for Drawing M2E801580A026 to remove the carbon-steel can spacer option.
1-139	Updated Drawing M2E801580A001 from Rev. B to Rev. C.
1-149	Updated Drawing M2E801580A005 from Rev. D to Rev. E.
1-157	Updated Drawing M2E801580A009 from Rev. C to Rev. D.
1-167	Updated Drawing M2E801580A013 from Rev. B to Rev. D.
1-175	Updated Drawing M2E801580A024 from Rev. B to Rev. C.
1-177	Delete Drawing M2E801580A026 to remove the carbon-steel can spacer option. Renumbered the subsequent pages accordingly.
1-179	Updated Drawing M2E801580A043 from Rev. 0 to Rev. B.
1-229–1-246	Added Appendix 1.4.11, Equipment Specification, SPC M801580-0002, *ES-3100 Ethylene Propylene Diene Monomer (EPDM) Containment Vessel (CV) O-rings*.
1-247	Updated the revision for 10 CFR 71 and 49 CFR.
	Section 2
2-6	Revised the maximum differential pressure for NCT and HAC in the 10 CFR 71.43(c) Compliance section of Sect. 2.1.2.1.
2-11	Revised the maximum normal operating pressure and maximum internal pressure differential in Sect. 2.1.2.2.
2-14	Revised Table 2.7 Specifications row entry for the can spacers to remove the carbon-steel option.
2-17	Revised Table 2.8 three Teflon bottle configuration column entries consistent with the CVA 7 mass limits for Teflon bottles (i.e., 1200 g Teflon and 400 g polyethylene).
2-24	Revised the Analysis section of Sect. 2.2.2 to remove the carbon-steel can spacer option.
2-26	Corrected description for the polyethylene bags and bottles in Sect. 2.2.3.
2-28	Deleted former contractor name in Sect. 2.3.2.1.
2-29	Deleted former contractor name in Sect. 2.3.2.2.
2-30	Deleted two occurrences of the former contractor name in Sect. 2.3.2.2.
2-35	Revised the maximum regulatory reference air leakage rate in Sect. 2.6.
2-36	Revised three occurrences of the maximum internal pressure during NCT in Sect. 2.6.

List of Changes, ES-3100 HEU SAR (Y/LF-717, Rev. 5)

Page	Description of Change
2-37	Revised the maximum cyclic pressure differential from low to high temperature in Sect. 2.6. Revised the maximum internal pressure in Table 2.20. Revised two occurrences of the maximum internal pressure in the Analysis section of Sect. 2.6.1.
2-41	Revised the calculated pressure in the Hot conditions column heading of Table 2.21. Revised the Hot conditions column entries for the calculated stress or load and the corresponding margin of safety.
2-42	Revised the maximum pressure differential in the Analysis section of Sect. 2.6.3.
2-43	Revised the calculated pressure in the Reduced external pressure column heading of Table 2.22. Rrevised the Reduced external pressure column entries for the calculated stress or load and the corresponding margin of safety.
2-53	Revised one occurrence of the maximum normal absolute operating pressure in Sect. 2.7.
2-80	Revised the calculated pressure in the Thermal condition column heading of Table 2.51. Revised the Thermal condition column entries for the calculated stress or load and the corresponding margin of safety.
2-893	Updated the revision for 10 CFR 71 and 49 CFR.
	Section 3
3-16	Revised CVA 7 to increase the Teflon bottle mass to 400 g each and limited offgassing material to 1600 g.
3-17	Revised Table 3.10 row entries for CVA 7 molar quantities of gas and the total pressure. Revised assumption 5 and the following text in Sect. 3.1.4.1 to be consistent with the CVA 7 mass limits for Teflon bottles (i.e., 1200 g Teflon and 400 g polyethylene).
3-18	Corrected description for the polyethylene bags and bottles. Revised assumption 5 in Sect. 3.1.4.2 to be consistent with the CVA 7 mass limits for Teflon bottles.
3-19	Revised Table 3.11 row entries for CVA 7 molar quantities of gas and the total pressure. Updated the text to be consistent with the CVA 7 mass limits for Teflon bottles (i.e., 1200 g Teflon and 400 g polyethylene).
3-29	Revised Table 3.16 row entry for maximum containment vessel pressure and clarified Footnote d.
3-30	Revised Table 3.17 row entry for maximum containment vessel pressure and clarified Footnote b.
3-31	Revised two occurrences of the maximum normal operating pressure in Sect. 3.4.1.

List of Changes, ES-3100 HEU SAR (Y/LF-717, Rev. 5)

Page	Description of Change
3-33	Revised maximum calculated internal absolute pressure in the containment vessel in Sect. 3.4.2.
3-35	Revised occurrence of the maximum normal operating pressure in Sect. 3.5.1.
3-149	Updated revision listing for App. 3.6.4.
3-151	Revised CVA 7 to increase the Teflon bottle mass to 400 g each and limited offgassing material to 1600 g. Revised assumption 3 and 5 to be consistent with the CVA 7 mass limits.
3-152	Revised text to be consistent with the CVA 7 mass limits for Teflon and polyethylene.
3-153	Revised the calculated free volume for CVA 7.
3-154	Revised Table 1 row entries for CVA 7 void volumes. Revised Table 2 molar quantity of gas and volume entries.
3-155	Revised Table 4 row entry for CVA 7 mass of polyethylene material. Revised Table 5 row entries for CVA 7 to be consistent with the Teflon bottle mass limit.
3-156	Revised Table 6 CVA column entry and the row entries for CVA 7 to be consistent with the Teflon bottle mass limit. Updated the calculation for the molar quantity of water vapor in Sect. IV.
3-157	Clarified the text to indicate 'V_V' is the void volume of CVA 7.
3-158	Revised Table 7 row entries for CVA 7 molar quantities of gas and the total pressure.
3-159	Updated revision listing for App. 3.6.5.
3-161	Revised CVA 7 to increase the Teflon bottle mass to 400 g each and limited offgassing material to 1600 g. Revised assumption 3 and 5 to be consistent with the mass limits.
3-162	Revised text to be consistent with the mass limits for Teflon and polyethylene. Revised Table 1 row entries for CVA 7 molar quantities of gas and the total pressure.
3-163	Revised Table 2 row entries for CVA 7 molar summary.
3-164	Revised Table 4 row entry for CVA 7 mass of polyethylene material. Revised Table 5 row entries for CVA 7 to be consistent with the Teflon bottle mass limit.
3-165	Revised Table 6 CVA column entry and the row entries for CVA 7 to be consistent with the Teflon bottle mass limit. Updated the calculation for the molar quantity of water vapor in Sect. IV.
3-166	Clarified the text to indicate 'n_{WV}' is the molar quantity for water vapor and 'V_V' is the void volume of CVA 7. Revised Table 7 row entries for CVA 7 molar quantities of gas and the total pressure.
3-349	Updated the revision for 10 CFR 71.

List of Changes, ES-3100 HEU SAR (Y/LF-717, Rev. 5)

Page	Description of Change
	Section 4
4-2	Corrected description for the polyethylene bags and bottles.
4-7	Revised Table 4.5 column headings for 'L_{RN}' for consistency and the Design row entries to be consistent with the Teflon bottle mass limit. Updated Table 4.6 to remove the references to Apps. 7.5.1 and 8.3.1. Revised two occurrences of the maximum normal operating pressure in Sect. 4.3.
4-9	Revised Table 4.7 column headings for 'L_{RA}' for consistency and the Design row entries to be consistent with the Teflon bottle mass limit for CVA 7.
4-23	Updated revision listing for App. 4.6.2.
4-27	Revised calculations for 'P_N' and 'P_A' to be consistent with the NCT and HAC pressures calculated for CVA 7.
4-28–4-30	Revised calculations to be consistent with the NCT pressure calculated for CVA 7.
4-31–4-33	Revised calculations to be consistent with the HAC pressure calculated for CVA 7.
4-34	Revised Table 1 column headings for 'L_{RN}' and 'L_{RA}' for consistency and revised column entries for NCT and HAC regulatory leakage criteria.
4-35	Updated the revisions for 10 CFR 71 and 49 CFR.
	Section 5
5-39	Updated the revision for 10 CFR 71 and 49 CFR.
	Section 6
6-1	Deleted the reference to Drawing M2E801580A026 in Sect. 6.1.1 to remove the carbon-steel can spacer option.
6-30	Corrected mass limit in Table 6.2a for solid HEU metal characterized as broken metal (>70, ≤80% enrichment, CSI=3.2) from 27.692 kg to 27.443 kg ^{235}U to be consistent with the results presented in Tables 6.1c and 6.9.1.1 for Case ncf5bmt11_35_1_5_3.
6-35	Deleted the reference to Drawing M2E801580A026 and revised text in Sect. 6.2.2 to remove the carbon-steel can spacer option.
6-891	Updated the revision for 10 CFR 71.
	Section 7
7-6	Revised Step 12 of Sect. 7.1.2.2 to attach either one or two TIDs through the drum TID lugs.
7-13	Updated the revisions for 10 CFR 20, 10 CFR 71, and 49 CFR.

List of Changes, ES-3100 HEU SAR (Y/LF-717, Rev. 5)

Page	Description of Change
	Section 8
8-11	Updated the revisions for 10 CFR 21, 10 CFR 71, and 49 CFR.
8-12	Updated distribution list.

Y/LF-717, Rev. 5
Docket No. 71-9315
Volume 1

Safety Analysis Report, Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents

Consolidated Nuclear Security, LLC
P.O. Box 2009
Oak Ridge, Tennessee 37831

March 24, 2016

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Safety Analysis Report, Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents

Volume 1
Sections 1-2

March 24, 2016

Prepared by
Consolidated Nuclear Security, LLC
Management & Operating Contractor
for the
Y-12 National Security Complex and Pantex Plant
under Contract No. DE-NA0001942
with the
U.S. Department of Energy
National Nuclear Security Administration

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APPROVALS

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ABBREVIATIONS

ALARA	as low as reasonably achievable
AM	as-manufactured
ANC	Average Net Count
ANSI	American National Standards Institute
AS	allowable stress
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
Cat 277-4	Thermo Electron Corporation (corporate name changed to Shieldwerx) Catalog No. 277-4™ (or Cat. No. 277-4)
CD	capacity discharge
CERCA	Compagnie pour l'Étude et la Realisation de Combustibles Atomiques
CFR	Code of Federal Regulations
CMTR	certified material test report
CoC	Certificate of Compliance
CSI	criticality safety index
CV	containment vessel
CVA	containment vessel arrangement
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPDM	ethylene-propylene-diene monomer
ETP	explicit triangular pack
FEA	finite element analysis
H/X ratio	hydrogen-to-fissile isotope ratio
HAC	Hypothetical Accident Conditions
HEU	highly enriched uranium
IAEA	International Atomic Energy Agency
k_{eff}	calculated neutron multiplication factor
LOD	loss on drying
LTL	lower tolerance limit
M.S.	margin of safety
MNOP	maximum normal operating pressure
MOCFR	moisture fraction inside the containment vessel
MOIFR	moisture fraction of the package external to the containment vessel
NCT	Normal Conditions of Transport
NLF	neutron leakage fraction
NRC	U.S. Nuclear Regulatory Commission
NTRC	National Transportation Research Center
OECD	Organization for Economic Cooperation and Development
ORNL	Oak Ridge National Laboratory
PGNAA	Prompt Gamma-ray Neutron Activation Analysis
ppb	parts per billion
ppm	parts per million
QA	quality assurance
QCPI	Quality Certification and Procurement
RCSB	Rackable Can Storage Box
SAR	safety analysis report
SCALE	Standardized Computer Analysis for Licensing Evaluation

ABBREVIATIONS

s_i	standard error
SRS	Savannah River Site
SS304	type 304 stainless steel
SST/SGT	Safe-Secure Trailer/Safeguards Transporter
TGA	thermogravimetric analysis
TI	transport index
TID	tamper-indicating device
TS	test sample
UNH	uranyl nitrate hexahydrate
UNX	uranyl nitrate crystals
USL	upper subcritical limit
VF	Volume Fraction
Y-12	Y-12 National Security Complex

REVISION LOG

Date	SAR Revision No.	Description	Affected Pages
2/25/05	0	Original issue	All
8/15/05	0, Page Change 1	Page changes resulting from *Responses to Request for Additional Information* #1, Y/LF-747	Title page, iv, xxiii, 1-4, 1-145, 2-2, 2-3, 2-6, 2-31, 2-32, 2-33, 2-34, 2-57, 2-59, 2-61, 2-107, 2-125, 2-131, 2-171, 2-173, 2-181, 2-183, 2-185, 2-186, 2-189, 2-367, 2-458, 2-675, 8-8, 8-9, 8-31
2/6/06	0, Page Change 2	Page changes resulting from *Responses to Request for Additional Information #2*, Y/LF-761	All sections
3/20/06	0, Page Change 3	Page changes resulting from *Responses to Request for Additional Information #3*, Y/LF-764	1.38, 1.48, Appendix 1.4.1, 2-120, Table 6.4
5/8/06	0, Page Change 4	Added polyethylene bottles and nickel alloy cans as convenience containers for authorized HEU contents (CoC Revision 1)	Various pages in Chaps. 1, 2, 3 and 4.
8/21/06	0, Page Change 5	Revised equipment specifications for Kaolite and 277-4 neutron absorber (CoC Revision 3)	Appendices 1.4.4 and 1.4.5.
11/15/06	1	• Updated definition of pyrophoric uranium • Evaluated air transport • Revised criticality safety calculations to remove bias correct factors • Added a CSI option of 3.2 • Increased mass of off-gassing material allowed in containment vessel • Increased carbon concentration in HEU contents • Increased Np-237 concentration is HEU contents • Added uranium zirconium hydride and uranium carbide as contents (TRIGA fuel) • Revised equipment specifications for 277-4 neutron absorber (CoC Rev. 3)	All sections

REVISION LOG

Date	SAR Revision No.	Description	Affected Pages
3/29/07	1, Page Change 1	Updated definition of TRIGA fuel for air transport and added TRIGA-related criticality safety cases	Title pages, viii, xi, xx, 1-12, 1-13, 1-20, 6-30, 6-54, 6-64, 6-66, 6-87, 6-119, 6-240 to 6-286, 6-385 to end
5/31/07	1, Page Change 2	Revised SAR in response to RAIs dated May 9, 2007 in reference to CoC Rev. 4	Title pages, xiii, xx, Sect. 1 and Sect. 6
6/30/07	1, Page Change 3	Revised SAR in response to RAIs dated May 9, 2007 in reference to CoC Rev. 5	Title pages, table of contents, Sect. 1, and Sect. 7
7/31/07	1, Page Change 4	Removed oxidation as an option for treating pyrphoric uranium metal	Title pages, xx, 1-12, 1-201, 1-203, 1-212, 2-26, 7-4
8/28/07	1, Page Change 5	Modified TRIGA fuel definition to include fuel pellets with cladding	Title page, xx, 1-13, 1-17, 2-4, 6-29, 6-30a, 6-66c, 6-66d, 6-73, 6-87, 6-119a
10/10/07	1, Page Change 6	• Revised criticality safety calculations to remove bias correction factors	Table 6.2a and supporting calculations
		• Added a CSI option of 3.2	Table 6.2a and supporting calculations
		• Increased mass of off-gassing material in containment vessel to allow Teflon bottles	Figure 1.4, page 1-15, and Appendices 3.6.4 and 3.6.5
		• Increased carbon and moisture concentration in HEU contents	Pages 1-10 and 1-11, Table 6.2a and pages 6-31 and 6-52
		• Increased Np-237 concentration is HEU contents	Pages 5-1 to 5-4, and supporting calculations
		• Revised equipment specifications for 277-4 neutron absorber	Pages 1-83 and 1-97
		• Details of alloys of uranium in contents definition	Page 1-12
		• More precise specification of maximum fissile mass in calculations (changed from 36 kg to 35.2 kg)	Administrative change affecting many pages. Removed round-off. No new calculations.

REVISION LOG

Date	SAR Revision No.	Description	Affected Pages
3/6/08	2	• Add the following contents for ground transport: – HEU oxides (U_3O_8-Al and UO_2-Mg) – Research reactor fuel elements or components (clad U-Al, U_3O_8-Al, UO_2, or UO_2-Mg) • Add the following contents for air transport: – HEU oxides (UO_2, UO_2-Mg, U_3O_8, and U_3O_8-Al) – Broken HEU bulk metal and uranium-aluminum alloy of unspecified geometric form – Research reactor fuel elements or components (clad U-Al, U_3O_8-Al, UO_2, or UO_2-Mg)	1-10 through 1-17, 1-20, 1-22, 2-1, 2-2, 2-4, 2-5, 2-15, 2-17, 2-18, 2-25, 2-26, 3-15 through 3-17, 3-22, 3-147, 3-149, 3-151 through 3-155, 3-157 through 3-161, 4-2, 6-1, 6-2, 6-4, 6-5, 6-30 through 6-34, 6-51, 6-56, 6-69, 6-78, 6-83, 6-87, 6-92, 6-93, 6-95, 6-119, 6-128 through 6-130, 6-168, 6-282 through 6-286, 6-303 through 6-305, and 6-488 through 6-501.
6/19/08	2, Page Change 1	Revised SAR in response to RAIs dated April 28, 2008 for review of CoC 9315, Rev. 8	i, ix, x, xxii, 1-15, 3-15 through 3-17, 3-154, 3-161, 4-3, 6-1, 6-3, 6-3a, 6-3b, 6-4, 6-5, 6-9 through 6-12, 6-29, 6-30, 6-35, 6-36, 6-67, 6-69, 6-70, 6-73, 6-74, 6-80, 6-81, 6-84, 6-96, 6-97, 6-99, 6-101, 6-103, 6-103a, 6-103b, 6-104a through 6-104n, 6-167, 6-188 through 6-197, 6-316 through 6-320, 6-320a through 6-320d, 6-321 through 6-324, 6-351 through 6-354, 6-354a through 6-354b, 6-355 through 6-362, 6-503 through 6-642, and 6-644.

REVISION LOG

Date	SAR Revision No.	Description	Affected Pages
8/28/08	2, Page Change 2	Revised SAR in response to RAIs dated April 28, 2008, for review of CoC 9315, Rev. 8	i, vi, viii, xii, xxiii, xxiv, 1-10, 1-14 through 1-16, 1-22, 2-1, 2-25 through 2-28, 2-894, 3-15, 3-16, 3-165 through 3-290, 4-1, 4-2, 6-1 through 6-3, 6-20 through 6-28, 6-30 6-32 through 6-34, 6-68 through 6-70, 6-70a, 6-70b, 6-75 through 6-77, 6-77a, 6-77b, 6-78, 6-81 through 6-83, 6-85, 6-86, 6-101 through 6-103, 6-103a through 6-103j, 6-104, 6-123 through 6-126, 6-167 through 6-170, 6-177, 6-177a, 6-177b, 6-218a through 6-218f, 6-219 through 6-234, 6-303 through 6-305, 6-331, 6-332, 6-332a, 6-332b, 6-333, 6-394 through 6-398, 6-501, 6-502, 6-502a through 6-502dd
2/26/09	2, Page Change 3	Revised SAR in response to RAIs dated January 12, 2009, for review of CoC 9315, Rev. 9	i, viii, ix, xxiv, 1-7, 1-10, 1-12 through 1-16, 1-21 through 1-23, 1-29 1-31, 1-33, 1-35, 1-37, 1-39, 1-41, 1-135, 1-157, 1-177, 2-6, 2-9, 2-18, 2-36 through 2-38, 2-41 through 2-43, 2-53, 2-78, 2-80, 3-15 through 3-17, 3-27, 3-28, 3-30, 3-32, 3-39, 3-41, 3-147, 3-149 through 3-154, 3-154a, 3-154b, 3-155, 3-158 through 3-161, 3-165 through 3-174, 3-289 through 3-344, 4-2, 4-7, 4-9, 4-27 through 4-34, 6-5, 6-29, 6-30, 6-34, 6-73 through 6-86, 6-86a through 6-86d, 6-96, 6-103a through 6-103c, 6-104b, 6-104c, 6-123, 6-124, 6-168, 6-219 through 6-221, 6-221a, 6-221b, 6-222, 7-7, 7-8, 7-10

REVISION LOG

Date	SAR Revision No.	Description	Affected Pages
5/6/09	3	This revision was issued to match Amendment 9 of the CoC. • Remove the following contents for ground transport that were not reviewed by NRC: – HEU oxides (U_3O_8-Al and UO_2-Mg) – Research reactor fuel elements or components (clad U-Al, U_3O_8-Al, UO_2, or UO_2-Mg) • Remove the following contents for air transport that were not reviewed by NRC: – HEU oxides (UO_2, UO_2-Mg, U_3O_8, and U_3O_8-Al) – Broken HEU bulk metal and uranium-aluminum alloy of unspecified geometric form – Research reactor fuel elements or components (clad U-Al, U_3O_8-Al, UO_2, or UO_2-Mg)	All
4/14/10	3, Page Change 1	Revised SAR to do the following: • Add uranium oxide loading with a CSI value of 0.4 • Remove the 8-lb minimum payload weight • Add stainless-steel option for can spacers • Revise allowable weight changes for drum body and top plug • Revise Drawing M2E801580A005 to clarify marking requirements on drum hex nuts • Allow methods other than sieving for establishing minimum content sizes for pyrophoric purposes • Revise the purity of the cover gas used for pyrophoric material	i, x, xxv, 1-13, 1-16, 1-22, 1-23, 1-24, 1-27, 1-89 through 1-126, 1-126a, 1-126b, 1-135, 1-147, 1-178a, 1-178b, 1-221, 2-1, 2-14, 2-24, 6-1, 6-3, 6-4, 6-31, 6-35, 6-57, 6-67 through 6-69, 6-104, 6-105, 6-195, 6-717 through 6-892, 7-3, 7-4, 8-9, 8-10

REVISION LOG

Date	SAR Revision No.	Description	Affected Pages
4/14/10 (cont.)		**Note:** The NRC performed an acceptance review of Page Change 1 and generated several Requests for Supplemental Information (RSIs). Therefore, Page Change 1 will be superseded by Page Change 2, which incorporates the responses to the RSIs.	
7/22/10	3, Page Change 2	Reissue of Page Change 1 with RSI responses incorporated	i, x, xiv, xxv, xxvi, 1-13, 1-16, 1-22, 1-23, 1-24, 1-27, 1-89 through 1-126, 1-126a, 1-126b, 1-135, 1-147, 1-178a, 1-178b, 1-221, 2-1, 2-6, 2-14, 2-24, 2-26, 3-8a, 3-8b, 3-9, 3-10, 3-12, 3-13, 3-18, 3-23, 3-27, 3-27a, 3-27b, 3-100, 3-104, 3-105, 3-115, 3-116, 3-140, 6-1, 6-3, 6-4, 6-31, 6-35, 6-57, 6-67 through 6-69, 6-104, 6-105, 6-195, 6-717 through 6-892, 7-3, 7-4, 8-9, 8-10
1/27/11	3, Page Change 3	Revised SAR in response to RAIs dated October 12, 2010, for review of CoC 9315, Rev. 10	i, vi, xiv, xxvi, 2-6, 2-11, 2-36, 2-37, 2-41 through 2-43, 2-53, 2-78, 2-80, 3-16 through 3-18, 3-23, 3-27, 3-27a through 3-27d, 3-28, 3-30, 3-39, 3-147, 3-153 through 3-157, 3-160 through 3-164, 4-7, 4-9, 4-23, 4-25 through 4-34, 7-2, 7-6, 7-7, 7-11
3/3/11	4	This SAR revision matches Rev. 10 of the CoC. Incorporated Page Changes 1–3 and revised MNOP value in two additional locations (Sects. 1.2.3.5 and 3.5.1)	All

REVISION LOG

Date	SAR Revision No.	Description	Affected Pages
3/24/16	5	Revised the SAR for recertification, which included the following changes: • Updated contractor name • Increased the Teflon bottle mass for CVA 7 • Removed the carbon steel option for can spacers • Updated the revision of package engineering drawings, specifications, and regulatory requirements • Added Appendix 1.4.11 for EPDM containment vessel O-ring requirements • Made editorial corrections, as necessary	Front covers, i, iii, v, xxvii, xxviii, 1-1, 1-4, 1-6, 1-15, 1-16, 1-22 through 1-24, 1-27, 1-55 through 1-66, 1-137, 1-139, 1-149, 1-157, 1-167, 1-175, 1-177, 1-179, 1-229 through 1-247, 2-6, 2-11, 2-14, 2-17, 2-24, 2-26, 2-28 through 2-30, 2-35 through 2-37, 2-41 through 2-43, 2-53, 2-80, 2-893, 3-16 through 3-19, 3-29 through 3-31, 3-33, 3-35, 3-149, 3-151 through 3-159, 3-161 through 3-166, 3-349, 4-2, 4-7, 4-9, 4-23, 4-27 through 4-35, 5-39, 6-1, 6-30, 6-35, 6-891, 7-6, 7-13, 8-11, 8-12

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1. GENERAL INFORMATION

1.1 INTRODUCTION

This safety analysis report (SAR) presents the results of the safety analysis prepared in support of Y-12's request for licensing of the ES-3100 package with bulk highly enriched uranium (HEU) contents and issuance of a Type B Fissile Material Certificate of Compliance. This SAR, published in the format specified in the Nuclear Regulatory Commission (NRC) draft guidance DG-7003 and using information provided in NRC Regulatory Guide 7.10, demonstrates that the Y-12 National Security Complex (Y-12) ES-3100 package with bulk HEU contents meets the applicable requirements of 10 CFR 71 and 49 CFR Pts. 100–178.

To protect the health and safety of the public, shipments of radioactive materials are made in packaging that is designed, fabricated, assembled, tested, procured, used, maintained, and repaired in accordance with the provisions cited above. Safety requirements addressed by the regulations that must be met when transporting radioactive materials are containment of radioactive materials, radiation shielding, and assurance of nuclear subcriticality.

A general description and a summary of the evaluation of the packaging are presented in this section. Subsequent sections address structural (Sect. 2) and thermal (Sect. 3) responses to Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) and the packaging's ability to contain the radioactive materials when subjected to the requirements of 10 CFR 71.71 and 71.73, respectively. A shielding evaluation was prepared to ensure adequate nuclear radiation shielding (Sect. 5). Criticality evaluations that are unique to the contents were prepared to ensure nuclear subcriticality (Sect. 6). Sections 7 and 8 discuss the operating procedures, the new packaging acceptance tests, and the maintenance program for the planned use and refurbishment of the packaging.

The ES-3100 package was subjected to verification (analysis, similarity comparisons, tests, or a combination of these) for NCT and HAC. Full-scale packages were used for design verification testing (see Sects. 2 and 3). The ES-3100 package with bulk HEU content was verified solely on the ability of the package to meet the requirements of 10 CFR 71. Transport vehicle influence on the package is not required to meet 10 CFR 71 requirements.

The packaging verification activities (Sects. 2, 3, and 4), using content test masses of between 3.6 and 50.3 kg (8 and 111 lb), show that the packaging meets the containment requirements of 10 CFR 71. The shielding evaluations (Sect. 5) show that the packaging meets the NCT requirements of 10 CFR 71.47, *External Radiation Standards for all Packages*, and the HAC requirements of 10 CFR 71.51, *Additional Requirements for Type B Packages*. Based on the results of the thermal and shielding evaluations, the ES-3100 package with bulk HEU content may be shipped as a nonexclusive use package. The criticality evaluation (Sect. 6) shows that the packaging meets the requirements of 10 CFR 71.55, *General Requirements for Fissile Material Packages*, and 10 CFR 71.59, *Standards for Arrays of Fissile Material Packages*.

1.2 PACKAGE DESCRIPTION

A schematic of the ES-3100 shipping package is shown in Fig. 1.1, and an exploded view of the packaging components is presented in Fig. 1.2. The packaging design drawings (Appendix 1.4.8) provide material lists, dimensions, safety components, welding requirements, and gasket requirements. The

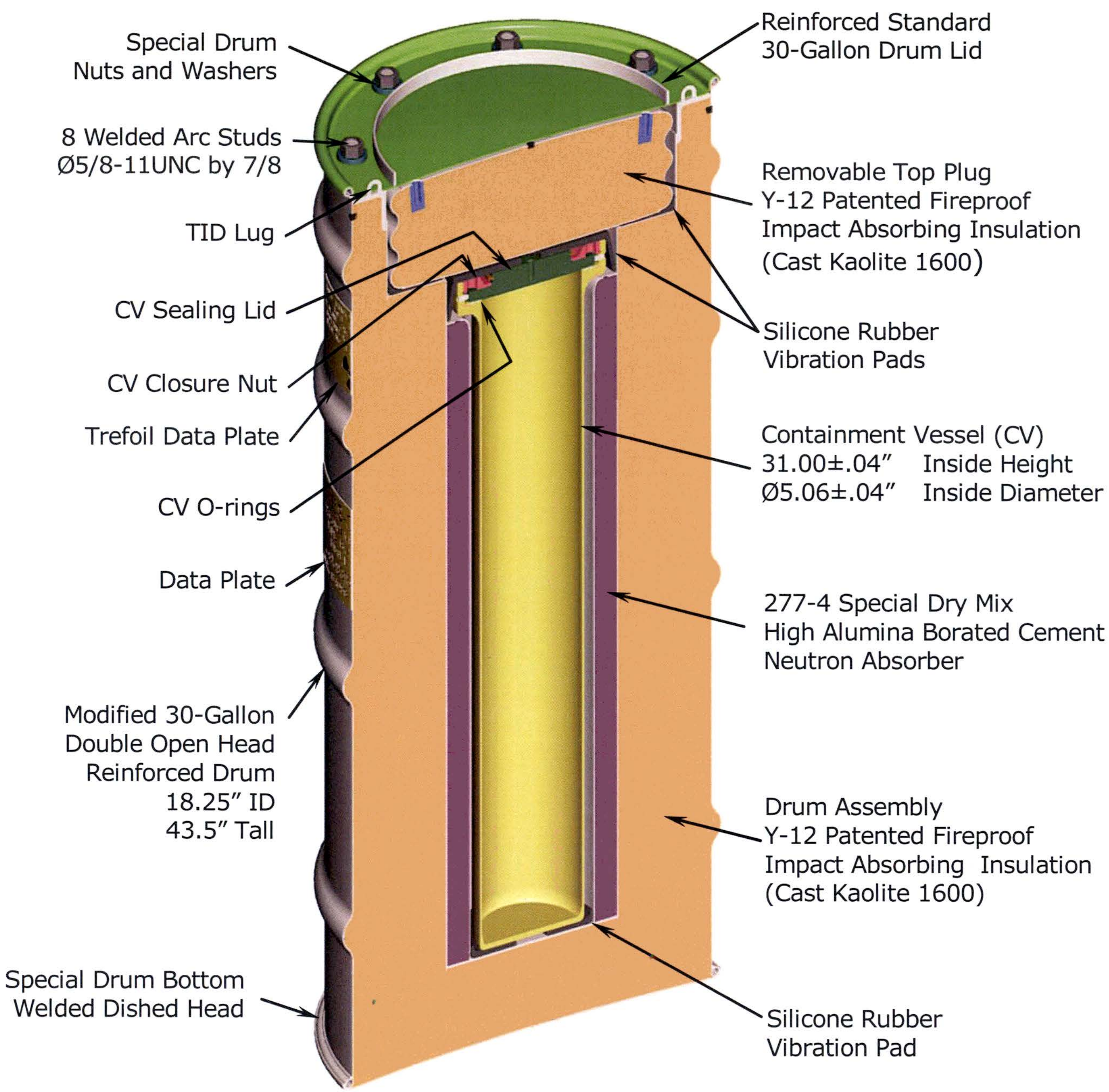


Fig. 1.1. Schematic of the ES-3100 shipping package.

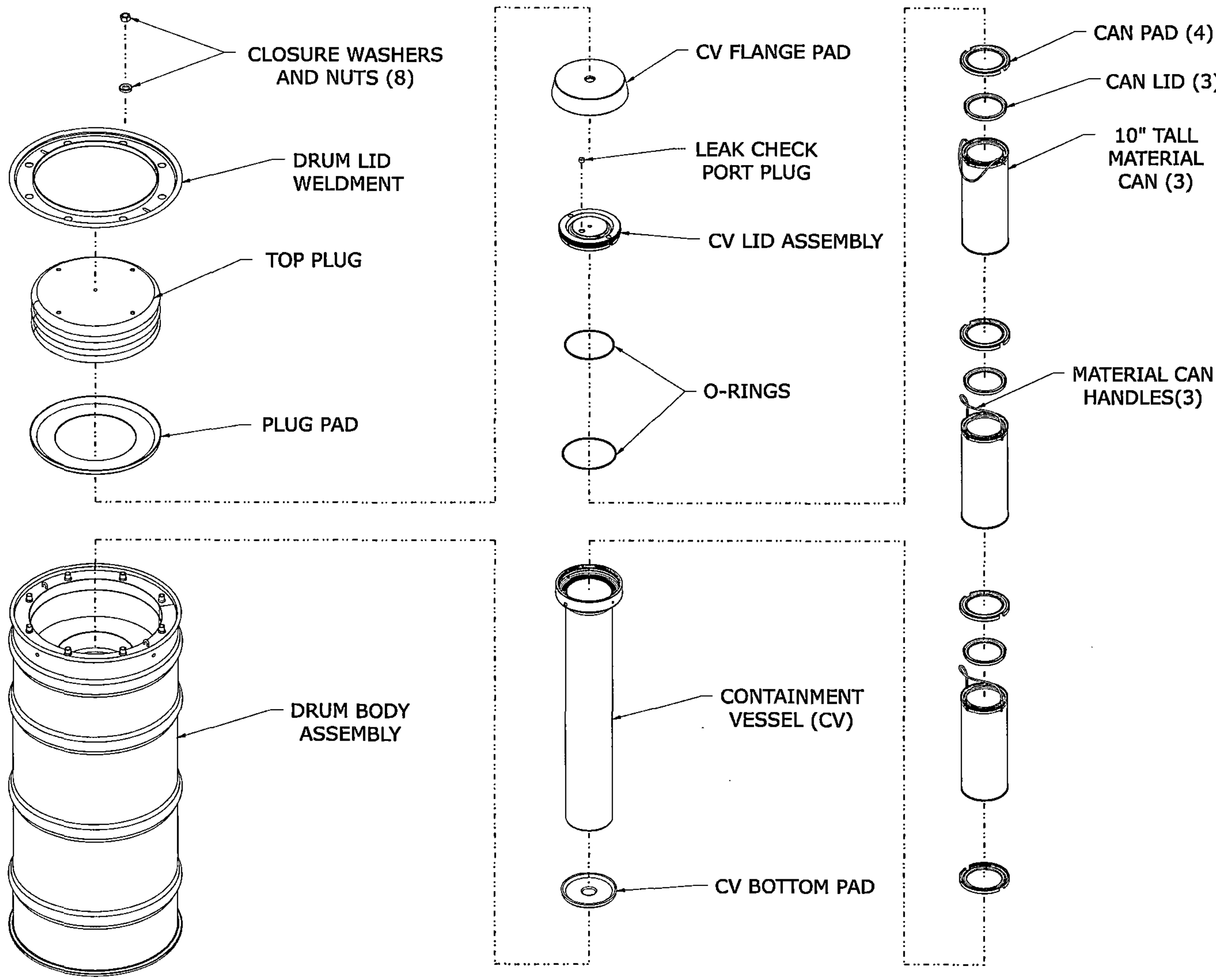


Fig. 1.2. Exploded view of the ES-3100 package with bulk HEU contents.

proposed maximum gross shipping weight of the ES-3100 package with bulk HEU content is 187.81 kg (414.05 lb). The certification drawing of the ES-3100 can be found in Appendix 1.4.1. The authorized maximum gross weight of the ES-3100 package is 190.5 kg (420 lb). The ES-3100 packaging as specified in this SAR is classified as a Category II package (see Appendix 1.4.6). However, since the ES-3100 shipping package may be used for future contents having higher A_2 values, the package has been designed and analyzed to meet the requirements of a Category I package.

1.2.1 Packaging

The main functions of the packaging are containment, shielding, and nuclear criticality safety. The bulk HEU contents create a maximum decay heat of approximately 0.4 W (Sect. 1.2.3.7 and Sect. 3.1.2); therefore, the packaging does not require any special design features such as coolant valves or continuous venting to meet the thermal requirements of 10 CFR 71.

1.2.1.1 Drum assembly

The drum assembly consists of a double open-head reinforced stainless-steel 30-gal drum, arched cover that forms the bottom, arched lid, inner liner, and top plug with cast refractory insulation (Kaolite) [see Drawing M2E801580A001, Appendix 1.4.8]. The inside diameter of the drum is 46.36 cm (18.25 in.) with an overall height of 110.49 cm (43.5 in.) including the cover and lid (Drawings M2E801580A004 and M2E801580A001, Appendix 1.4.8). The outside diameter of the drum (including the chimes) is 49.2 cm (19.37 in.). The drum and lid are made from 16-gauge [~0.152-cm (0.0598-in.)-thick] type 304 or 304L stainless steel. A 12-gauge [~0.267-cm (0.105-in.)-thick] stainless-steel arched cover (Drawing M2E801580A005, Appendix 1.4.8) is welded to the double open-head drum to create the bottom of the drum assembly. An inner liner (Drawing M2E801580A003, Appendix 1.4.8) is attached to the drum by an internal flange (angle) that is welded to both the drum and liner. The cavity created by the inner liner for placement of a containment vessel is a three-tier volume. The uppermost tier accommodates the top plug and has an inside diameter of 37.52 cm (14.77 in.) and is 13.26 cm (5.22 in.) deep (Drawing M2E801580A003, Appendix 1.4.8). The second tier, which accommodates the containment vessel flange, has a 21.84-cm (8.60-in.) inside diameter that is 5.59 cm (2.20 in.) deep (Drawing M2E801580A003, Appendix 1.4.8). The third tier, which accommodates the containment vessel body, has a 15.85-cm (6.24-in.) inside diameter that is 78.31 cm (30.83 in.) deep (Drawing M2E801580A003, Appendix 1.4.8). An additional cavity is created between the second and third tier liners. This cavity runs the full length of the third tier height [78.31 cm (30.83 in.)] and is approximately 3.00 cm (1.18 in.) thick (Drawing M2E801580A003, Appendix 1.4.8). This cavity is filled with a castable refractory (277-4 special dry mix) for neutron attenuation purposes. The additional cavities between the liner and the drum are filled with an inorganic castable refractory material (Kaolite 1600), which acts as both an impact-absorbing and thermal-insulating material.

In accordance with NUREG/CR-3854, Part 4.3 for a Category I shipping package, an acceptable specification for drums used in any of the component safety groups is U.S. Department of Transportation (DOT) Specification 17C or better. The drum used in the ES-3100 is fabricated in accordance with the dimensional requirements of MIL-D-6054F and modified as shown on Drawing M2E801580A004 (Appendix 1.4.8). Material, fabrication, and quality control criteria are generally equivalent to those imposed for a DOT Specification 17C drum. Furthermore, the drum of the ES-3100 is part of a performance-based package that has been tested and analyzed to demonstrate its ability to maintain confinement and containment of its contents under both NCT and HAC. By certifying that the outer shell of the Drum Assembly used in production meets the same specifications as those tested and analyzed, as described in subsequent sections of this SAR, the outer drum shell used for the ES-3100 is acceptable for a Category 1 shipping package.

As previously discussed, the drum has been modified by the attachment of an inner liner connected to the drum by an internal flange welded to both the drum and the liner. Weld studs are attached to the upper face of the internal flange. The body seams are welded. The following items are conducted in accordance with Sect. IX of the *American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code* (B&PVC, Sect. IX): welding procedures qualification and welders certification to these qualified procedures.

The drum has four circumferential hoops formed into the body. The drum has four 0.795-cm (0.313-in.)-diam holes equally spaced around the circumference about 3.81 cm (1.50 in.) from the top rim to relieve pressure in the drum in the event of a thermal accident (Drawing M2E801580A002, Appendix 1.4.8). Plastic plugs (Nylon 6/6, Micro Plastic, Inc., Item Number 62MP0312) are placed into these holes from the outside to prevent leakage of water into the drum during NCT and storage. The drum is fabricated with a data plate, trefoil data plate, paint, and two lid TID lugs for use with tamper-indicating devices (TIDs). The two electrochemically etched data plates are affixed to the exterior of the drum body in the locations, and with the methods, indicated on Drawing M2E801580A031 (Appendix 1.4.8). The trefoil data plate (M2E8015803A010-1) provides the owner's return address, container model, container serial number, and the trefoil symbol. The other data plate (M2E801580A010-2) provides the required DOT markings—certificate number, maximum gross weight, and "Type B" designation.

The removable lid is attached to the drum body by a flange with eight silicon bronze, 5/8-11-UNC-2B hex-head nuts [C65100, American Society for Testing and Materials (ASTM) F-467] with stainless-steel washers. These nuts are tightened onto the weld studs (304 or 304L stainless steel, 5/8-11-UNC-2A, ASTM A-493 or F-593) to 40.67 ± 6.78 N·m (30 ± 5 ft-lb) of torque with no sequence specified.

The top plug is 36.5 cm (14.37 in.) in diameter and 13.41 cm (5.28 in.) in height at the center. The skin is made from 16 gauge [~0.152-cm (0.0598-in.)-thick] type 304 or 304L stainless steel and is filled with Kaolite 1600.

The drum assembly also contains three silicone rubber pads. The first pad (CV bottom pad) is placed on the bottom of the innermost liner to support the containment vessel bottom during transport. The second pad (CV flange pad) is placed on top of the containment vessel lid during transport. The third pad (plug pad) is placed on the top shelf of the mid-liner to cushion the top plug during transport. The locations of these three pads are shown on Drawing M2E801580A001 (Appendix 1.4.8), and the dimensions of the pads are shown on Drawing M2E801580A009 (Appendix 1.4.8).

The drum is designed so that lifting can be accomplished with a forklift. It can either be placed on the tines of the forklift from below, or a pincher assembly can be placed on the forklift and used to grasp the exterior of the drum assembly. Based on analytical results for a similar package (the Model ES-2100), forklift gripping forces of up to 5400 lb can be used with no detrimental effects on the package.

No tie-down devices are integral to the package, nor can any features be used for these purposes. The ES-3100 package is designed to be shipped in accordance with the safe-secure trailer/safeguards transporter (SST/SGT) requirements.

1.2.1.2 Insulation

The void area formed by the drum and the attached inner liner is filled with an inorganic castable refractory material (Kaolite 1600) made by Thermal Ceramics, Inc., which acts as both a thermal insulating and an impact limiting material. The top plug assembly, which is placed between the containment vessel and the drum lid, is also filled with Kaolite 1600. This material is a mixture of cement and vermiculite and has a nominal cured density of ~358.8 kg/m^3 (22.4 lb/ft^3). Additional information regarding the characteristics and properties of this material is presented in Appendix 2.10.3. Casting takes place while the drum is being vibrated in an inverted orientation to ensure that the castable material penetrates into all areas in the void space formed by the drum and the inner liner and that no considerable voids are formed during this process. The Kaolite material is then baked in a furnace at elevated temperatures [~260°C (500°F)] as prescribed in Manufacturing Process Specification, JS-YMN3-801580-A003, *Manufacturing Process Specification for Casting Kaolite 1600 into the ES-3100 Shipping Package,* the specification which controls manufacture of Kaolite 1600 for the ES-3100 (Appendix 1.4.4). The use of a thermal ceramic material, such as Kaolite 1600, as an impact limiting/thermal insulating material in a Type B fissile material shipping package has been previously used in other Y-12 owned and licensed packages (i.e., ES-2100 and DPP-2). The original decision to use this material was the result of considerable research. This manufacturing process is protected under U.S. Patent 6,299,950 B1 (Byington et al. 2001). The United States Government has rights in this invention pursuant to Contract No. DE-NA0001942 between DOE and Consolidated Nuclear Security, LLC.

One of the design goals of Y-12's packaging development program was to build a shipping package entirely of materials that do not char, burn, or thermally decompose when exposed to the temperatures and conditions associated with HAC [800°C (1475°F)]. Cellulosic fiber board and polyurethane foams, typically used for packaging applications, undergo decomposition when exposed to these HAC thermal conditions. During thermal decomposition, these materials off-gas, producing conditions that are potentially detrimental to the performance of the package. The hot gases generated within the packaging can transfer heat to inner regions adjacent to the containment closure seals. Under severe circumstances, this process could lead to loss of containment due to overheating of containment seals. The Kaolite material is nonflammable and will not undergo chemical decomposition at temperatures below 1260°C (2300°F). When Kaolite is heated above 100°C (212°F), water vapor from free water contained within the casting will form. Pressurization of the drum and top plug is prevented by pressure relief holes (vent holes) located near the top of the drum and on the top center of the top plug (see Sect. 1.2.1.1 and Drawings M2E801580A002 and M2E801580A008, Appendix 1.4.8). The cured Kaolite 1600 material does not decompose, and thus there are no exothermic chemical reactions that could produce superheated off-gasses.

Extensive testing of Kaolite 1600 was performed by the Y-12 Development Division to determine the performance of the material for this type of application (Oakes, Appendix 2.10.3). Testing showed that Kaolite 1600 has a tremendous ability to absorb shock over a wide range of material densities, curing temperatures and times, and material temperatures. The 10 CFR 71.73 HAC testing documented in Sect. 2.7 demonstrates that Kaolite 1600 is a robust impact limiter and good thermal insulating material for Type B shipping containers. Post HAC drop testing radiographs of a similar package, the ES-2100, showed some minor cracking of the Kaolite structure in some cases. However, subsequent thermal testing of these ES-2100 packages demonstrated that these cracks were inconsequential to the package's ability to meet regulatory requirements.

Insulation thicknesses within the liner/drum volume adjacent to the side walls of the ES-3100 containment vessel are at least 4.27 cm (1.68 in.), with typical thicknesses of approximately 12.10 cm (4.77 in.). Below the containment vessel, the minimum thickness of insulation is 10.05 cm (3.96 in.), and the top plug, which is above the containment vessel, includes a 12.55-cm (4.94-in.) thickness of insulation.

1.2.1.3 Shielding

The ES-3100 packaging does not require dedicated shielding materials of specific design to control external radiation levels for the bulk HEU contents. However, the intervening packaging materials of construction (stainless steel of the drum and containment vessel, the Kaolite material, and the 277-4 material) provide some attenuation of the relatively low levels of penetrating radiation emitted by the contents. The amount of shielding modeled for the NCT analysis is represented by the thickness and density of the materials reported in Sects. 1.2.1.1, 1.2.1.2, and 1.2.2 and the packaging dimensions (Appendix 1.4.8). HAC physical testing showed that the containment vessel and insulation remain confined within the drum assembly. However, the HAC shielding evaluation conservatively assumes that only the containment vessel remains for shielding purposes (i.e., no shielding credit is taken for the drum and insulation in the HAC analysis).

1.2.1.4 Nuclear criticality safety

The packaging materials of construction in the ES-3100 provide neutron absorption (stainless steel and 277-4) and reflection (stainless steel and insulation). The 277-4 (or Cat 277-4 as it is sometimes referred) material is a noncombustible cast neutron-absorbing material. This material is cast into the innermost liner of the package adjacent to the containment vessel as shown in Fig. 1.1. The material is a high alumina borated concrete composed of aluminum, magnesium, calcium, boron, carbon, silicone, sulfur, sodium, iron, and water. The 277-4 material was manufactured specifically for the ES-3100 package by adding boron carbide to a standard material (Cat No. 277-0) and increasing the boron content from 1.56 wt % to 4.23 wt%. Additional information on the neutron-absorbing characteristics of this material is presented in Appendix 6.9.3. Properties of the 277-4 material are presented in Table 2.17 and Appendix 2.10.4. The cast material has a nominal density of 1681.9 kg/m^3 (105 lb/ft^3). The procedure for mixing this material and casting it into the ES-3100 shipping package is documented in JS-YMN3-801580-A005, *Casting Catalog No. 277-4 Neutron Absorber for the ES-3100 Shipping Package* (Appendix 1.4.5).

Although shown by tests up to HAC as not being credible, the criticality analysis considers water leakage into the containment vessel in accordance with 10 CFR 71.55(b). Depending on the content being shipped and the shipping configuration being used, criticality safety index (CSI) values for the ES-3100 package may range from 0 to 3.2 (see Sect. 1.2.3).

1.2.2 Containment System

A single containment vessel is used in the ES-3100 shipping package for the transport of bulk HEU contents. The ES-3100 containment boundary (consisting of the containment vessel body, lid assembly, and inner O-ring) is shown in Fig. 1.3.

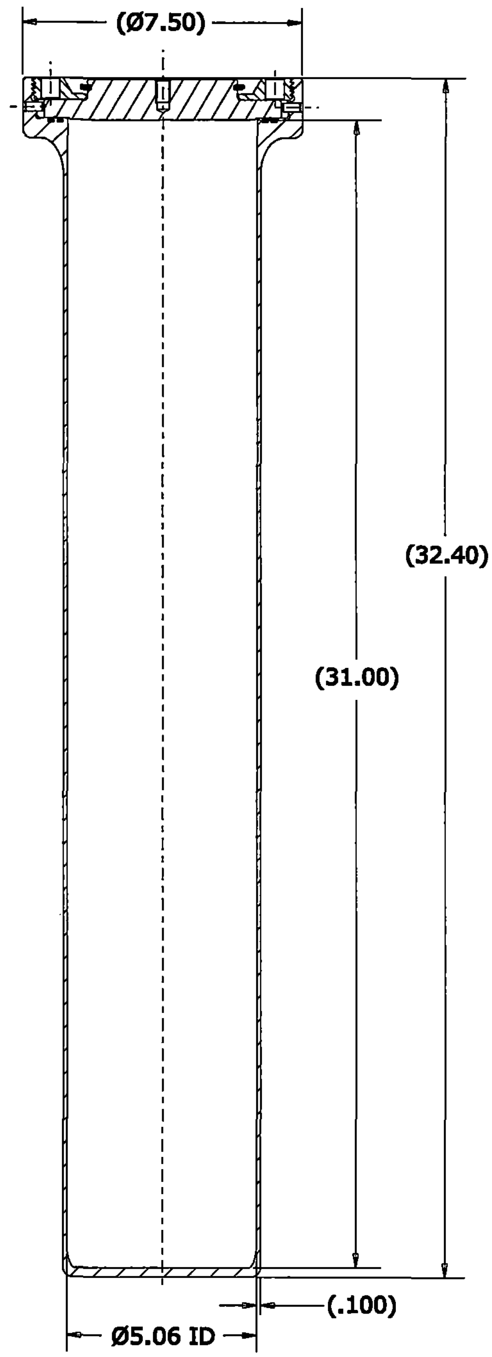


Fig. 1.3. Containment boundary of the ES-3100 shipping package.

During fabrication, all ES-3100 containment vessels will be inspected and tested to the requirements specified on the design drawings (Appendix 1.4.8) and equipment specification (Appendix 1.4.3). Certification documents received from the vendor with each component acknowledge the use of these drawings and specifications. These certifications are on file with the Y-12 Quality Organization.

The containment boundary of the ES-3100 package is a pressure vessel that is designed, fabricated, examined, and tested in accordance with the *ASME Boiler and Pressure Vessel Code,* Sect. III, Division I, Subsection NB (B&PVC, Sect. III, Div. I). The ES-3100 containment vessel body is constructed of 304L stainless steel and may be fabricated by one of two methods. The first method uses a standard 5-in., schedule 40 stainless-steel pipe (ASME SA-312 Type TP304L), a machined flat-head bottom forging (ASME SA-182 Type F304L), and a machined top flange forging (ASME SA-182 Type F304L). Each of these pieces is joined with circumferential welds as shown on Drawing M2E801580A012 (Appendix 1.4.8). The top flange is machined to provide two concentric half-dove-tailed O-ring grooves in the flat face, to provide locations for two 18-8 stainless steel dowel pins, and to provide the threaded portion for closure using the lid assembly. The second fabrication method for the ES-3100 containment vessel uses forging, flow forming, or metal spinning to create the complete body (flat bottom, cylindrical body, and flange) from a single forged billet or bar with final material properties in accordance with ASME SA-182 Type F304L. The top flange area using this fabrication technique is machined identically to that of the welded forging method.

The lid assembly, which completes the containment boundary structure, consists of a sealing lid, closure nut, and external retaining ring (Drawing M2E801580A014, Appendix 1.4.8). The containment vessel sealing lid (Drawing M2E801580A015, Appendix 1.4.8) is machined from Type 304 stainless-steel bar with final material properties in accordance with ASME SA-479. The containment vessel closure nut is machined from a Nitronic 60 stainless-steel bar with material properties in accordance with ASME SA-479. These two components are held together using a WSM-400-S02 external retaining ring made from Type 302 stainless steel. The sealing lid is further machined to accept a ⅜-16 swivel hoist ring bolt, to provide a leak-check port between the elastomeric O-rings, and notched along the perimeter to engage two dowel pins. The swivel hoist ring is only intended for use when loading and unloading the containment vessel. The swivel hoist ring will be removed for shipment. The lid assembly, with the O-rings in place on the containment vessel body, are joined together by torquing the closure nut and sealing lid assembly to 162.70 ± 6.78 N·m (120 ± 5 ft-lb). The sealing lid portion of the assembly is restrained from rotating during this torquing operation by the two dowel pins installed in the body flange.

The use of a design that includes two O-ring seals permits assembly verification leak testing of the containment vessel by measuring the leak rate from the volume between the inner and outer O-rings. An evacuation port is located between the O-rings in the containment vessel to facilitate a pressure rise or drop leakage test following assembly or 10 CFR 71 compliance testing. This port is sealed during transport using a modified VCO threaded plug. Only the inner O-ring is considered a part of the containment boundary. All O-rings on this containment vessel are fabricated to ASTM D2000, M3BA712A14B13F17.

The inner diameter of the containment vessel is 12.852 cm (5.06 in.) and the usable height inside the containment vessel is 78.74 cm (31.0 in.). The wall thickness of the body excluding the flange is 0.254 cm (0.10 in.). The maximum nominal diameter of the containment vessel body is 19.05 cm (7.50 in.). The nominal thicknesses of the containment vessel's flat bottom is 0.635 cm (0.25 in.). The overall height of the containment vessel without the swivel hoist ring is 82.296 cm (32.40 in.). The containment vessel drawing number, drawing revision, and serial number are electroetched onto the side of the containment vessel body, as well as onto the top of the sealing lid and the closure nut (Drawing M2E801580A011, Appendix 1.4.8). All outer surfaces, unless otherwise specified, are either sand- or bead-blasted, buffed, or sanded to a matte finish. No penetrations, connections, or fittings into this sealed container exist.

1.2.3 Contents

The ES-3100 shipping package will be used to ship bulk HEU in the form of oxide (UO_2, UO_3, or U_3O_8), uranium metal and alloy in the form of solid geometric shapes or broken pieces, uranyl nitrate crystals (UNX), and fuel elements from Training, Research, Isotopes, and General Atomics (TRIGA) reactors. The ES-3100 package has been designed to accommodate uranium oxide, UNX crystals, uranium metal, and uranium alloys. Actual loading limits are presented in subsequent sections of the SAR. The maximum weight of all contents (including convenience cans or bottles, can spacers, polyethylene bagging and other packing materials) shall not exceed 40.82 kg (90 lb). The maximum concentration of uranium isotopes permitted in the ES-3100 content are listed in Table 1.1. In addition to the uranium isotopes shown in Table 1.1, transuranic isotopes (with the exception of ^{237}Np) may be present in the contents at a maximum concentration of 40.0 μg/gU. The concentration of ^{237}Np is limited to 0.0250 g/gU. Unless otherwise specified, the contents described in this section pertain to ground transport only. A discussion of contents of air-transport is included in Sect. 1.2.3.1.

Table 1.1. Uranium concentration limits

Uranium isotope	Limit
^{232}U	0.040 μg/gU
^{233}U	0.006 g/gU
^{234}U	0.02 g/gU
^{235}U	1.00 g/gU
^{236}U	0.40 g/gU
^{238}U	1.00 g/gU

HEU Oxide

The HEU oxide content in the ES-3100 package includes UO_2, UO_3, and U_3O_8. Seven different oxide categories have been identified (Appendix 1.4.7). Maximum overall uranium isotopic weight percents representative of all seven oxide categories are presented in Table 1.2. The physical form of all contents is dense, loose powder which may contain clumps. Moisture content in oxide is limited to 3 wt % water (Note: loading restriction #8 in Sect. 1.2.3.8 also applies). Theoretical densities of UO_2, U_3O_8, and UO_3 are 10.96 g/cm^3, 8.30 g/cm^3, and 7.29 g/cm^3, respectively. Allowable oxide densities are 2.0 to 6.54 g/cm^3. Oxide may be shipped in tin-plated carbon steel, stainless steel, or nickel-alloy convenience cans; or polyethylene convenience bottles.

Table 1.2. Bounding uranium isotopic concentrations in oxide

Isotope	Bounding limit
^{232}U	40 ppb
^{233}U	200 ppm
^{234}U	2.0 wt %
^{235}U	97.7 wt % [a]
^{236}U	40.0 wt %
^{238}U	80.0 wt %

[a] ^{235}U must be ≥20 wt %.

For convenience, the seven oxide categories are referred to as Groups 1-7. Groups 1 to 6 are product oxides, and Group 7 is skull oxide. These groups are briefly described below.

Group 1 oxides are in the form of UO_x. Material from this group contains at least 83.0% uranium by weight and displays typical isotopic content (≤0.977 g^{235}U/gU, ≤0.014 g ^{234}U/gU, ≤0.010 g^{236}U/gU, ≤0.040 μg^{232}U/gU, ≤50.0 μg^{233}U/gU with the balance of the uranium being ^{238}U).

Group 2 oxides are in the form of UO_x. Material from this group contains at least 20.0% uranium by weight and displays typical isotopic content (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤50.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U).

Group 3 oxides are contaminated with up to 40 μg Pu/g U and are in the form of UO_x. Material from this group contains at least 83.0% uranium by weight and displays typical isotopic content for uranium (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤50.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U).

Group 4 oxides are in the form of U_3O_8. Material from this group contains at least 83.0% uranium by weight and displays typical isotopic content (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤50.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U).

Group 5 oxides are in the form of UO_x. Material from this group contains at least 20.0% uranium by weight and displays typical isotopic content (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 µg ^{232}U/g U, ≤50.0 µg ^{233}U/g U with the balance of the uranium being ^{238}U). This material may contain considerable activity in the form of unspecified beta emitters.

Group 6 oxides are in the form of UO_x. Material from this group contains at least 20.0% uranium by weight and may display unusually high isotopic concentrations of ^{233}U, ^{234}U, and ^{236}U (≤0.977 g ^{235}U/g U, ≤0.020 g ^{234}U/g U, ≤0.40 g ^{236}U/g U, ≤0.040 µg ^{232}U/g U, ≤200.0 µg ^{233}U/g U with the balance of the uranium being ^{238}U).

Group 7 oxides are in the form of U_3O_8. Material from this group is a mixture of graphite and U_3O_8, also referred to as skull oxides. The uranium concentration is up to 84.5% by weight and enrichment is up to 93.2% by weight. Concentrations of other uranium isotopes are ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 µg ^{232}U/g U, ≤50.0 µg ^{233}U/g U with the balance of the uranium being ^{238}U. The carbon content in these oxides is limited to 921 g per ES-3100 package.

The oxides in Groups 1, 3, 4 and 7 are high purity uranium oxide purity (the remainder is only trace impurities). Oxide Groups 2, 5, and 6 are listed to contain at least 20% uranium by weight, which allows up to 80% non-uranium material. As oxides, depending on the purity and chemical form, 3% to 17% of the total material composition will be oxygen, leaving up to 77% impurity or "filler". These three oxide groups include a range of scrap and recovered materials. For the least pure uranium oxides, the majority of the filler material is aluminum oxide (from recovered alumina traps or from oxidized uranium-aluminum alloys). Other materials that occur in appreciable quantities in some scrap materials are oxides and compounds of boron, calcium, iron, sodium, lead, zinc, magnesium, copper, molybdenum, and tungsten. These materials are essentially inert from the standpoint of criticality safety and chemical interaction with the ES-3100 convenience cans and bottles identified in this section for the shipment of oxides.

Uranium oxide shipments must be completed within 12 months after sealing the containment vessel in order to prevent the buildup of hydrogen gas beyond 5 mol %. The time period begins when the containment vessel is sealed. Hydrogen generation calculations are provided in Appendix 3.6.7.

HEU Metal and Alloy

HEU metal and alloy (alloys of uranium with aluminum, molybdenum, or zirconium) may be in the form of solid geometric shapes. Solid shapes may include the following:

1. cylinders having a diameter no larger than 4.25 in. (maximum of one cylinder per convenience can);

2. square bars having a cross section no larger than 2.29 in. × 2.29 in. (maximum of one bar per convenience can); and

3. slugs having dimensions of 1.5 in. diameter × 2 in. tall (maximum of 10 per convenience can).

HEU bulk metal and alloy contents not covered by the geometric shapes category specified above will be in the broken metal category, and will be so limited.

Alloys of uranium may include aluminum, molybdenum, or zirconium. Uranium-aluminum alloys are typically 70 to 95% aluminum. Uranium-molybdenum alloys are typically 1 to 12% molybdenum. Uranium/molybdenum alloys may be plated with, clad with, or contain traces of aluminum, gold, stainless steel, nickel and/or chromium.

HEU bulk metal and alloy contents in the broken metal category may be of unspecified geometric form. HEU bulk metal and alloy in this category may also be of a specific shape where one or more of the characteristic dimensions vary from piece to piece (i.e., the height, width, length, radius, etc.).

For pyrophoric considerations, HEU metal and alloy must meet the following restrictions:

1. Uranium metal and alloy (broken) pieces must have a surface-area-to-mass ratio of not greater than 1 cm^2/g or must not pass through a 3/8-in. mesh sieve (or equivalent size-grading method).

2. Particles and small shapes which do not pass the size restriction tests in #1, and powders, foils, turnings, and wires, are not permitted unless they are in a sealed, inerted container.

Metal and alloy may be shipped in tinned-carbon steel, stainless steel, or nickel-alloy convenience cans. The only hydrogenous packing materials that can be used inside the containment vessel when shipping broken HEU metal are those that have a hydrogen density less than or equal to water.

<u>Uranyl Nitrate Crystals</u>

Uranyl nitrate crystals (UNX) are formed by dissolving uranium metal or any of the uranium oxides in nitric acid. Uranyl nitrate hexahydrate (UNH) has a chemical formula of $UO_2(NO_3)_2 + 6\ H_2\ O$. This most reactive form is used as the bounding composition for uranyl nitrate crystals in the criticality evaluation. Therefore, for UNX contents, X must be less than or equal to 6. The theoretical density of UNH crystals is 2.79 g/cm^3; however, the working densities will be less.

The user of the ES-3100 for UNX shipments will be required to use non-metallic containers only (Teflon bottles) as the convenience container.

Shipments of UNX crystals must be completed within the times shown in Table 1.3a in order to prevent the buildup of hydrogen gas beyond 5 mol %. The time period begins when the containment vessel is sealed. Hydrogen generation calculations are provided in Appendix 3.6.7.

TRIGA Fuel Elements

Fuel pellets from Training, Research, Isotopes, and General Atomics (TRIGA) reactor elements are authorized to be shipped in the ES-3100. The fuel shall be unirradiated. The TRIGA fuel shall be in the form of uranium zirconium hydride (UZrHx), where x ≤ 2. Fuel from three types of TRIGA fuel elements are allowed; TRIGA Standard Fuel Elements (SFE), Instrumented TRIGA Standard Fuel Elements (FTC), and TRIGA Fuel Follower Control Rods (FFCR). These fuel elements have three fuel pellets (or sections) per element. The fuel pellets from the SFEs and FTCs to be shipped are 8.5 wt% uranium and 70% enriched. Fissile loading is 45.33 g ^{235}U per pellet (136 g ^{235}U per element) and the dimensions are 5 in. in length and 1.44 in. in diameter. The fuel pellets from the FFCRs to be shipped are 8.5 wt% uranium and 70% enriched. Fissile loading is 37.33 g ^{235}U per pellet (113 g ^{235}U per element) and the dimensions are 5 in. in length and 1.31 in. in diameter. Specific TRIGA fuel element data is given in Table 1.4.

TRIGA fuel may be shipped as crimped fuel elements or as UZrHx fuel pellets (if disassembled), both of which shall be packed into convenience cans prior to shipment. Convenience cans of 4.25-in. diameter by various lengths shall be used. Fuel pellets loaded into convenience cans shall be up to 5 in. in length (full-length) and no more than three full-length pellets shall be loaded into a convenience can. Crimped fuel rods are clad fuel pellets and can be up to 15 in. in length (full-length of the fuel section from one fuel element). Cladding material is stainless steel or aluminum. Only the fuel section of the TRIGA fuel element is allowed to be shipped (Fig. 1.5); however, there may be residual cladding up to ½ in. in length at either end of the crimped fuel rod. Up to three 15-in. long crimped fuel elements shall be loaded into a single 17.5-in. long convenience can for shipping (Fig 1.4). Maximum loading of bare fuel pellets and crimped fuel elements shall be 3 fuel element equivalence per ES-3100 containment vessel. Only 70% enriched TRIGA fuel will be shipped. For SFEs and FTCs, the maximum allowable loading is 408 g ^{235}U per package, and for FFCRs, the maximum allowable loading is 339 g ^{235}U per package. No spacer cans are required.

1.2.3.1 Radioactive/fissile constituents

For the ES-3100 package with bulk HEU content, the maximum number of A_2s is 294.00 (at 70 years) and the maximum activity is 0.3243 TBq (at 10 years) [Table 4.4].

Ground Transport

Fissile material loading limits for the contents of the ES-3100, as determined by criticality analyses, structural analyses, or hydrogen gas generation evaluations, are presented in Tables 1.3 and 1.3a.

Table 1.3. Authorized content [a] and fissile mass loading limits [b, c] for ground transport

Content description		Enrichment	CSI	No spacers, ^{235}U (kg)	Basis for limit	277-4 can spacers, [d] ^{235}U (kg)	Basis for limit
Solid HEU metal or alloy (specified geometric shapes) [e]	Cylinder A	≤ 100%	0.0	15.000	Crit.	25.000	Crit.
	Cylinder B	≤ 100%	0.0	18.000	Crit.	30.000	Crit.
	Square bars	≤ 100%	0.0	30.000	Crit.	35.200 [f]	Struct.
	Slugs	≤ 95%	0.0	17.374	Crit.	-	-
	Slugs	≤ 80%	0.0	-	-	29.318	Crit.
	Slugs	> 80%, ≤ 95%	0.0	-	-	24.324	Crit.
	Slugs	> 80%, ≤ 95%	0.4	-	-	34.749	Crit.
Broken HEU metal or alloy [g]		> 95%, ≤ 100%	0.0	Spacers req'd [d]		2.774	Crit.
			0.4	Spacers req'd		5.549	Crit.
			0.8	Spacers req'd		9.248	Crit.
			2.0	Spacers req'd		13.872	Crit.
			3.2	Spacers req'd		24.969	Crit.
		> 90%, ≤ 95%	0.0	Spacers req'd		3.516	Crit.
			0.4	Spacers req'd		6.154	Crit.
			0.8	Spacers req'd		10.549	Crit.
			2.0	Spacers req'd		18.461	Crit.
			3.2	Spacers req'd		26.373	Crit.
		> 80%, ≤ 90%	0.0	Spacers req'd		3.333	Crit.
			0.4	Spacers req'd		7.500	Crit.
			0.8	Spacers req'd		12.500	Crit.
			2.0	Spacers req'd		20.000	Crit.
			3.2	Spacers req'd		28.334	Crit.
		> 70%, ≤ 80%	0.0	2.967	Crit.	4.450	Crit.
			0.4	5.192	Crit.	8.900	Crit.
			0.8	8.900	Crit.	16.317	Crit.
			2.0	17.059	Crit.	25.218	Crit.
			3.2	27.443	Crit.	28.184	Crit.
		> 60%, ≤ 70%	0.0	3.249	Crit.	5.198	Crit.
			0.4	5.848	Crit.	12.996	Crit.
			0.8	13.646	Crit.	20.793	Crit.
			2.0	21.444	Crit.	24.692	Crit.
			3.2	24.692	Crit.	24.692	Crit.
		≤ 60%	0.0	5.576 kg U	Crit.	11.154 kg U	Crit.
			0.4	14.872 kg U	Crit.	28.813 kg U	Crit.
			0.8	28.814 kg U	Crit.	35.20 kg U [f]	Struct.
			2.0	35.20 kg U [f]	Struct.	35.20 kg U [f]	Struct.
			3.2	35.20 kg U [f]	Struct.	35.20 kg U [f]	Struct.

Table 1.3. Authorized content [a] and fissile mass loading limits [b, c] for ground transport

Content description	Enrichment	CSI	No spacers, ^{235}U (kg)	Basis for limit	277-4 can spacers, [d] ^{235}U (kg)	Basis for limit
HEU oxide [h]	≤ 100%	0.0	15.13 kg oxide 9.682 kg ^{235}U 921 g carbon	Crit., H_2 gen.	Spacer not req'd	-
		0.4	15.13 kg oxide 12.323 kg ^{235}U	Crit., H_2 gen.	Spacer not req'd	-
TRIGA fuel	20 %	0.0	0.921	Crit.	Spacer not req'd	-
	70 %	0.0	0.408	Crit.	Spacer not req'd	-

[a] HEU in solution form is not permitted for shipment in the ES-3100.
[b] All limits are expressed in kg ^{235}U unless otherwise indicated.
[c] Mass loadings cannot be rounded up.
[d] 277-4 can spacers as described on Drawing No. M2E801580A043 (Appendix 1.4.8).
[e] Geometries of solid shapes are as follows:
- Cylinder A is larger than 3.24 in. diameter but no larger than 4.25 in. diameter: maximum of 1 cylinder per can.
- Cylinder B is no larger than 3.24 in. diameter: maximum of 1 cylinder per can.
- Square bars are no larger than 2.29 in. × 2.29 in. (cross section): maximum of 1 bar per can.
- Slugs are a maximum of 1.5 in. diameter × 2.0 in. tall: a maximum of 10 per convenience can where the actual number permitted is restricted by the stated loading limit.

[f] Maximum planned content weight is 35.20 kg. Maximum analyzed for criticality safety is 35.32 kg.
[g] Mass limits for alloys (uranium with aluminum, molybdenum, or zirconium) must assume that non-uranium portion is ^{235}U.
[h] Seal time must be 12 months or less. Seal time is the length of time after the ES-3100 containment vessel is sealed that the shipment must be complete.

Table 1.3a. Uranyl nitrate crystal content loading limits for ground transport

Product [a, b]	Seal time [c] (months)	CSI	Loading limit [d, e] (kg UNX)	U content [f] (wt %)
UNX, $0 < X \leq 3$	2	0.4	11.90	$52 < U \leq 61$
	4	0.4	6.70	$52 < U \leq 61$
UNX, $X > 3$	2	0.4	9.17	$46 < U \leq 52$
	4	0.0	4.75	$46 < U \leq 52$

[a] UNX is uranyl nitrate hydrate $[UO_2(NO_3)_2 * XH_2O]$ where $0 < X \leq 6$. Uranyl nitrate solution is not allowed.
[b] Must be shipped in Teflon bottles.
[c] Seal time—length of time after the ES-3100 containment vessel is sealed that the shipment must be complete. The listed seal times have been reduced for additional conservatism compared to the calculated values shown in Table 3.6.7.1.
[d] Total mass of UNX crystals. Spacers are not required for this content type.
[e] Loading limits for uranyl nitrate crystals are based on hydrogen generation calculations presented in Appendix 3.6.7.
[f] Enrichment up to 100%.

Air Transport

Content for air transport of the ES-3100 includes HEU in the form of unirradiated TRIGA fuel pellets or crimped fuel elements. Fissile material mass loading limits for these contents, as determined by the criticality analyses, are presented in Table 1.3b for air transport. The characteristics of the air transport contents shall be similar to the ground transport contents. Fissile loading per package will be as follows:

> TRIGA fuel elements and pellets - 3 fuel element equivalence per package. Fuel shall be 70% enriched and in the form of SFEs, FTCs, and FFCRs. Maximum fissile loading for SFEs and FTCs shall be 408 g ^{235}U per package, and for FFCRs, the maximum allowable load shall be 339 g ^{235}U per package.

Table 1.3b. Authorized content and fissile mass loading limits [a, b] for air transport

Content Description	Enrichment	CSI	^{235}U (kg)
TRIGA fuel	20%	0.0	0.716
	70%	0.0	0.408

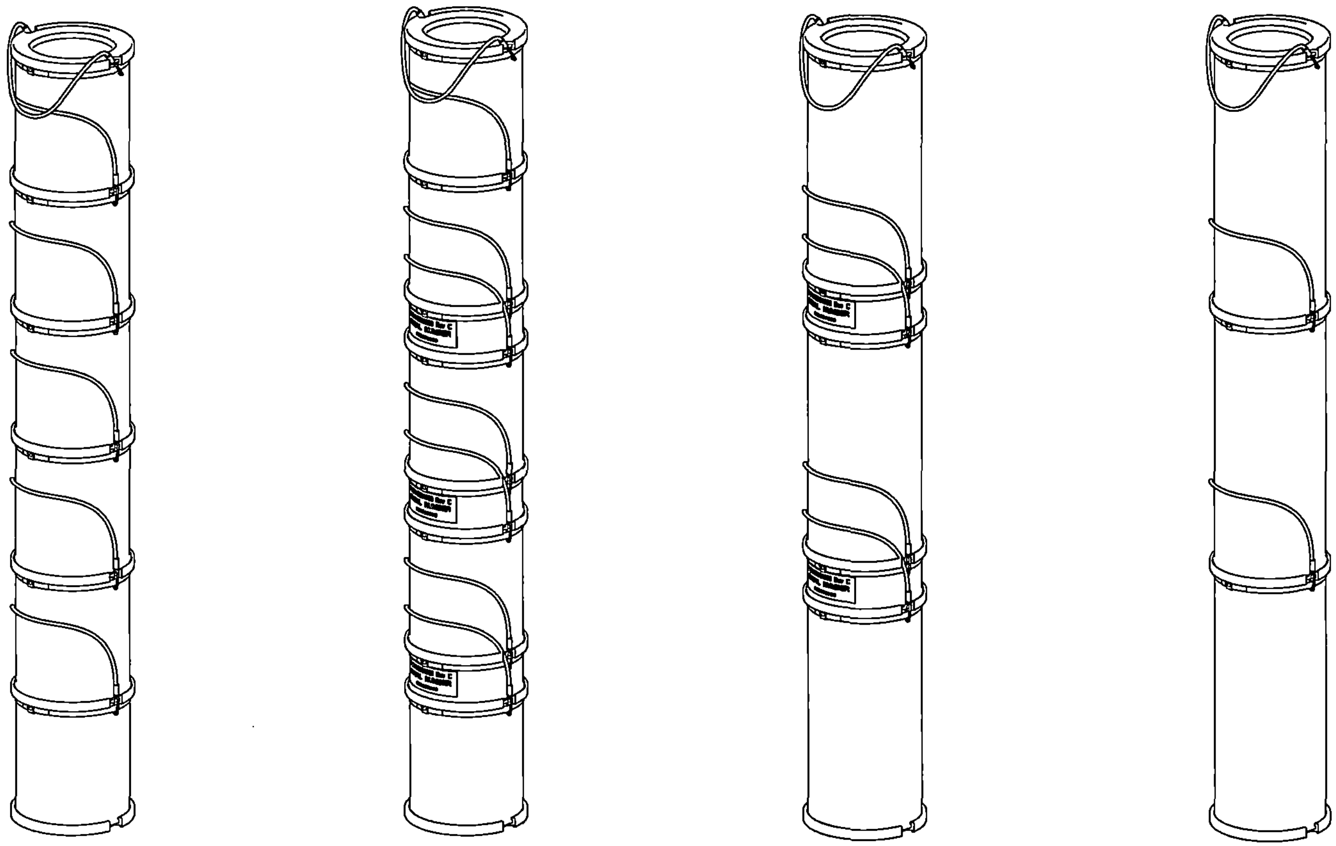
[a] All limits are expressed in kg ^{235}U unless otherwise indicated.
[b] Mass loadings cannot be rounded up.

1.2.3.2 Chemical and physical form

The fissile material contents are in solid (HEU metal, alloy, or TRIGA fuel), crystalline (UNX), or powder (HEU oxide) form. Some moisture (up to 3 wt %) may be present in the HEU oxide material, thereby making the oxide content clump together.

Table 1.4. TRIGA fuel specifications

Uranium Content/Cladding/Type	Fuel Properties						
	U (wt% of fuel)	U235 (wt% of U)	Active Fuel Length (in.)	Fuel OD (in.)	U (grams)	U235 (grams)	Hydrogen to Zirc Ratio
STANDARD ELEMENTS							
8.5 wt% aluminum clad element, 15 inch	8.5	20	15.00	1.41	189	37	1.0
8.5 wt% stainless steel clad element	8.5	20	15.00	1.44	197	39	1.6
12 wt% stainless steel, smooth clad element	12	20	15.00	1.44	285	56	1.6
12 wt% stainless steel, dimpled clad element	12	20	15.00	1.40	271	53	1.6
8.5 wt% stainless steel clad, High Enriched Uranium	8.5	70	15.00	1.44	194	136	1.6
20 wt% stainless steel clad element	20	20	15.00	1.44	503	99	1.6
30 wt% stainless steel clad element	30	20	15.00	1.44	825	163	1.6
45 wt% stainless steel clad element	45	20	15.00	1.44	1560	307	1.6
INSTRUMENTED ELEMENTS							
8.5 wt% aluminum clad element, 15 inch	8.5	20	15.00	1.41	189	37	1.6
8.5 wt% instrumented, stainless steel clad element	8.5	20	15.00	1.44	197	39	1.6
12 wt% instrumented, stainless steel, smooth clad element	12	20	15.00	1.44	285	56	1.6
12 wt% instrumented, stainless steel, dimpled clad element	12	20	15.00	1.40	271	53	1.6
8.5 wt% instrumented stainless steel clad, High Enriched Uranium	8.5	70	15.00	1.44	194	136	1.6
20 wt% instrumented, stainless steel clad element	20	20	15.00	1.44	503	99	1.6
30 wt% instrumented, stainless steel clad element	30	20	15.00	1.44	825	163	1.6
45 wt% instrumented stainless steel clad element	45	20	15.00	1.44	1560	307	1.6
FUELED FOLLOWER CONTROL RODS							
8.5 wt% stainless steel clad fueled follower control rod	8.5	20	15.00	1.31	163	32	1.6
12 wt% stainless steel, smooth clad fueled follower control rod	12	20	15.00	1.31	237	47	1.6
12 wt% stainless steel, dimpled clad fueled follower control rod	12	20	15.00	1.40	257	50	1.6
12 wt% stainless steel, dimpled clad fueled follower control rod	12	20	15.00	1.40	271	53	1.6
8.5 wt% stainless steel high enriched fueled follower control rod for a cluster rod assy	8.5	70	15.00	1.31	162	113	1.6
20 wt% stainless steel clad fueled follower control rod	20	20	15.00	1.31	418	82	1.6
30 wt% stainless steel clad fueled follower control rod	30	20	15.00	1.31	685	135	1.6
45 wt% stainless steel clad fueled follower control rod	45	20	15.00	1.31	1560	307	1.6
STANDARD RODS FOR CLUSTER ASSEMBLY							
8.5 wt% stainless steel clad cluster rod	8.5	20	15.00	1.37	166	33	1.6
12 wt% stainless steel, smooth clad cluster rod	12	20	15.00	1.37	243	58	1.6
8.5 wt% stainless steel clad, High Enriched Uranium, cluster rod	8.5	70	15.00	1.37	175	122	1.6
20 wt% stainless steel clad cluster rod	20	20	15.00	1.37	427	85	1.6
30 wt% stainless steel clad cluster rod	30	20	15.00	1.37	710	141	1.6
8.5 wt% stainless steel clad, HEU, fueled follower control rod	8.5	70	15.00	1.31	160	112	1.6
45 wt% stainless steel clad fueled follower control rod	45	20	15.00	1.37	1348	267	1.6



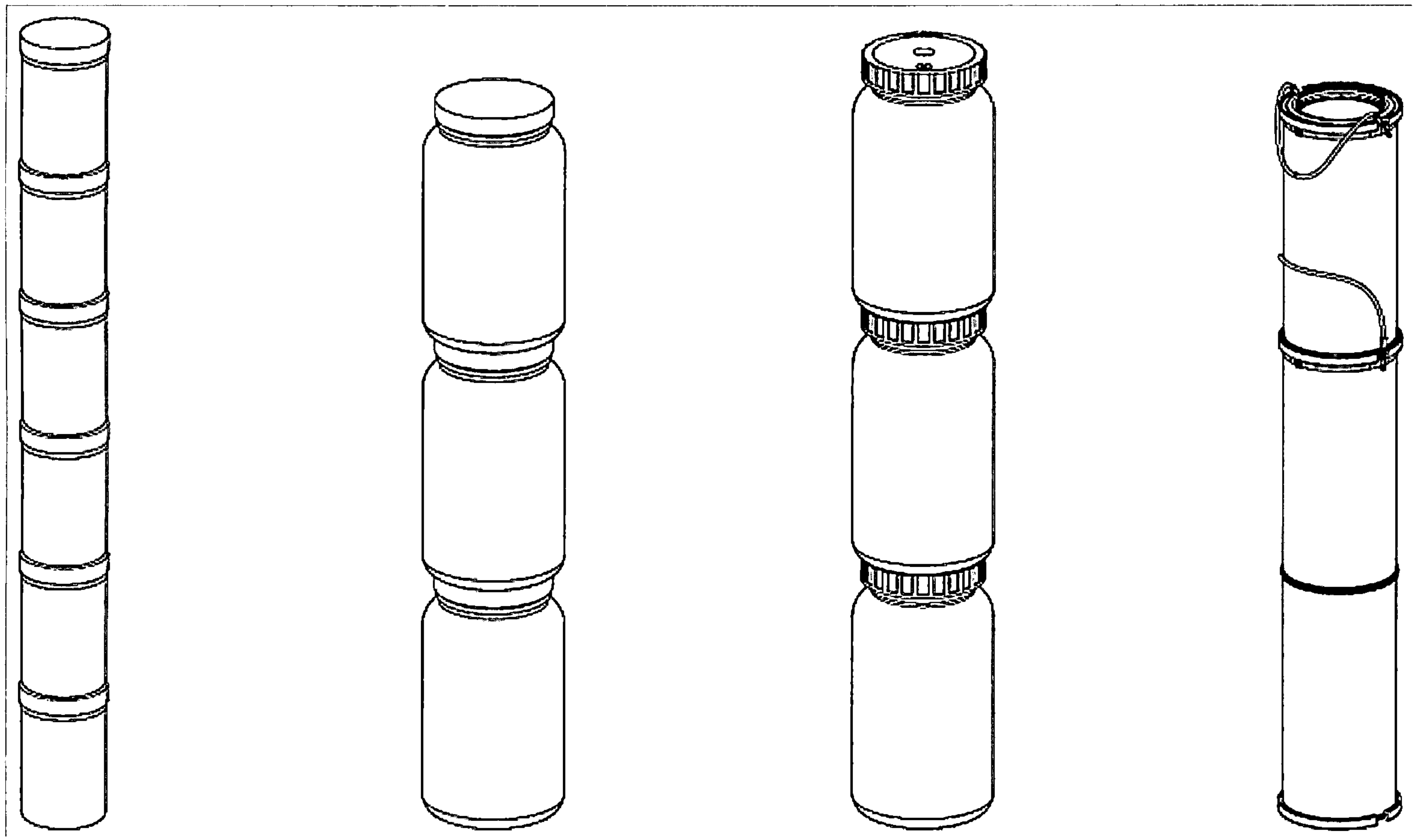
Six Cans
⌀4.25" × 4.88" Tall

Five Cans
⌀4.25" × 4.88" Tall
& three spacers
(one empty can)

Three Cans
⌀4.25" × 8.75" Tall
& two spacers

Three Cans
⌀4.25" × 10" Tall
⌀4.25" × 8.75" Tall

Fig. 1.4. Typical shipping configurations inside the ES-3100 containment vessel.



Six Nickel Cans
⌀3.0" × 4.75" Tall

Three Poly Bottles
⌀4.94" × 8.7" Tall

Three Teflon Bottles
⌀4.69" × 9.4" Tall

One Can
⌀4.25" × 17.5" Tall (two 8.75-in. cans brazed together) & one empty can

Fig. 1.4. Typical shipping configurations inside the ES-3100 containment vessel (cont.).

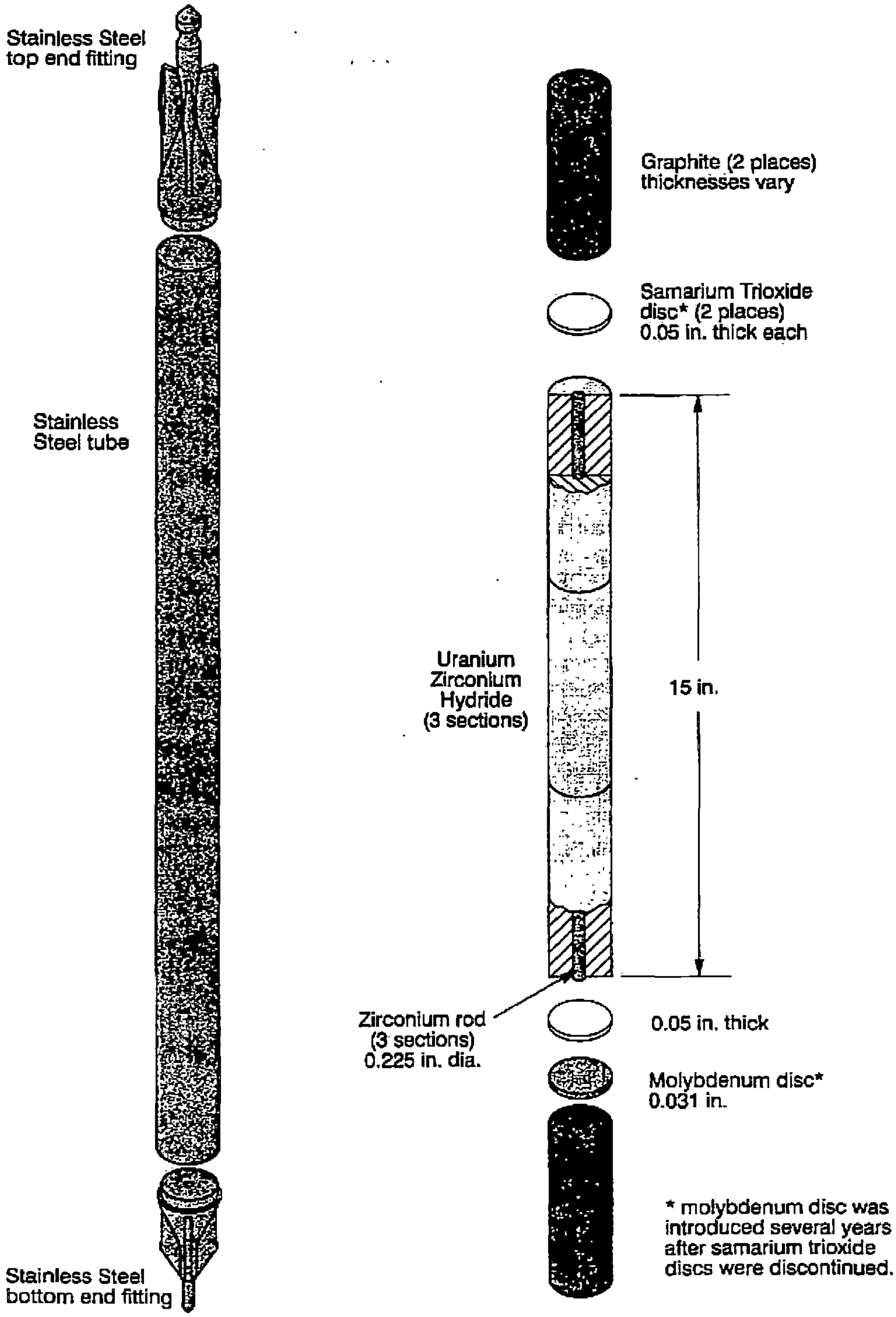


Fig 1.5. TRIGA fuel element.

1.2.3.3 Reflectors, absorbers, and moderators

The reflectors, absorbers, and moderators present in the ES-3100 package are those associated with the materials of construction. For example, the thermal insulation acts as a neutron reflector to the contents of a single package and as a neutron moderator in an array of packages. The degree of neutron moderation is a function of the hydrogen content in the Kaolite 1600 and 277-4 materials. The stainless-steel materials of the containment vessel and the drum also act as neutron reflectors to the contents of a single package but act as neutron absorbers in an array of packages. The nuclear properties of the materials of construction and of the contents are important and have been taken into account in the criticality safety evaluation (Sect. 6). In addition to the materials of construction in the ES-3100 shipping package mentioned above, the 277-4 material has been specifically added to the ES-3100 package for the purpose of enhancing the neutron absorption characteristics for safety purposes (see Sect. 6 for additional discussion of the neutron-absorbing characteristics of this material).

1.2.3.4 Shipping configurations

Authorized content convenience containers for the ES-3100 are cans constructed of stainless steel, tin-plated carbon steel, or nickel-alloy (series 200, passivated), and polyethylene and Teflon convenience bottles. These convenience containers are used to hold the HEU contents for shipment in the ES-3100 package and to assure that the inside of the containment vessel does not become contaminated with HEU under NCT. Convenience containers used in the ES-3100 package must have an outer diameter less than or equal to 12.7 cm (5 in.). The height can vary up to the full internal height of the containment vessel or 78.74 cm (31 in.). Some contents require the use of can spacers (see Table 1.3). These can spacers are thin-walled stainless-steel cans filled with 277-4 material (Drawing M2E801580A043, Appendix 1.4.8). Each convenience can and spacer may be equipped with a stainless-steel band and nylon-coated wire to facilitate loading and unloading operations. Silicone rubber pads may also be used between convenience cans to dampen vibration and minimize contact between metal components. Any combination of convenience containers will be allowed in a single package, as long as the total height of the stack-up (including spacers, if required) does not exceed the inside working height of the containment vessel [78.74 cm (31 in.)]. If can spacers are required, no more than one-third of the total HEU content mass limit shown in Table 1.3 may be placed between any two spacers.

Typical configurations of authorized ES-3100 convenience containers are shown in Fig. 1.4. The shipping configurations shown in Fig. 1.4 utilize 3.00 and 4.25-in.-diameter convenience cans of various heights (such as 4.75, 4.88, 8.75, and 10 in.), 4.94 in. diameter by 8.7 in. tall polyethylene bottles, and 4.69 in. diameter by 9.4 in. tall Teflon bottles. Although any combination of the convenience cans that will fit inside the internal volume of the containment vessel may be used, content forms shall not be mixed in a single package (i.e., HEU oxides may not be packed with HEU metal). Empty cans and/or stainless-steel scrubbers may be used to fill the void space at the top of the containment vessel. If empty cans are shipped, a minimum 0.32-cm (0.125-in.)-diam hole must be placed through the lid to prevent over-pressurization of the can in the event of a thermal accident. In addition, these empty cans must be placed on top of the loaded cans. In configurations not requiring can spacers for criticality control, can spacers may be shipped for convenience if placed on top of loaded cans in the containment vessel. The HEU contents may be bagged or wrapped in polyethylene, and the convenience containers may also be wrapped in polyethylene to further reduce the possibility of contamination. If metal cans or polyethylene bottles are used as convenience containers, the total amount of offgassing material (including polyethylene bottles, polyethylene bagging, and lifting slings) is limited to 500 g per package. If Teflon bottles are used as convenience containers, the total amount of off-gassing material (including Teflon bottles, polyethylene bagging, and lifting slings) is limited to 1600 g per package (limit established by

assuming three 400-g Teflon bottles and 400-g polyethylene bagging). If closed convenience cans with an outer diameter greater than 4.25 in. are used, the containment vessel cannot contain any materials that off-gas. The only hydrogenous materials that can be present in the containment vessel when shipping HEU broken metal are those that have a hydrogen density less than or equal to water. In some shipping configurations, silicone rubber pads will be placed between the convenience cans to reduce vibration.

1.2.3.5 Maximum normal operating pressure

As defined in 10 CFR 71.4, the maximum normal operating pressure is the maximum gauge pressure that would develop in the containment system in one year under an ambient temperature of 38°C (100°F) in still air, with appropriate insolation in the absence of venting, external cooling by an ancillary system, or operational controls during transport. Under these conditions, the maximum normal operating pressure in the ES-3100 containment vessel would be 98.84 kPa (14.336 psig) [200.20 kPa (29.036 psia)]. In comparison, the design internal pressure of the containment vessel is 801.17 kPa (116.2 psia). The design internal pressure is a conservatively assumed value that was assigned for the purpose of the ASME code calculations in Appendix 2.10.1.

1.2.3.6 Maximum and minimum weight

The maximum gross shipping weight for the ES-3100 package is 190.5 kg (420 lb). The proposed maximum gross shipping weight of the ES-3100 package with any proposed content is 187.81 kg (414.05 lb) [Table 2.8]. The total weight of the tested ES-3100 units ranged from 157.4 to 203.7 kg (347 to 449 lb) [Table 2.9].

The weight of HEU contents in the ES-3100 shipping package is limited to 35.2 kg (77.60 lb). This limit has been established as a bounding case for the maximum structural, thermal, and containment limit for the package. Actual mass restrictions for the various contents based on the various analyses presented in the SAR are listed in Tables 1.3, 1.3a, and 1.3b. The maximum allowable payload weight of any configuration, including packing components (convenience cans and bottles, polyethylene bags, silicone pads, can spacers, etc.), is 40.82 kg (90 lb). There is no minimum payload weight requirement. ES-3100 shipping package weights are discussed in greater detail in Sect. 2 and are broken down into individual component weights in Tables 2.8 and 2.9.

The payload weight (including convenience cans, silicone rubber pads, can spacers, and the HEU mockup) used in the ES-3100 package tests ranged from a minimum of 3.6 kg (8 lb) to a maximum of 50.3 kg (111 lb).

1.2.3.7 Maximum decay heat

As shown in Sect. 3.1.2 , the conservatively calculated maximum heat generation rate of the contents is approximately 0.4 W. The ES-3100 package was designed for a maximum heat load of 20 W. Thermal analyses have been performed assuming heat sources of 0.4, 20, and 30 W in the ES-3100 containment vessel (Appendix 3.6.2).

1.2.3.8 Loading restrictions

Loading restrictions based upon the results of the criticality safety calculations presented in Sect. 6.2.4 and additional limitations on packing materials outlined in Sect. 3 are as follows:

(1) HEU fissile material to be shipped in the ES-3100 package must be placed in stainless-steel, tin-plated carbon steel or nickel alloy convenience cans, polyethylene bottles, or Teflon bottles. Convenience containers used in the ES-3100 package must have an outer diameter less than or equal to 12.7 cm (5 in.). The height can vary up to the full internal height of the containment vessel or 78.74 cm (31 in.). Any closure on the convenience can is allowed.

(2) Any combination of convenience cans is allowed in a single package, as long as the total height (including silicone rubber pads and can spacers, if required) does not exceed the inside working height of the containment vessel (approximately 31 in.).

(3) In situations where empty convenience cans are shipped in the package, they must be placed on top of the loaded cans, and a minimum 0.32-cm (0.125-in.)-diam hole must be placed through the lid to prevent over pressurization of the can.

(4) The concentration of uranium isotopes in the content is limited as shown in Table 1.1.

(5) For pyrophoric considerations, HEU metal or alloy pieces must have a specific area not greater than 1 cm^2/g or must not pass through a 3/8-in. (0.95 cm) mesh sieve (or equivalent size-grading method). Incidental small pieces that do not pass the size restriction tests, and powders, foils, turnings, and wires, may only be shipped if they are in a sealed, inerted container.

(6) The content shall not exceed "per package" fissile material mass loading limits specified in Table 1.3 based on the CSI. Where can spacers are required for a "per package" mass loading, the quantity of fissile material located in any vacancy between or adjacent to can spacers shall not exceed one-third of the mass loading limit in Table 1.3.

(7) The package content is defined as the HEU fissile material, the convenience cans and can spacers, and the associated packing materials (plastic bags, pads, tape, etc.) inside the ES-3100 containment vessel.

(8) If metal cans are used as convenience containers, the amount of polyethylene bagging and lifting slings is limited to 500 g per package. If Teflon bottles are used as convenience containers, the total amount of offgassing material (including Teflon bottles, polyethylene bagging, and lifting slings) is limited to 1600 g per package. If metal cans or polyethylene bottles are used as convenience containers, the total amount of offgassing material (including polyethylene bottles, polyethylene bagging, and lifting slings) is limited to 500 g per package (see Item 7 in Sect. 6.2.4). If closed convenience cans with an outer diameter greater than 4.25 in. are used, the containment vessel cannot contain any materials that offgas. These mass limits do not include moisture in oxide. Moisture is accounted for in criticality safety calculations (Sect. 6.1.2).

(9) The only hydrogenous packing materials that can be used in the containment vessel when shipping broken HEU metal are those that have a hydrogen density less than or equal to water.

(10) Shipments of UNX crystals must be completed in the time period noted in Table 1.3a. Shipments of uranium oxide must be completed in 12 months. This time period begins when the containment vessel is sealed.

(11) The mass of any unidentified constituents in content to be shipped in the ES-3100 must be counted against the fissile mass loading limit. Content must not contain unevaluated moderating materials.

1.2.4 Operational Features

The ES-3100 package is a Type B fissile material package designed in accordance with DOT and NRC regulations. These regulations require that the package be operated without undue risk to the public, even in the event of a severe accident, and that the dose rate and nonfixed radioactive contamination on the external surface of the package conform with 49 CFR 173.441 and 173.443, respectively. These requirements are translated into the designs for the containment, shielding, and nuclear criticality safety of the contents when subjected to NCT and HAC. Designs for containment, shielding, and nuclear subcriticality safety are supported by operational procedures for loading, unloading, and refurbishing to ensure that those design features are used and maintained in a manner commensurate with their intended function. Drop tests, crush tests, puncture tests, thermal tests, and water immersion tests (Sects. 2.6 and 2.7) show that the drum assembly maintains the insulation and the containment vessel in their intended configurations when subjected to NCT and HAC.

The decay heat generated by the contents (maximum of approximately 0.4 W) is negligible for a package of this size (Sect. 1.2.3.7 and Sect. 3.1.2).

Design features that provide shielding, containment, and nuclear criticality control perform these functions in a passive manner. No valves, connections, gauges, active coolants, or operationally pressurized parts are integral to the ES-3100 package.

1.3 GENERAL REQUIREMENTS FOR ALL PACKAGES

This section demonstrates compliance with 10 CFR 71.43(a) and (b), "General Standards for All Packages."

1.3.1 Minimum package size

Requirement. The smallest overall dimension of a package may not be less than 10 cm (4 in.).

Analysis. The drum's outside diameter (including the chimes or rolling rings) is 49.2 cm (19.37 in.), and the outside height including the lid is 110.49 cm (43.5 in.). The minimum outside diameter of the ES-3100 containment vessel is 13.36 cm (5.26 in.), and the overall height is 82.30 cm (32.4 in.). Therefore, the packaging meets this requirement.

1.3.2 Tamper-indicating feature

Requirement. The outside of a package must incorporate a feature, such as a seal, that is not readily breakable and that, while intact, provides evidence that the package has not been opened by unauthorized persons.

Analysis. The removable drum head is attached to the body by eight 5/8-11-UNC-2B silicon bronze nuts and 5/8-in. nominal washers. Two 0.51-cm (0.20-in.)-thick lugs with 0.953-cm (0.375-in.)-diam holes project through slots in the drum lid and provide attachment for wire-type TIDs. These TIDs consist of a stainless-steel cable with an aluminum crimp closure or equivalent. The requirement is satisfied by the TIDs, which are installed as specified in Sect. 7.1.2.2. The seal is only required when HEU is in the package. It is not required for empty shipments.

1.4 APPENDICES

Appendix	Description
1.4.1	PACKAGE CERTIFICATION DRAWING
1.4.2	EQUIPMENT SPECIFICATION JS-YMN3-801580-A002, *ES-3100 DRUM ASSEMBLY*
1.4.3	EQUIPMENT SPECIFICATION JS-YMN3-801580-A001, *ES-3100 CONTAINMENT VESSEL*
1.4.4	EQUIPMENT SPECIFICATION, JS-YMN3-801580-A003, *MANUFACTURING PROCESS SPECIFICATION FOR CASTING KAOLITE 1600™ INTO THE ES-3100 SHIPPING PACKAGE*
1.4.5	EQUIPMENT SPECIFICATION, JS-YMN3-801580-A005, *CASTING CATALOG NO. 277-4 NEUTRON ABSORBER FOR THE ES-3100 SHIPPING PACKAGE*
1.4.6	PACKAGE CATEGORY DETERMINATION
1.4.7	HEU OXIDE MATERIAL SPECIFICATION AS PROVIDED BY Y-12 HIGHLY ENRICHED URANIUM DISPOSITION PROGRAM OFFICE
1.4.8	PACKAGE ENGINEERING DRAWINGS
1.4.9	DESIGN ANALYSES AND CALCULATIONS, MIXING WEIGHTS AND ELEMENTAL COMPOSITION OF 277-4 NEUTRON POISON USED IN THE ES-3100
1.4.10	PYROPHORICITY OF URANIUM METAL
1.4.11	EQUIPMENT SPECIFICATION SPC M801580-0002, *EQUIPMENT SPECIFICATION FOR ES-3100 ETHYLENE PROPYLENE DIENE MONOMER (EPDM) CONTAINMENT VESSEL (CV) O-RINGS*

Appendix 1.4.1

PACKAGE CERTIFICATION DRAWING

Drawing No.	Rev.	Title
M2E801580A037	C	ES-3100 Shipping Container, Consolidated Assembly Drawing

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NOTES

1. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.

2. DIMENSIONS ARE IN INCHES [mm].

3. APPROXIMATE WEIGHT: 325 LBS [147.4 Kg] FOR F/N 1 EMPTY.

4. WELDING SYMBOLS SHALL BE INTERPRETED IN ACCORDANCE WITH AWS A2.4.

[5] SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002 ES-3100 DRUM ASSEMBLY.

[6] SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A001 ES-3100 CONTAINMENT VESSEL.

[7] SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A003 MANUFACTURING PROCESS SPECIFICATION FOR CASTING KAOLITE 1600™ INTO THE ES-3100 SHIPPING PACKAGE.

[11] SEE PROCUREMENT DOCUMENTS FOR PROPER REGISTERED USER NAME AND LOCATION.

[8] SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A005 CASTING CATALOG # 277-4 NEUTRON ABSORBER FOR THE ES-3100 SHIPPING PACKAGE.

[9] DURING INSTALLATION OF O-RINGS APPLY A THIN COAT OF SUPER-O-LUBE

[10] DURING INSTALLATION OF CONTAINER VESSEL LID ASSEMBLY, APPLY A LIGHT COAT OF KRYTOX GREASE TO THE THREADS AND UNDER THE NUT.

[11] SEE PROCUREMENT DOCUMENTS FOR PROPER REGISTERED USER NAME AND LOCATION. △C

NOTE	QTY REQ'D	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPECIFICATION	SHEET NO	FIND NO
10	AR	KRYTOX #240AC OR EQUAL THREAD LUBRICANT	FLUORINATED GREASE MILLER-STEPHENSON CHEMICAL CO.	NA	18
9	AR	SUPER-O-LUBE OR EQUAL O-RING LUBRICANT	CLEAR DIMETHYL SILOXANE POLYMER PARKER HANNIFIN CORP	NA	17
	1	MODIFIED VCO THREADED PLUG	BRASS	5	16
	1	EXTERNAL RETAINING RING	302 SST	5	15
	1	PLUG PAD	SILICONE RUBBER 22±5 SHORE A COLOR BLACK/GRAY	2	14
	1	CV FLANGE PAD		2	13
	1	CV BOTTOM PAD		2	12
	1	OUTER O-RING Ø5.859±.035 ID X Ø.139 ±.004	ETHYLENE PROPYLENE 70±5 SHORE A COLOR BLACK	2	11
	1	INNER O-RING Ø5.359±.035 ID X Ø.139±.004		2	10
5	1	ES3100 DATA PLATE	16 GA 304/304L SST ASTM SA240	2	9
5	1	ES3100 TREFOIL DATA PLATE		2	8
6	1	CONTAINMENT VESSEL CLOSURE NUT	NITRONIC 60 SST ASME SA-479 UNS-S21800	5	7
6	1	CONTAINMENT VESSEL SEALING LID	304 SST ASME SA-479	5	6
6	1	CONTAINMENT VESSEL BODY	304L SST	5	5
7 5	1	TOP PLUG WELDMENT	16 GA 304/304L SST ASTM SA240	4	4
5	1	DRUM LID WELDMENT		3	3
8 7 5	1	DRUM WELDMENT		3	2
	X	MAIN ASSEMBLY		2	1
	-1	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPECIFICATION	SHEET NO	FIND NO
		← QTY REQ'D NEXT ASSEMBLY	PARTS LIST		

M2E801580A037

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
C	09/10/08	J.F. DeCLUE

This document has been reviewed by a Y-12 DC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: R.D. AIGNER Date: 9/11/08

P THIS DRAWING PRODUCED ON PRO/ENGINEER

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DM	DATE	PE	DATE	PM	DATE
C	REVISED TREFOIL DATA PLATE, F/N 8, ADDED NOTE 11	JRJ	RDA	LR	GAB	WIN	[illegible]	LR	[illegible]	JGA	[illegible]
B	REVISED TREFOIL DATA PLATE, F/N 8	JRJ	RDA	JRJ	GAB	WIN	[illegible]	[illegible]	[illegible]	JGA	[illegible]
A	PAGE 1: MODIFIED GENERAL NOTES AND UPDATED FIELD NOTES ADDED TOLERANCES TO ORINGS. PAGE 3: ADDED CORRECT TOLERANCES AND REF. DIMS. PAGE 4. ADDED CORRECT INSPECTION DIMS. AND WELD SYMS. PAGE 5. ADDED CORRECT TOLERANCES AND INSPECTION DIMS. AND ADDED NOTE TO -5 ADDED SHEET 6 RN Y2003-0328	RDA	JSL	GAB	JRJ	WDS	3/22/06	RDA FOR CH	3/22/06	DBM	3/22/06
0	RN: Y2003-0328 ORIGINAL ISSUE	JMR	GM	GAB	RBC	MLG	1/23/06	RDA	1/23/06	JGA	1/23/06

REVISION OR ISSUE PURPOSE — REVISION APPROVALS (WE, DATE, DN/SO, DATE) — SQUAD CHECK (AR, CV, ST, HV, EN, FP, PD, EE, IE, M, NP)

SCALE: N.T.S.

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±.03
XXX DECIMALS ±.010
ANGLES ±0.5°
BREAK SHARP EDGES .03 MAX
FINISH 125 RMS

DRAWING APPROVALS		DATE
DRW	JM RAY	1/18/06
CHKR	G MCGINNIS	1/18/06
DE	GA BYINGTON	1/23/06
DVR	RB CONATSER	1/18/06
DM	ML GOINS	1/23/06
PE	RD AIGNER	1/23/06
PM	JG ARBITAL	1/23/06

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PROJECT NAME: ES-3100 SHIPPING PACKAGE

CONSOLIDATED ASSEMBLY DRAWING

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	6	A	U

51	52	53		REV
CM	PKG	IN	M2E801580A037	C

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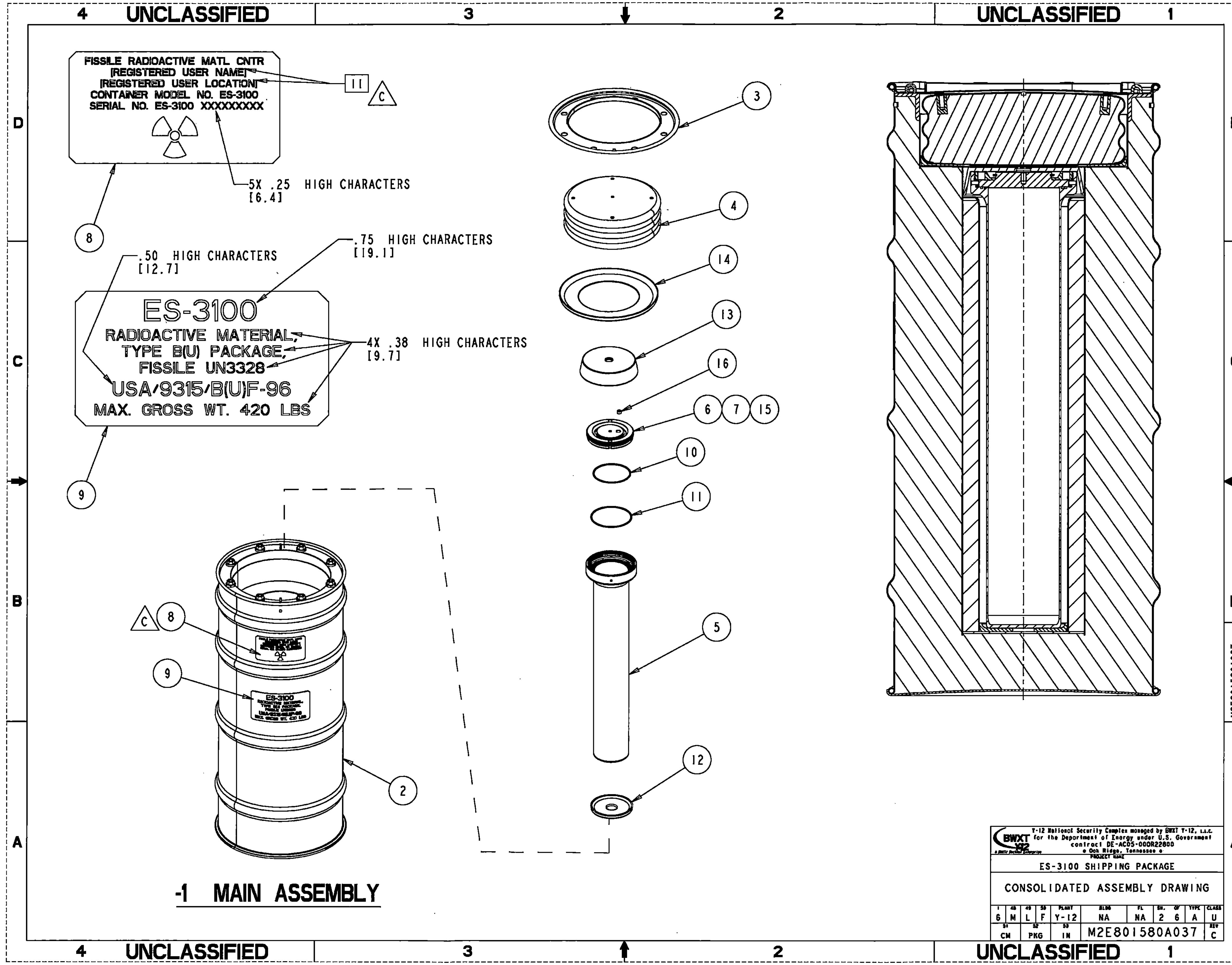

UNCLASSIFIED
FISSILE RADIOACTIVE MATL CNTR
[REGISTERED USER NAME]
[REGISTERED USER LOCATION]
CONTAINER MODEL NO. ES-3100
SERIAL NO. ES-3100 XXXXXXXXX
11
C
5X .25 HIGH CHARACTERS [6.4]
8
.50 HIGH CHARACTERS [12.7]
.75 HIGH CHARACTERS [19.1]
ES-3100
RADIOACTIVE MATERIAL,
TYPE B(U) PACKAGE,
FISSILE UN3328
USA/9315/B(U)F-96
MAX. GROSS WT. 420 LBS
4X .38 HIGH CHARACTERS [9.7]
9
3
4
14
13
16
6 7 15
10
11
5
12
2
-1 MAIN ASSEMBLY
M2E801580A037
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Oak Ridge, Tennessee
ES-3100 SHIPPING PACKAGE
CONSOLIDATED ASSEMBLY DRAWING
6 M L F Y-12 NA NA 2 6 A U
CM PKG IN M2E801580A037 C

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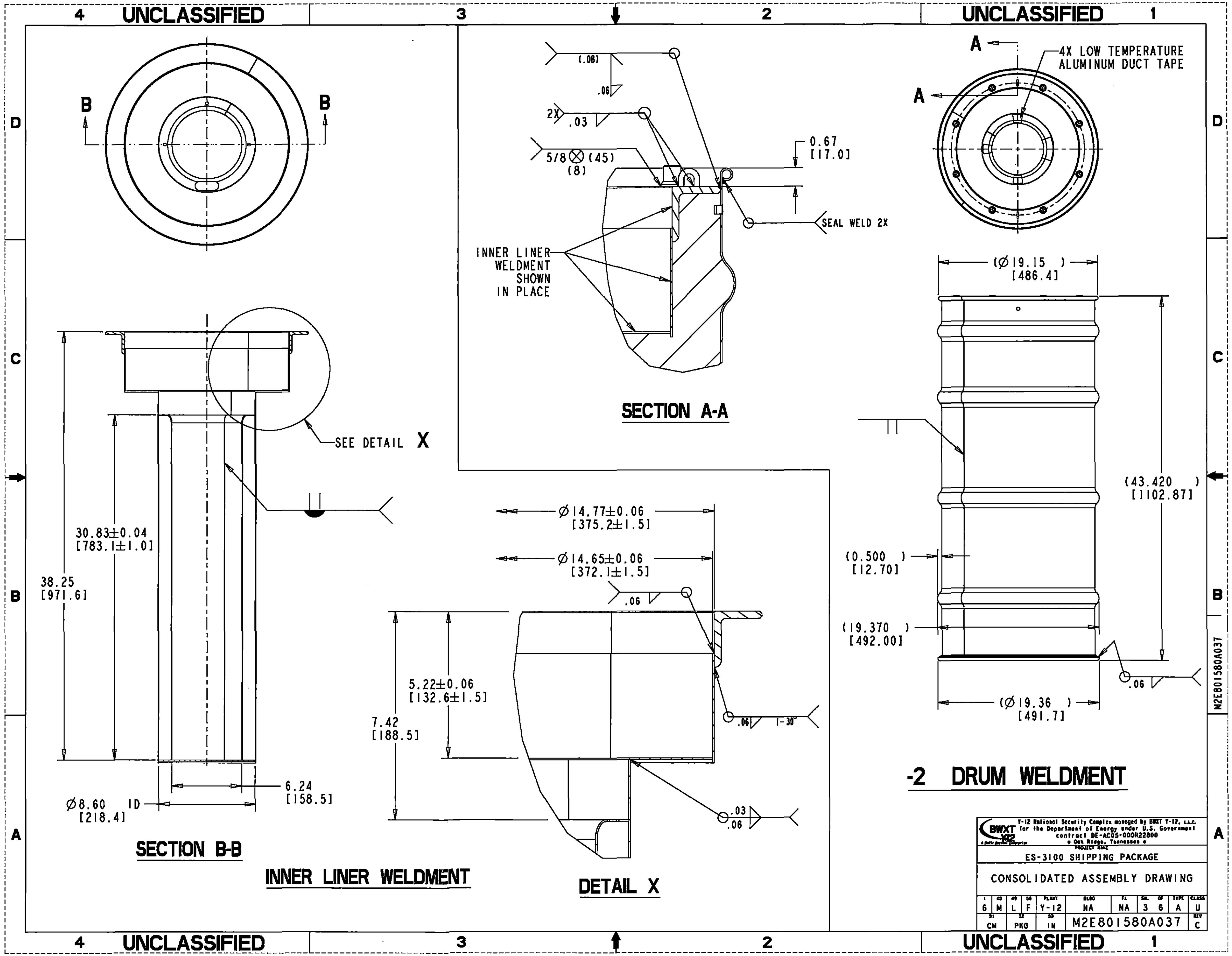

UNCLASSIFIED
4
3
2
1
D
C
B
A
B
B
SECTION B-B
SEE DETAIL X
30.83±0.04
[783.1±1.0]
38.25
[971.6]
6.24
[158.5]
Ø8.60 ID
[218.4]
INNER LINER WELDMENT
(.08)
.06
2X .03
5/8 (45)
(8)
0.67
[17.0]
SEAL WELD 2X
INNER LINER WELDMENT SHOWN IN PLACE
SECTION A-A
Ø14.77±0.06
[375.2±1.5]
Ø14.65±0.06
[372.1±1.5]
.06
5.22±0.06
[132.6±1.5]
7.42
[188.5]
.06 1-30°
.03
.06
DETAIL X
A
A
4X LOW TEMPERATURE ALUMINUM DUCT TAPE
(Ø19.15)
[486.4]
(43.420)
[1102.87]
(0.500)
[12.70]
(19.370)
[492.00]
.06
(Ø19.36)
[491.7]
-2 DRUM WELDMENT
M2E801580A037
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ES-3100 SHIPPING PACKAGE
CONSOLIDATED ASSEMBLY DRAWING
6 M L F Y-12 NA NA 3 6 A U
CM PKG IN M2E801580A037 C
UNCLASSIFIED

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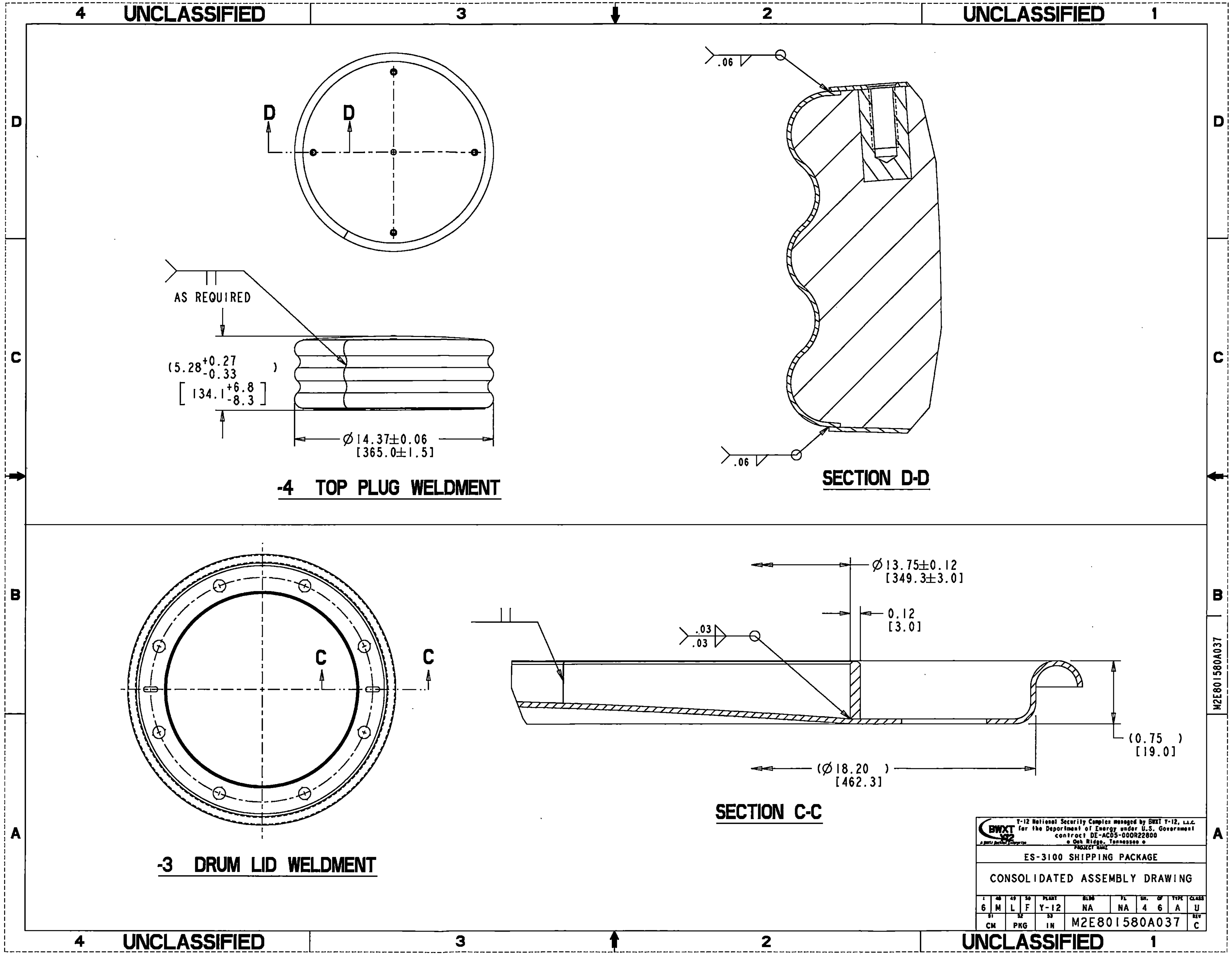

UNCLASSIFIED
D
D
AS REQUIRED
(5.28 +0.27 -0.33)
[134.1 +6.8 -8.3]
Ø14.37±0.06
[365.0±1.5]
-4 TOP PLUG WELDMENT
.06
.06
SECTION D-D
C
C
-3 DRUM LID WELDMENT
Ø13.75±0.12
[349.3±3.0]
0.12
[3.0]
.03
.03
(0.75)
[19.0]
(Ø18.20)
[462.3]
SECTION C-C
M2E801580A037
BWXT Y-12
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CONSOLIDATED ASSEMBLY DRAWING
6 M L F Y-12 NA NA 4 6 A U
CM PKG IN M2E801580A037 C
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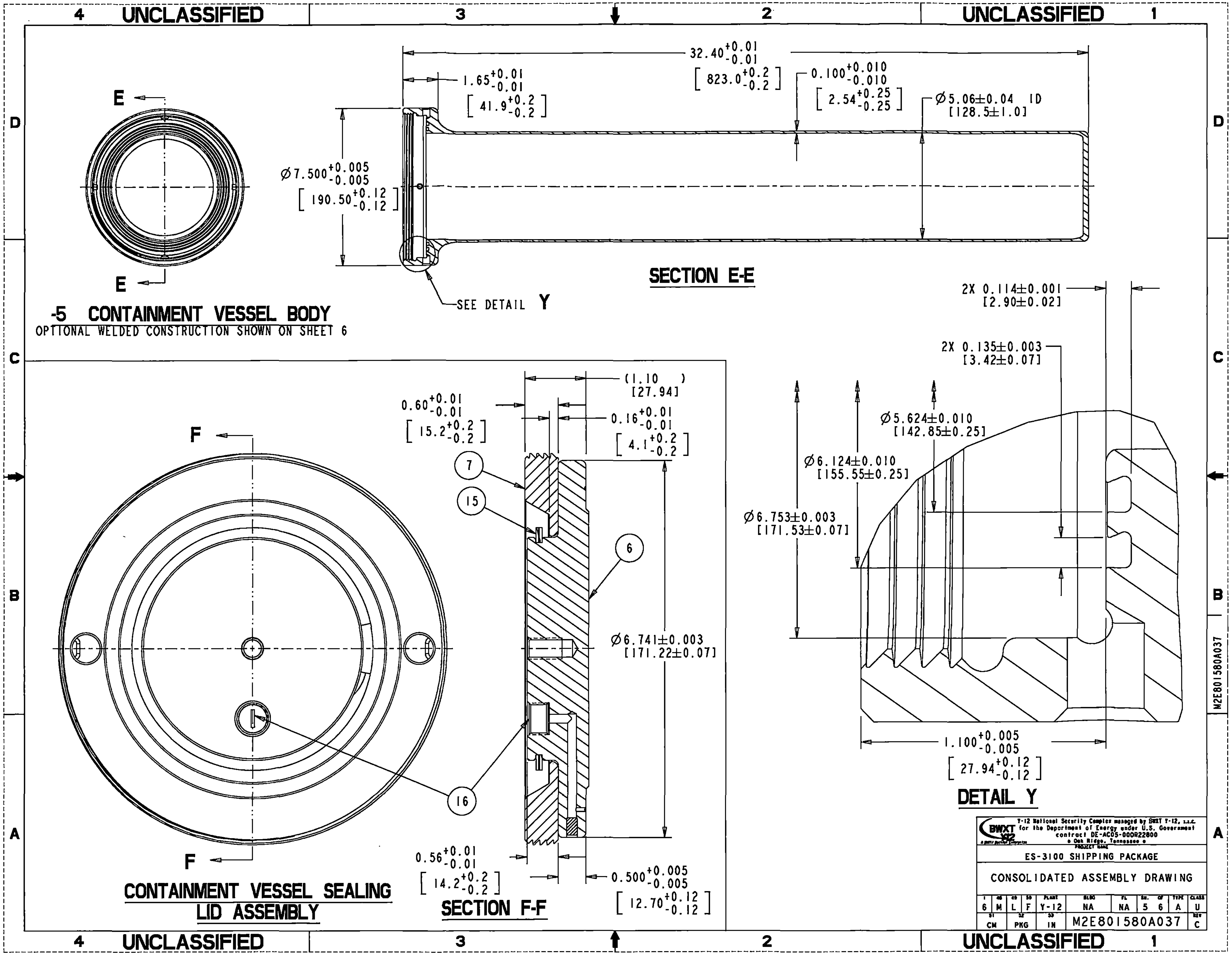

UNCLASSIFIED
-5 CONTAINMENT VESSEL BODY
OPTIONAL WELDED CONSTRUCTION SHOWN ON SHEET 6
SECTION E-E
SEE DETAIL Y
32.40 +0.01 -0.01 [823.0 +0.2 -0.2]
1.65 +0.01 -0.01 [41.9 +0.2 -0.2]
0.100 +0.010 -0.010 [2.54 +0.25 -0.25]
Ø5.06±0.04 ID [128.5±1.0]
Ø7.500 +0.005 -0.005 [190.50 +0.12 -0.12]
CONTAINMENT VESSEL SEALING LID ASSEMBLY
SECTION F-F
(1.10) [27.94]
0.60 +0.01 -0.01 [15.2 +0.2 -0.2]
0.16 +0.01 -0.01 [4.1 +0.2 -0.2]
Ø6.741±0.003 [171.22±0.07]
0.56 +0.01 -0.01 [14.2 +0.2 -0.2]
0.500 +0.005 -0.005 [12.70 +0.12 -0.12]
DETAIL Y
2X 0.114±0.001 [2.90±0.02]
2X 0.135±0.003 [3.42±0.07]
Ø5.624±0.010 [142.85±0.25]
Ø6.124±0.010 [155.55±0.25]
Ø6.753±0.003 [171.53±0.07]
1.100 +0.005 -0.005 [27.94 +0.12 -0.12]
ES-3100 SHIPPING PACKAGE
CONSOLIDATED ASSEMBLY DRAWING
M2E801580A037

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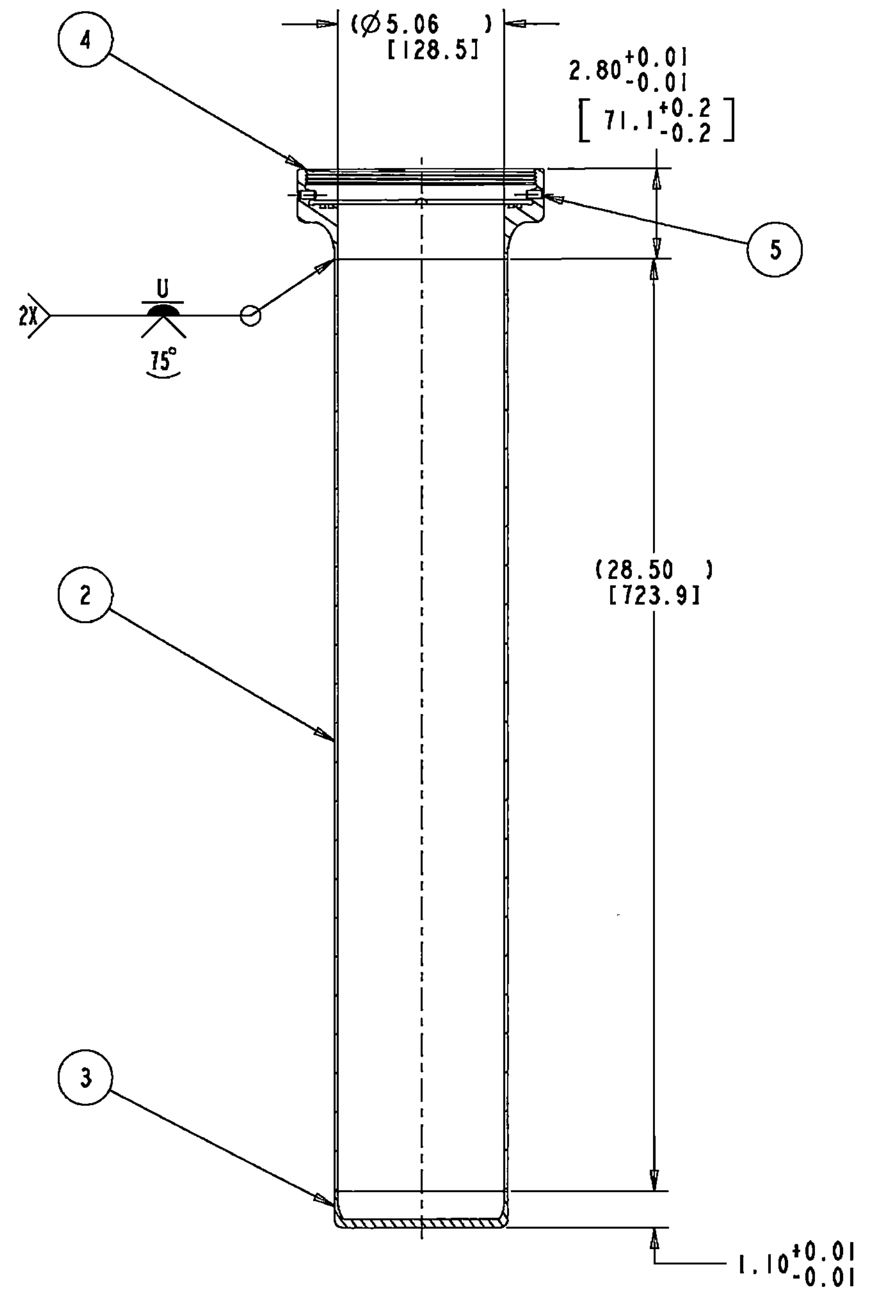

CONTAINMENT VESSEL BODY ASSEMBLY WELDED OPTION

WELD NOTES:

1. ALL WELDS ON THE CONTAINMENT VESSELS SHALL BE DONE EITHER BY THE GTAW OR GMAW PROCESS, MANUAL OR AUTOMATIC, AT THE DISCRETION OF THE SELLER UNLESS SPECIFICALLY CALLED OUT ON THE DRAWINGS. BACKING RINGS, EVEN IF REMOVED AFTER THE WELD HAS BEEN MADE, SHALL NOT BE USED. AS PREVIOUSLY STATED, WELD SYMBOLS ARE PROVIDED ON THE DRAWING INDICATING FOR EACH WELD THE TYPE OF WELD AND DIMENSIONS OF THE WELD.
2. EXCEPT AS LIMITED BY THIS SPECIFICATION, THE APPLICABLE REQUIREMENTS OF NB-4300 AND NB-4400 SHALL APPLY TO THE CONTAINMENT VESSEL.
3. PRIOR TO WELDING, ALL WELD PREPARATION AREAS AND THE SURFACES WITHIN ONE INCH OF THE WELD AREA SHALL BE EXAMINED VISUALLY AND WITH LIQUID PENETRANT. THE ACCEPTANCE CRITERIA FOR THESE EXAMINATIONS ARE THOSE STATED IN NB-5130 (A) THROUGH NB-5130 (D). THE RESULTS OF THESE SURFACE EXAMINATIONS SHALL BE REPORTED TO THE COMPANY TOGETHER WITH THE WELD EXAMINATION REPORTS, SEE SECTION 3.4 OF THIS SPECIFICATION.
4. WELDERS PERFORMING TWO OR MORE WELDS IN ONE DAY THAT ARE REJECTED BASED UPON WELDER TECHNIQUE SHALL BE SUBJECT TO BE RE-QUALIFIED TO THE APPROPRIATE WELDING PROCEDURES, SEE SECTION IX, PARAGRAPH QW-320 OF THE ASME CODE.
5. THE APPLICABLE REQUIREMENTS IN PARAGRAPHS NB-5110, NB-5120, NB-5210, NB-5220, NB-5260, AND NB-5300 SHALL APPLY TO THE CONTAINMENT VESSELS. THE PLUG WELD SHOWN ON DRAWING M2E801580A015 SHALL BE EXAMINED VISUALLY AND WITH PENETRANT. THE APPLICABLE REQUIREMENTS IN PARAGRAPHS NB-5110, AND NB-5350 SHALL APPLY TO THE PLUG WELD. NOTE THAT THE REFERENCE TO THE INSPECTOR IN NB-5112, FOR THE PURPOSES OF THIS SPECIFICATION IS EITHER THE COMPANY'S INSPECTOR OR A SUBCONTRACTOR DESIGNATED BY THE COMPANY.
6. MATERIALS USED IN THE PENETRANT EXAMINATION OF WELDS AND IN THE FINAL SURFACE EXAMINATION OF FINISHED COMPONENTS (SEE SECTION 3.7) SHALL BE SPECIFICALLY RECOMMENDED BY THEIR SUPPLIERS FOR USE WITH AUSTENITIC STAINLESS STEELS, AND COPIES OF THE CERTIFICATION OF CONTAMINANT CONTENT OF MATERIALS USED (SEE SECTION V, ARTICLE 6, T-641) SHALL BE SUPPLIED TO THE COMPANY WITH THE EXAMINATION REPORTS.
7. REPAIR WELDING SHALL MEET THE APPLICABLE REQUIREMENTS OF NB-2500.
8. CERTIFIED WRITTEN WELD EXAMINATION REPORTS TOGETHER WITH THE CORRESPONDING MATERIAL SURFACE EXAMINATION REPORTS, AND WELD MAP SHALL BE SUBMITTED TO THE COMPANY AS STATED IN THE PROCUREMENT SPECIFICATION FOR THE ES-3100 CONTAINMENT VESSEL. WELD EXAMINATION REPORTS FOR ALL WELD AND SURFACE EXAMINATION SHALL INCLUDE: THE CONTAINMENT VESSEL SERIAL NUMBER, A WELD MAP SHOWING THE LOCATION OF THE WELD AND EXAMINATION AREA, THE WELDER'S NAME, THE EXAMINER S NAME, THE TIME AND DATE OF THE WELD EXAMINATION, THE EXAMINATION PROCEDURE(S) NUMBER USED, THE WPS NUMBER, THE HEAT NUMBERS OF THE MATERIALS JOINED, THE HEAT NUMBER OF THE WELD FILLER, AND EXAMINER S REMARKS. THE EXAMINER S REMARKS SHALL INCLUDE THE RESULTS OF THE EXAMINATION AND ACCEPTANCE, OR REJECTION OF THE WELD BASED ON THE STATED CRITERIA. ONE SET OF RADIOGRAPHS SHALL BE PROVIDED TO THE COMPANY WITH RADIOGRAPHIC EXAMINATION REPORTS. IF THE WELD OR SURFACE IS REJECTED, A DESCRIPTION OF THE DEFECT AND SKETCH SHOWING THE LOCATION SHALL BE PROVIDED.
9. IF A WELD IS REJECTED, THE AREA SHALL BE WELD REPAIRED BY THE SELLER AND RE-EXAMINED. AFTER TWO UNSUCCESSFUL REPAIR ATTEMPTS, THE COMPANY SHALL BE NOTIFIED FOR APPROVAL TO PERFORM MORE REPAIR ATTEMPTS. THE COMPANY MAY, AT ITS OPTION, CHOOSE TO REJECT FURTHER REPAIR EFFORTS AND REQUIRE THAT A REPLACEMENT PART BE FABRICATED.

2	-5	.2501/.2503 OD DOWEL PIN	ANSI B18.8.2 18-8-SST	5
1	-4	VESSEL FLANGE	ASME SA-182 TYPE F304L	4
1	-3	VESSEL END CAP	ASME SA-182 TYPE F304L	3
1	-2	VESSEL BODY SCH40 PIPE	ASME SA-182 TYPE F304L	2
X	-1	CONTAINMENT VESSEL WELDED ASSEMBLY		1
—	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL/ SPECIFICATION	FIND NO
← QTY REQ'D NEXT ASSEMBLY			PARTS LIST	

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PROJECT NAME: ES-3100 SHIPPING PACKAGE

CONSOLIDATED ASSEMBLY DRAWING

6	M	L	F	PLANT Y-12	BLDG NA	FL NA	SH. 6	OF 6	TYPE A	CLASS U
CM	PKG	IN	M2E801580A037							REV C

M2E801580A037

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Appendix 1.4.2

EQUIPMENT SPECIFICATION JS-YMN3-801580-A002,
ES-3100 DRUM ASSEMBLY

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EQUIPMENT SPECIFICATION APPROVAL/REVISION PAGE

SPECIFICATION NO. JS-YMN3-801580-A002	REV. D	ISSUE DATE 10-15-03
PAGE i OF ii	REVISION DATE 03/15/06	
PROCURED BY BWXT L.L.C.	INSTALLED BY BWXT L.L.C.	
PROJECT TITLE ES-3100 Shipping Package	PLANT Y-12	BUILDING AREA
JOB TITLE Design Definition	W.O. OR E.S.O. 7RCPCA5A	RECORD NUMBER 2003-0328
SPECIFICATION FOR ES-3100 DRUM ASSEMBLY		SSC IDENTIFICATION NUMBER

ENGINEERING AND PLANT APPROVALS

SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY J.L. Heck	10-21-03	PROJECT ENGINEER: M.R. Feldman	10-29-03
DISCIPLINE MANAGER J.C. Walls	10-29-03	OPERATIONS MANAGER/SYSTEM OWNER:	
DESIGN VERIFICATION Roger Aigner	10-21-03		

REVISIONS/ENGINEERING AND PLANT APPROVALS

REV. NO.	DESCRIPTION OF REVISION
A	Issue Approved
B	Change the title of drawing M2E-801580-A001 from Confinement Boundary Assembly to Drum Assembly. Change the title this specification from ES-3100 Confinement Boundary Drums to ES-3100 Drum Assembly. Deleted reference to drawing M2E-801580-A009, Pad Details. Added the reference to drawings M2E-801580-A010, Data Plates and M2E-801580-A031, Main Assembly. Changed the wording in the first paragraph of Section 3.3
C	Revised the third paragraph of Section 3.0 in accordance with REDC PE-06-058.
D	Section 3.0, paragraph 3, the phrase "certifying authority's written approval" has been revised to "regulatory authority's written approval."

SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY G. A Byington /s/	3/14/06	PROJECT ENGINEER J. Arbital /s/	3/14/06
DISCIPLINE MANAGER C. M. Amonett /s/	3/14/06	OPERATIONS MANAGER/SYSTEM OWNER:	
DESIGN VERIFICATION Roger D. Aigner /s/	3/14/06		

This document has been has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: Roger D. Aigner /s/ Date: 3/14/06

EXEMPT FROM IO-155

TABLE OF CONTENTS **PAGE**

LIST OF COMPANY DRAWINGS

Drawing Number	Title
M2E-801580-A001	Drum Assembly
M2E-801580-A002	Body Weldment
M2E-801580-A003	Inner Liner Weldment
M2E-801580-A004	Double Open Head Reinforced Drum
M2E-801580-A005	Misc. Details
M2E-801580-A006	Drum Lid Weldment
M2E-801580-A007	Drum Lid
M2E-801580-A008	Top Plug Weldment
M2E-801580-A010	Data Plates
M2E-801580-A031	Main Assembly

1.0 SCOPE

This specification, the Procurement Specification for the ES-3100 Drum Assembly, specifications JS-YMN3-801580-A003 and JS-YMN3-801580-A005, the Company's drawings, and the referenced codes and standards in section 2.0 of this specification state the requirements for the procurement of materials and components, fabrication, inspection, examination, assembly, and testing of the Drum Assembly for the ES-3100 shipping package. If conflicting requirements appear between the Company's documents, and the standards listed in section 2.0 of this document, the Seller shall immediately notify the Company, so that these can be resolved. The Seller shall provide the number of completed assemblies specified in the purchase order.

This specification describes the applicable procedures to be followed in the fabrication, welding, examination, inspection, quality assurance, and documentation requirements for a Drum Assembly used in a Type B nuclear shipping package.

The Drum Assembly shall be manufactured in accordance with those paragraphs of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1 that are specified in this document. The Drum Assemblies are not pressure vessels and are not to be hydrostatically tested, nor are they to be stamped. If the Seller does not have certificate of authorization from the ASME to apply the U stamp, the Seller shall be familiar with, and capable of meeting those requirements in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code that are referenced in this specification.

Company specification JS-YMN3-801580-A003 gives requirements for casting Kaolite, and JS-YMN3-801580-A005 gives requirements for casting Catalog No. 277-4 in the drum as shown on the Company's drawings.

2.0 APPLICABLE CODES AND STANDARDS

The Drum Assembly shall be fabricated, inspected, and tested according to the design drawings, and the portions of the codes, standards, and regulations to the extent described herein.

- American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section VIII, Division 1, 2001 Edition with 2002 and 2003 addenda

- American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section II, Parts A and C, 2001 Edition and 2002 and 2003 addenda

- American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section V, 2001 Edition and 2002 and 2003 addenda

- American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section IX, 2001 Edition and 2002 and 2003 addenda

- American Society For Nondestructive Testing, No. SNT-TC-1A-1992, Recommended Practice for Nondestructive Testing Personnel Qualification and Certification, Dec 1992

- Military Standard, MS27683, Drum, Metal-Shipping and Storage 16 to 80 Gallons

- American Society For Testing Materials, ASTM A 380-99^{e1}, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment and Systems.

All references to the ASME Code in this document are to the ASME Boiler and Pressure Vessel Code, the 2001 Edition with the 2002 and the 2003 addenda.

3.0 DETAILED REQUIREMENTS

Detailed dimensional requirements and the materials of construction are called out on the Company's drawings. Additional requirements for materials are given in section 3.1 of this specification. The Seller shall be responsible for determining stock sizes so that the finished machined components meet the dimensions, tolerances and surface features called out on the attached drawings.

Weld symbols are provided on the Company's drawings indicating for each weld the type of weld and dimensions of weld. Additional welding requirements are stated in section 3.2 of this specification

Any material substitution or any other deviation from the requirements shown on the Company's drawings, or stated in the Company's document is not permitted without the Seller submitting a written request for waiver or deviation, Company's written approval, and regulatory authority's written approval (see the Procurement Specification for the ES-3100 Drum Assembly).

The assembled Drum Assembly shall be marked according to the Company's drawings. The Company will assign permanent serial numbers for each Drum Assembly. Drum Assembly's records may be maintained based upon a temporary serial number assigned by the Seller. The temporary serial number for the Drum Assembly shall be cross-referenced to the Drum Assembly's permanent serial number.

The following additional requirements apply as follows:

3.1 Materials

Except for the weld studs, documented Certified Material Test Reports (CMTR's) shall be provided to the Company for all materials used in weldments for the fabrication of the Drum Assembly, including weld filler metal. The CMTR's shall be traceable to heat numbers and shall demonstrate compliance with the SA or SFA material specifications called out. For all other the materials documented Certificates of Compliance shall be provided to the Company certifying that the materials provided comply the requirements stated on the Company's drawings and specifications. See the Procurement Specification for the ES-3100 Drum Assembly for specific documentation requirements.

The markings on the weldment materials shall not be removed until after all weld examination is complete. Note that the heat numbers of base metals and weld filler are required on all weld examination reports (see section 3.3 of this specification).

The weld filler metal used in the fabrication of the Drum Assemblies shall be procured to comply with the SFA specifications of Section II, Part C of the ASME Code that are stated in the Seller's welding procedure specifications. Weld filler metal shall be procured traceable to heat numbers, and Certified Material Test Reports shall be furnished to the Company for each heat of weld wire filler. The control of weld filler by the Seller shall permit a weld examiner to be able to determine the heat number of the weld filler used in any weld on the Drum Assembly.

Prior written approval of the Company shall be obtained for any weld repair on materials, and the weld repair areas shall be noted in a sketch supplied with the CMTR for the material that was weld repaired. Note that depending on the specific defect in a specific material, the Company may or may not approve the weld repair, even if it is permitted by the material specification.

3.2 Welding

All welding shall be done in accordance with welding procedure specifications that are written and performance qualified in accordance with the ASME Code, Section IX. All welders shall be performance qualified to weld using these procedures, and their qualifications documented in accordance with the ASME Code, Section IX. The welding fabrication requirements stated in the ASME Code, Section VIII, Division 1, paragraphs UW-26 through UW-48 shall be met. The Inspector referenced in these paragraphs shall be an individual or individuals that are employed by the Company or subcontractors to the Company.

All butt welds in rolled sheet, pipe and angle joints shall be full penetration butt welds. With the exception of the seam welds in the drum body, all welds shall be done by the GTAW, GMAW, PAW or a Capacitive Discharge (CD) stud welding process.

Welders performing two or more welds in one day that are rejected shall be subject to be re-qualified to the appropriate welding procedures, see Section IX, and paragraph QW-320 of the ASME Code.

3.3 Weld Examination

A qualified weld examiner using a written weld examination procedure shall visually examine all designated welds. Weld examiners shall be qualified to perform visual weld inspection in accordance with their employer's written practice, which must be in accordance with either SNT-TC-1A (2001 Edition), "Personnel Qualification and Certification in Nondestructive Testing;" or ANSI/ASNT CP-189 (2001 Edition), "ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel;" published by the American Society for Nondestructive Testing. The weld examination procedure shall meet the requirements of the ASME Code, Section V. The weld examination procedures, the weld examiners qualifications, and the weld examination reports shall be submitted to the Company.

Written weld examination reports for all weld examination shall include: the Drum Assembly serial number, a weld map showing the location of the weld, the welder's name, the examiner's name, the time and date of the weld examination, the examination procedure number used, the WPS number, the heat numbers of the materials joined, the heat number of the weld filler, and the examiner's remarks. The examiner's remarks shall include the results of the examination, and acceptance or rejection of the weld based on the stated criteria and include a description and sketch showing the location of any defects found. Weld examination reports shall be submitted to the Company as stated in the Procurement Specification for the ES-3100 Drum Assembly.

The acceptance criteria for joint fit-up and alignment, and for visual examination of welds are given in the ASME Code, Section VIII, Division 1, paragraphs UW-31 through UW-36. In addition, any visible defects such as lack of fusion, lack of penetration, linear or crack like defects, and visible porosity, shall be cause for rejection.

If a weld is rejected, the area may be weld repaired by the Seller and re-examined. After two unsuccessful repair attempts, the Company shall be notified for approval to perform more repair attempts. The Company may, at its option, choose to reject further repair efforts and require that a replacement part be fabricated.

If penetrant examination of welds or materials is performed the materials used in the examination shall be specifically recommended by their suppliers for use with austenitic stainless steels, and copies of the certification of contaminant content of materials used (see Section V, Article 6, T-641) shall be supplied to the Company with the examination reports.

3.4 Cleaning and Passivation

Cleaning procedures for the stainless steel, including weld areas, shall be submitted to the Company for approval prior to the start of fabrication, see the Procurement Specification for the ES-3100 Drum Assembly. Only non-chloride bearing chemicals shall be used for cleaning (such as trisodium phosphate detergent or acetone). Water used in cleaning shall have a maximum chlorine content of 0.5 parts per million.

Finished components awaiting assembly and assemblies shall be free of dirt, debris, foreign objects, cutting fluids, metal chips, grinding residue, and other foreign substances. The Seller shall clean, cover, and protect parts and subassemblies from becoming dirty while in storage, and to the extent practical, in the shop environment while in work.

After final machining and examination of all welds except the attachment welds for the drum bottom and the closure weld on the top plug, and prior to filling with Kaolite and Catalog No. 277-4 (see JS-YMN3-801580-A003 and JS-YMN3-801580-A005), clean and passivate all stainless steel surfaces of the Drum Assembly in accordance with ASTM A 380. After the closure weld on the top plug weldment and the attachment weld on the drum bottom are examined, clean and locally passivate the weld areas and heat affected zone areas.

3.5 Dimensional Inspection Reports

Straightening, flattening, and forming by mechanical or thermal means of some features and components after welding may be required to ensure proper assembly. The surfaces of areas of the weldment that have been worked shall be visually examined to ensure that no cracks are present or that the weldment has been degraded. Adjacent welds to these areas shall also be visually examined. The acceptance criteria are that no cracks are found. The areas worked and the visual inspections shall be noted on the dimensional inspection report. This work and examination shall be performed prior to the installation of Kaolite or Catalog No. 277-4.

After all testing, inspection and final machining, the Drum Assemblies shall be dimensionally inspected. The dimensions, and features such as flatness, runout, etc, to be inspected are indicated on the Company's drawings. A written inspection report shall be prepared, and submitted to the Company as stated in the Procurement Specification for the ES-3100 Drum Assembly.

Appendix 1.4.3

EQUIPMENT SPECIFICATION JS-YMN3-801580-A001, *ES-3100 CONTAINMENT VESSEL*

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EQUIPMENT SPECIFICATION APPROVAL/REVISION PAGE

SPECIFICATION NO.	REV.	ISSUE DATE
JS-YMN3-801580-A001	G	10-15-03
PAGE	REVISION DATE	
i OF ii	06-11-12	
PROCURED BY	INSTALLED BY	
B&W Y-12 LLC	B&W Y-12 LLC	

PROJECT TITLE	PLANT	BUILDING
ES-3100 Shipping Package	Y-12	AREA
JOB TITLE	**W.O. OR E.S.O.**	**RECORD NUMBER**
Production Design Definition	7RCPCA5A	Y2003-0328
SPECIFICATION FOR		**SSC IDENTIFICATION NUMBER**
ES-3100 CONTAINMENT VESSEL		

ENGINEERING AND PLANT APPROVALS

SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY J.L. Heck	10-21-03	PROJECT ENGINEER: M.R. Feldman	10-29-03
DISCIPLINE MANAGER J.C. Walls	10-29-03	OPERATIONS MANAGER/SYSTEM OWNER:	
DESIGN VERIFICATION Roger Aigner	10-21-03		

REVISIONS/ENGINEERING AND PLANT APPROVALS

REV. NO.	DESCRIPTION OF REVISION
A	Issued Approved
B	Included the requirements for a Containment Vessel that was fabricated by welding a forged bottom, a forged top flange and a cylindrical shell as shown on the revised drawing, M2E801580A012, Rev B.
C	In all locations removed the references to the Procurement Specification document number OO-PP-1210. Modified the Weld Repair reject and re-qualification requirements in Section 3.3 in the fourth paragraph. In Section 3.9, first, third, and fourth paragraphs changed the units from ref-cm3/sec to cm3/sec helium. Also added new Section 3.6 Welding Documentation Submittals.
D	Added two paragraphs to the end of Section 3.1 for reference to ASTM A 262 in accordance with REDC #PE-05-046-A. Added a sentence to the beginning of the first paragraph in Sect. 3.9 in accordance with REDC # PE-06-059.
E	Section 3.0, paragraph 3, the phrase "the Company's written approval" has been revised to "the Company's written approval, and regulatory authority's written approval."
F	Removed statement about metal spinning in Section 3.1, page 4. Also made many editorial changes on page 9 to support SARP defined in EC-801940-0001.
G	Added Viton O-ring drawing as a optional O-ring. Changed Procurement Specification OO-PP-986 to Equipment Specifications SPC-M801580-0001 (for Viton O-ring) and SPC-M801580-0002 (for EPDM O-ring).

SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY L. Roberson	6/11/12	PROJECT ENGINEER L. Roberson	6/13/12
DISCIPLINE MANAGER [signature]	6/12/12	OPERATIONS MANAGER/SYSTEM OWNER: N/A	
DESIGN VERIFICATION Monty L Sorie	6/12/12	Program Mgr. [signature]	6/13/12

This document has been has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: [signature] Date: 06/13/12

EXEMPT FROM IO-155

EQUIPMENT SPECIFICATION
ES-3100 Containment Vessel

TABLE OF CONTENTS

LIST OF COMPANY DRAWINGS

Drawing Number	Title
M2E-801580-A011	Containment Vessel Assembly
M2E-801580-A012	Containment Vessel Body Assembly
M2E-801580-A013*	Containment Vessel O-ring Details
M2E-801580-A014	Containment Vessel Lid Assembly
M2E-801580-A015	Containment Vessel Sealing Lid
M2E-801580-A016	Containment Vessel Closure Nut
M2E-801580-A021	Containment Vessel Body Test Flange Assembly
M2E-801580-A022	Containment Vessel Lid Test Flange Assembly
M2E-801580-A023	Containment Vessel Leak Test Assemblies
M801580-0013*	Containment Vessel Viton O-ring Details

* Either O-ring set may be used in Containment Vessel Assembly.

EQUIPMENT SPECIFICATION
ES-3100 Containment Vessel

1.0 SCOPE

This specification, equipment specifications (SPC-M801580-0001, *ES-3100 Fluorocarbon Rubber Elastomer (Viton) O-rings*, and SPC-M801580-0002, *ES-3100 Ethylene Propylene Diene Monomer (EPDM) CV O-rings*), the Company's drawings, and the referenced codes and standards in Sect. 2.0 of this specification state the requirements for the procurement of materials and components, fabrication, inspection, examination, assembly, and testing of the containment vessels for the ES-3100 shipping package. If conflicting requirements appear between the Company's drawings and specifications, the Seller shall immediately notify the Company, so that these can be resolved. The Seller shall provide the number of completed assemblies specified in the purchase order.

The containment vessel will be manufactured in accordance with the applicable requirements stated in the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* (ASME Code), Sect. III, Div. 1, Subsection NB for Class 1 Components as described on the Company's drawings and in this specification. If the Seller does not have certificate of authorization from the ASME to apply the N stamp, the Seller shall be familiar with, and capable of meeting those requirements in Sect. III, Div. 1, Subsections NB and NCA of the ASME Code that are referenced in this specification. The reference to the Inspector in any of the ASME Codes shall in this particular case be that person designated by the Company.

2.0 APPLICABLE CODES AND STANDARDS

The Containment Vessel shall be fabricated, inspected, and tested according to the design drawings and the following codes, standards, and regulations as described in this document.

- ANSI N14.5-1997, *American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment,* American National Standards Institute.
- *ASME Boiler and Pressure Vessel Code*, Sect. III, Div. 1 - Subsections NB and NCA, Class 1 Components, 2001 Edition and 2002 and 2003 addenda.
- *ASME Boiler and Pressure Vessel Code*, Sect. II, Parts A and C, 2001 Edition and 2002 and 2003 addenda.
- *ASME Boiler and Pressure Vessel Code*, Sect. V, 2001 Edition and 2002 and 2003 addenda.

- *ASME Boiler and Pressure Vessel Code*, Sect. IX, 2001 Edition and 2002 and 2003 addenda.
- ASTM A 380-99^{e1}, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment and Systems,* American Society for Testing and Materials.
- SNT-TC-1A-1992, *Recommended Practice for Nondestructive Testing Personnel Qualification and Certification*, American Society for Nondestructive Testing, Dec 1992.
- SSPC SP 5/NACE No. 1, *White Metal Blast Cleaning,* Society for Protective Coatings.

3.0 DETAILED REQUIREMENTS

Detailed dimensional requirements and the materials of construction are called out on the Company's drawings. Additional requirements for materials are given in Sect. 3.1 of this specification. The Seller shall be responsible for determining stock sizes so that the finished machined components meet the dimensions, tolerances and surface features called out on the attached drawings.

Weld symbols are provided on the Company's drawings indicating the type of weld and dimensions for each weld. Additional welding and repair welding requirements are stated in Sects. 3.1 and 3.3 of this specification.

Any material substitution or other deviation from the requirements shown on the Company's drawings or stated in the Company's specifications is not permitted without the Seller submitting a written request for waiver or deviation, and Company's written approval, and regulatory authority's written approval.

The term ASME Code in this specification refers to the *ASME Boiler and Pressure Vessel Code.* A paragraph referenced as NB-XXXX or NCA-XXXX, where XXXX is a specific paragraph number, is that paragraph in Sect. III, Subsection NB or Subsection NCA, respectively, of the ASME Code. If a given paragraph is referenced as a requirement, all the paragraphs under the stated paragraph are also to be considered as requirements. For example, if NB-2430 is referenced as a requirement, not only do the applicable requirements of NB-2430 apply, but also those of NB-2431, NB-2431.1, NB-2431.1(a), NB-2432, etc. apply. Note that the Company shall act as the Authorized Inspector, and that the Inspector referenced in the ASME Code shall be a representative of the Company.

The assembled containment vessels shall be marked according to the Company's drawings. Permanent serial numbers for each containment vessel shall be assigned by the Company. Containment vessel records may be maintained based upon a temporary serial number assigned by the Seller. The temporary serial number for the containment vessel shall be cross referenced to the containment vessel's permanent serial number.

The following additional requirements apply as follows:

3.1 Materials and Material Examinations

The containment vessel body (Drawing M2E-801580-A012), the sealing lid, (Drawing M2E-801580-A015), and the closure nut (Drawing M2E-801580-A016), shall be considered pressure retaining materials as defined in NB-2110, and meet the applicable requirements of NB-2120. Documented Certified Material Test Reports (CMTRs) shall be provided to the Company for the materials used to fabricate these components in accordance with NCA-3860. The suppliers of these materials shall meet the requirements of NCA-3800. Such parts shall be traceable to each containment vessel by means of a serial number assigned by the Company. The Seller shall maintain control of materials to ensure this traceability. Other metallic materials, and the O-ring seals shall be supplied with Certificate of Compliances in accordance with NCA-3862(g) and (h).

Procured materials shall be examined in accordance with NB-2500, and shall meet the stated acceptance criteria. The results of these examinations shall be included with the CMTRs provided to the Company. Prior written approval of the Company shall be obtained for any weld repair on materials, and the weld repair areas shall be both surface and volumetrically examined. The repair area shall be noted in a sketch supplied with the CMTR for the material that was weld repaired and the documented results of the weld examination shall be provided to the Company. Note that depending on the specific defect in a specific material, the Company may or may not approve the weld repair, even if it is permitted by the material specification or by NB-2500.

The weld filler metal used in the fabrication and repair welding as permitted, of the containment vessels shall meet the applicable requirements of NB-2400. It shall be procured to comply with the SFA specifications of Sect. II, Part C of the ASME Code that is stated in the Seller's welding procedure specifications. Weld metal filler shall be procured traceable to heat numbers, and CMTRs shall be furnished to the Company for each heat of weld wire filler used. The results of the delta ferrite determination shall be included in the CMTR for the weld filler metal (see NB-2433). The control of weld filler by the Seller shall permit a weld examiner to be able to determine the heat number of the weld filler used in any weld on the containment vessel.

The Seller shall provide the Company with CMTRs, certified material examination reports and Certificates of Compliance for the materials stated above as required.

There are two containment vessel assemblies shown on Drawing M2E801580A012, Parts M2E801580A012-1 and M2E801580A012-4. The containment vessel assembly(s) to be fabricated will be specified in the Company's purchase order. Note that Part M2E801580A012-4 is fabricated by welding a forged bottom, and forged top flange to a cylindrical shell machined from seamless pipe as shown on the drawing.

The formed containment vessel body, Part M2E801580A012-1, shall be flow formed from a single forged billet or bar. Special requirements for this part are given as follows.

Repair welds may be permitted depending on the nature of the defect to be weld repaired, and after receiving the written approval of the Company for such repair welds.

The formed, heat treated, and finished machined containment vessel body, Part M2E801580A012-1, shall meet the applicable requirements of ASME SA-182 for Grade F304L for a forged component. After final forming, parts shall be solution annealed and quenched per the requirements of ASME SA-182 for Grade F304L. In addition, the requirements of NB-2180 shall also apply. A certified heat treatment report shall be provided stating for each furnace charge the following information: the serial numbers of the containment vessel bodies heat treated in the furnace charge, the time and date of the heat treating, the person responsible for the heat treating, the time-temperature profile of the furnace and representative parts of the furnace charge, the quench medium, and all other pertinent details of the heat treating. Such a heat treating report is required for all heat treating, both in process annealing and final heat treatment.

It shall be demonstrated that the formed, heat-treated containment vessel bodies, Part M2E801580A012-1, meet the mechanical property requirements of ASME SA-182 for Grade F304L by mechanical testing of coupons. The test coupons are to be machined from the same heats of materials used to form the containment vessel bodies, and shall have the same or greater amount of cold word (plastic strain) as the containment vessels will have as a result of the forming process. The mechanical tensile testing of coupons shall be done in accordance with ASME SA-370. A minimum of six test coupons shall be tested for each final heat treatment furnace charge. The first set of three test coupons, chosen at random, shall be tested without being heat treated. The second set of three of more test coupons shall be heat treated together with the containment vessel bodies, and then tested. The heating rates and maximum temperatures of the test coupons shall be representative of the entire furnace charge. Test coupons are not required to be heat treated with intermediate processing annealing steps, but are required in the final heat treatment furnace charge.

The results of all the testing of the sample coupons shall be documented, certified and reported to the Company. The mechanical properties test report shall contain the following information: a descriptor of the furnace charge in which the test coupons are to represent; the times and dates of the heat treating and the testing; the person responsible for the testing; a statement that these coupons are prior to or after heat treatment; a description of the testing including a sketch of the tensile test specimen; the make, model, serial number, and current calibration data of the testing machine(s) used in the testing; reference to the written testing procedure used; the resulting measure yield strength, ultimate strength, % elongation and % reduction in area; and any pertinent remarks.

It is permissible to deviate from the liquid quench requirements stated in SA-182 provided that the cooling rates of the alternate quench are such that the heat treated material is not susceptible to intergranular corrosion due to chromium carbide precipitation. This is to be demonstrated by testing according to Practice E of ASTM A 262, and meeting the stated acceptance criteria. This shall be accomplished by obtaining test coupons from each furnace batch that represent the slowest cooling rates of the batch, or by following a heat treating procedure that has been qualified to ensure that the

heat treated batch will not be sensitive to intergranular corrosion. In any case, the requirements of NB-2180 shall apply.

The heat treating procedure must be qualified by measuring the annealing temperatures, soak times and cooling rates of the furnace batch, and then testing heat treated specimens that represent the lowest annealing temperatures, soak times and cooling rates for that furnace batch for sensitivity to intergranular corrosion using Practice E of ASTM A 262. For subsequent annealing operations, the temperatures, soak times, and cooling rates of subsequent furnace batches must be measured and compared to the qualified procedure. Other factors, such as variations of the size and arrangement of the furnace batch that can affect part temperatures and part cooling rates, and the calibration of the furnace temperature sensors must be assessed in the procedure qualification to ensure that minimum temperatures and cooling rates of production heat treating batches can be properly compared to those of the qualified procedure. Such a procedure should be requalified for each individual furnace used, and for significantly different furnace batch sizes. The procedure shall be requalified annually, or if it has not been used for a period of at least three months.

3.2 Forming, Fitting and Alignment

The forming, fitting and alignment requirements stated in NB-4200 shall be met in the fabrication of the Containment Vessels unless more stringent requirements are called out on the Company's drawings.

The roundness of cylinders, profile of formed head surfaces, and misalignment or offsets in weld joints shall be included in the dimensional inspection reports for the each containment vessel, see Sect. 3.11 of this specification.

3.3 Welding and Weld Repair

All welds on the Containment Vessels shall be done either by the GTAW or GMAW process, manual or automatic, at the discretion of the Seller unless specifically called out on the drawings. Backing rings, even if removed after the weld has been made, shall not be used. As previously stated, weld symbols are provided on the drawing indicating for each weld the type of weld and dimensions of the weld.

Except as limited by this specification, the applicable requirements of NB-4300 and NB-4400 shall apply to the containment vessel.

Prior to welding, all weld preparation areas and the surfaces within one inch of the weld area shall be examined visually and with liquid penetrant. The acceptance criteria for these examinations are those stated in NB-5130 (a) through NB-5130 (d). The results of these surface examinations shall be reported to the Company together with the weld examination reports, see Sect. 3.4 of this specification.

Welders performing two or more welds in one day that are rejected based upon welder technique shall be subject to be re-qualified to the appropriate welding procedures, see Sect. IX, Paragraph QW-320 of the ASME Code.

3.4 Weld Examination

The applicable requirements in NB-5110, NB-5120, NB-5210, NB-5220, NB-5260, and NB-5300 shall apply to the containment vessels. The plug weld shown on Drawing M2E801580A015 shall be examined visually and with penetrant. The applicable requirements in NB-5110 and NB-5350 shall apply to the plug weld. Note that the reference to the Inspector in NB-5112, for the purposes of this specification is either the Company's inspector or a subcontractor designated by the Company.

Materials used in the penetrant examination of welds and in the final surface examination of finished components (see Sect. 3.7) shall be specifically recommended by their suppliers for use with austenitic stainless steels, and copies of the certification of contaminant content of materials used (see Sect. V, Article 6, T-641) shall be supplied to the Company with the examination reports.

Repair welding shall meet the applicable requirements of NB-2500.

Certified written weld examination reports together with the corresponding material surface examination reports, and weld map shall be submitted to the Company. Weld examination reports for all weld and surface examination shall include: the containment vessel serial number, a weld map showing the location of the weld and examination area, the welder's name, the examiner's name, the time and date of the weld examination, the examination procedure(s) number used, the welding procedure specifications (WPS) number, the heat numbers of the materials joined, the heat number of the weld filler, and examiner's remarks. The examiner's remarks shall include the results of the examination and acceptance, or rejection of the weld based on the stated criteria. One set of radiographs shall be provided to the Company with radiographic examination reports. If the weld or surface is rejected, a description of the defect and sketch showing the location shall be provided.

If a weld is rejected, the area shall be weld repaired by the Seller and re-examined. After two unsuccessful repair attempts, the Company shall be notified for approval to perform more repair attempts. The Company may, at its option, choose to reject further repair efforts and require that a replacement part be fabricated.

3.5 NDE Examiner Qualifications

The qualifications of the personnel performing material or weld examination shall be those stated in NB-5500.

3.6 Welding Documentation Submittals

Submittal of the following are required with the bid unless the current revisions of these submittals have been previously approved by the Company. Submittals that do not demonstrate compliance with this specification will be cause for rejection of the proposal.

- Typical WPS for the applicable code.
- Procedure qualification records (PQR).
- Typical welder performance qualification (WPQ) records for the appropriate code.

Submittal of the following documents are required prior to welding unless the current revisions of these submittals have been previously approved by the Company.

- WPS.
- PQR.
- WPQ records, including evidence of process usage updates.
- Visual examination and nondestructive examination procedures.
- Certification records of examination personnel.
- CMTR.

To facilitate prompt review by the Company of the Seller's weld program, the welding documentation required above shall be submitted electronically in Adobe pdf format either on compact disk (CD) or by email. All information submitted shall reflect the Seller's most current documentation. Upon review and approval of the documentation, the Seller will be notified.

If the latest revision of the Seller's welding documentation required above has been previously submitted electronically and reviewed and approved by the Company, this shall be so stated with the offer. The Seller shall submit a detailed list of the welding documentation to be used for this contract including title, revisions/dates, type components to be used on (i.e., piping, structural, sheet metal, etc.) and indicate the previous contract and approval date. The Company will then review the documentation for applicability on the new contract and approve or comment.

If changes have occurred since the last approval of the welding documentation, in addition to the list of welding documentation that they propose to use the Seller shall submit those documents that have changed. The Company will then review, comment, and/or approve the Seller's documentation.

3.7 Hydrostatic Testing

After all machining is complete, the assembled Containment Vessel shall be hydrostatic tested by the Seller in accordance with the applicable sections of NB-6000 at a test pressure of 150 psig +/- 5 psig at ambient temperature (60°F to 90°F). Water with a maximum chlorine content of 0.5 parts per million shall be used as a test medium.

It will be necessary to hydrostatically test the container body assembly separately from the lid assembly. It is recommended that the tooling shown on the Company's Drawings M2E801580A021, M2E801580A022, and M2E801580A023 be used to pressurize the components to be tested. The use of this tooling is not mandatory, but the Seller shall provide suitable fittings to perform the hydrostatic testing.

A written hydrostatic test procedure shall be prepared by the Seller and submitted to the Company for approval prior to testing. Certified written hydrostatic test reports for each containment vessel shall contain the following data: serial number of the containment vessel; time and date of the test; name of person responsible for the hydrostatic testing; the hydrostatic test procedure number; the name, serial number and calibration date of all gages and transducers; and a sketch showing any areas of leakage or any areas where surface defects were observed after hydrostatic testing. Hydrostatic test reports shall be submitted to the Company.

3.8 Final Examination of Finished Surfaces

After all finish machining, load testing and hydrostatic testing, all surfaces of the containment vessel body, Drawing M2E801580A012; the containment vessel sealing lid, Drawing M2E801580A015; and the containment vessel closure nut, Drawing M2E801580A016, shall be examined with penetrant in accordance with NB-2546. See Sect. 3.4 for additional requirements for the materials used in the penetrant examination. The results of the final surface examinations shall be documented in a certified examination report and provided to the Company.

If a defect is found, the Company shall be notified in writing. The area may be weld repaired by the Seller only if specifically permitted by the Company in writing, and the area re-examined. After two unsuccessful repair attempts, the Company may, at its option, choose to reject further repair efforts and require that a replacement part be fabricated.

3.9 Leak Testing

There are three leak tests to be performed on the ES-3100 containment vessel. The leak testing is to be performed after hydrostatic testing. Following the hydrostatic pressure test and prior to conducting any leak test, the containment vessel and O-ring cavities must be thoroughly dried. The leak testing is to be performed in accordance with the applicable sections of ANSI N14.5-1-1997. A written leak test procedure(s) shall be prepared to perform this testing and submitted to the Company for approval. The written test procedure(s) and leak testing report shall comply with the applicable requirements of Sect. V of the ASME Code. The leak testing for the first two leak tests shall have the sensitivity to detect a leak less than or equal to 5×10^{-8} ref-cm^3/sec of air, or 1×10^{-7} cm^3/sec helium and shall use the leak test fixtures shown on the Company's Drawings M2E801580A021, M2E801580A022, and M2E801580A023.

If a leak is found the Company shall be notified in writing. The leak may be weld repaired by the Seller only if specifically permitted by the Company in writing, and the leak test repeated. After two

unsuccessful repair attempts, the Company may, at its option, choose to reject further repair efforts, and require that a replacement part be fabricated.

The first leak test shall be performed with the containment vessel body assembled as shown on Drawing M2E801580A023, (Part M2E801580A023-1, *Containment Vessel Body Leak Test Assembly*). Note that the outer O-ring in the containment vessel body is not to be installed for this test. The leak testing acceptance criteria is that the assembly shall not have an integrated leak rate greater than 1×10^{-7} ref-cm^3/sec of air, or 2×10^{-7} cm^3/sec helium.

The second leak test shall be performed with the containment vessel lid assembly as shown on Drawing M2E801580A023, (Part M2E801580A023-2, *Containment Vessel Lid Leak Test Assembly*). The leak testing acceptance criteria is that the assembly shall not have an integrated leak rate greater than 1×10^{-7} ref-cm^3/sec of air, or 2×10^{-7} cm^3/sec helium.

The third leak test is to be performed with the containment vessel assembled as shown on Drawing M2E801580A011. The leak testing acceptance criteria is that the assembly shall not have an air leak rate greater than 1×10^{-4} ref-cm^3/sec and the sensitivity of the leak testing procedure shall be less than or equal to 5×10^{-5} ref-cm^3/sec.

Certified written leak test reports shall be supplied to the Company that describes the leak testing and results. The test report shall identify the containment vessel serial number, identify all standard leaks, gauges, transducers and electronic readouts, give the date on which these instruments were certified, identify the leak detector, give the date on which the leak detector was last certified, the date of the test, time of the start and end of the test, the recorded pressures and leak rates at the start and end of the test, the name of the person conducting the test, the qualifications of the person conducting the test, identify areas of the Containment Vessel where repairs were made and any pertinent remarks. Leak testing reports shall be submitted to the Company.

3.10 Cleaning, Passivation, and Bead Blasting

Cleaning procedures for the stainless steel, including weld areas, shall be submitted to the Company for approval prior to the start of fabrication. Only non-chloride bearing chemicals shall be used for cleaning (such as trisodium phosphate detergent or acetone). Water used in cleaning shall have a maximum chlorine content of 0.5 parts per million.

Finished components awaiting assembly and assemblies shall be free of dirt, debris, foreign objects, cutting fluids, metal chips, grinding residue, dye penetrant and developer, and other foreign substances. The Seller shall clean, cover, and protect parts and subassemblies from becoming dirty while in storage, and to the extent practical, in the shop environment while in work.

After final machining, and all examination of welds and surfaces, clean and passivate all stainless steel surfaces of the containment vessel in accordance with ASTM A 380. After passivating is complete, bead

blast all exterior surfaces in accordance with SSPC-SP 5/NACE No. 1, *White Metal Blast Cleaning*, with the exception of all sealing surfaces and threaded surfaces.

3.11 Dimensional Inspection Reports

After all testing, inspection and final machining, the containment vessels shall be dimensionally inspected. The dimensions and features to be inspected are indicated on the Company's drawings by a diamond symbol containing an "I". This dimensional inspection includes surface features such as flatness, runout, etc, as called out on the drawings. The dimensional inspection report shall also include the recorded diameter dimensions that show compliance with the requirements of NB-4200. A certified written inspection report shall be prepared and submitted to the Company.

Appendix 1.4.4

EQUIPMENT SPECIFICATION, JS-YMN3-801580-A003, *MANUFACTURING PROCESS SPECIFICATION FOR CASTING KAOLITE 1600™ INTO THE ES-3100 SHIPPING PACKAGE*

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EQUIPMENT SPECIFICATION APPROVAL/REVISION PAGE

SPECIFICATION NO.	REV.	ISSUE DATE
JS-YMN3-801580-A003	C	11/24/03

PAGE	REVISION DATE
i OF ii	6/1/06

PROCURED BY	INSTALLED BY
BWXT L.L.C.	BWXT L.L.C.

PROJECT TITLE	PLANT	BUILDING
ES-3100 SHIPPING PACKAGE	Y-12	YAREA-00

JOB TITLE	W.O. OR E.S.O.	RECORD NUMBER
Production Design Definition	7RCPCA08	2003-0328

SPECIFICATION FOR	SSC IDENTIFICATION NUMBER
MANUFACTURING PROCESS SPECIFICATON FOR CASTING KAOLITE 1600™ INTO THE ES-3100 SHIPPING PACKAGE	

ENGINEERING AND PLANT APPROVALS

SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY: R. D. Aigner	11-25-03	PROJECT ENGINEER: G. A. Byington	11-25-03
DISCIPLINE MANAGER: J. C. Walls	11-25-03	OPERATIONS MANAGER/SYSTEM OWNER:	
DESIGN VERIFICATION: R. D. Aigner	11-25-03		

REVISIONS/ENGINEERING AND PLANT APPROVALS

REV. NO.	DESCRIPTION OF REVISION
A	Issue for procurement
B	Removed the reference to the Prototype Procurement Specification document number OO-PP-1210. Change the equipment reference in Section 3.1.3(c) from a "large mortar mixer or plaster mixer with moving vanes or a smooth wall cement mixer with the fixed vanes removed" to "Whiteman Multiquip's WM700S-H8 plaster/mortar mixer, refereed to as WM700". In Section 3.2 changed the method and time that the water and dry mix were added into the mixer based upon the mixer qualification in Section 3.5. Added Section 3.5, added attachments E and F to determine the proper mixing time and the Mixer Qualification Castings. In section 3.3.1 and 3.3.3 added misting procedure. Section 3.3.2(b) added a circular concave of .32±.10 to the Kaolite before it is baked to match drawing M2E801580A002. Section 3.3.4(b) add a circular convex scrape of .09±.06 to the Kaolite before it is baked to match drawing M2E801580A008. Updated the attachments with general revisions. Section 3.4 has been subdivided into 3.4.1 Baking Instruction and 3.4.2 Baking Documentation and added attachment F to this section.
C	Revised patent information in scope. Added recommended "Before Baking" weights for the Body Weldment and Top Plug Weldment based upon a more refined Kaolite 1600™ product code GI80ACCUMD0027 that is produced to the lower side and a smaller range of the manufactures normal tolerance band. This Kaolite 1600™ product code requires using 1.65 times the dry weight for the water weight (instead of 1.5) and generates an acceptable wet mix density of 56.2+/− 5.8 lb/ft³. This additional water requires between 36 to 46 hours of bake time at 500°F.

SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY: G A Byington (signature)	6/1/06	PROJECT MANAGER: George Singleton (signature)	6/1/06
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This document has been has been reviewed by a Y-12 ADC and UNCI RO and has been determined to be UNCLASSIFIED and not UNCI. This review does not constitute clearance for public release.

Name: (signature) Date: 06/01/06

EXEMPT FROM IO-155

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ATTACHMENTS

1 Scope

This manufacturing process specification describes the quality assurance and technical requirements that shall be met when weighing, mixing, pouring, vibrating, curing, and baking the Kaolite 1600™ for the ES-3100 shipping container Body Weldment and Top Plug Assemblies. The product produced by following this manufacturing process is protected under U.S. Patent 6,299,950. The United States Government has rights in this invention pursuant to Contract No. DE-AC05-84OR21400, between the U.S. Department of Energy and BWXT Y-12 L.L.C.

This specification describes the instructions that shall be followed for these activities. The components (Body Weldment and Top Plug Assembly) will be fabricated to the design requirements specified on the engineering drawings for the components.

Reference to the Company in this specification shall mean the package certificate holder and reference to the Seller shall mean the supplier of the fabricated Body Weldment and Top Plug Assemblies.

2 Applicable Documents

The following documents apply when Casting Kaolite 1600™ Into ES-3100 Shipping Containers.

ES-3100 Drawing Numbers
M2E801580A002, Body Weldment
M2E801580A008, Top Plug Weldment,

Procurement Specification for ES-3100 Confinement Boundary Assembly
JS-YMN3-801580-A002 Equipment Specification for the ES-3100 Drum Assembly

3 Kaolite 1600™ Processing Requirements

3.1 General

The Kaolite 1600™ material referenced with in this specification shall be provided by Thermal Ceramics, Incorporated or an authorized distributor. The material certification documentation (Certificate of Conformance) for the Kaolite 1600™ must be provided by the supplier for each manufacturer's lot of material to a product code of GI80ACCUMD0027.

3.1.1 Kaolite 1600™ Receiving and Storage Instructions

a. Damaged packages of Kaolite 1600™ shall be rejected by the Seller upon receipt. Damaged packages are those that are wet, those that are visually determined to have been wet, and packages that have been torn.

b. Packages of Kaolite 1600™ must be stored unopened in a dry location and protected from damage. Opened unused and partial used Kaolite 1600™ packages are to be discarded at the end of the work shift. The term work shift shall be defined by the Seller and approved by the Company before commencing operations.

3.1.2 Cleaning Instructions

a. Use <u>NO CHLORINE BLEACH</u> for cleaning. Potable water shall be used and if required some mild soap (tri-sodium phosphate) may be added to the water to clean all processing equipment and manufactured components before casting. Before the start of any mixing/blending operation, the mixer shall be clean from all foreign materials or previous mixing residues from the inner surface of the mixer. The mixer shall be flushed thoroughly with potable water at the completion of the final mixing operation of the work shift to remove residues. Mixing, and casting shall be performed within a temperature range of 70 (± 25) °F.

b. Fabricated assemblies must be cleaned and protected prior to the casting operation to prevent the introduction of foreign materials into the assemblies. The assemblies shall be inspected and wiped clean prior to casting to ensure no visible contaminants are present inside the casting cavity. This inspection shall be documented in the checklist.

3.1.3 Mixing Water and Mixing Equipment Requirements

a. Potable water, that has been filtered through a 20-micron filter and has a chlorine content less than 4 mg/L (4 ppm, 0.0004 percent by mass) for chlorine shall be used for the mixing of Kaolite 1600™. If the potable water is higher then 4 ppm, then use an activated charcoal filter or some other means to reduce the amount of chlorine to at or below 4 ppm. Test the water quality for chlorine weekly during casting operations. Unfiltered potable water may be used for the cleaning of equipment used to process Kaolite 1600™.

b. All weighing operations of assemblies and materials shall be conducted on certified scales with a minimum accuracy of ½ lb.

c. This specification has been developed around the Whiteman Multiquip's WM700S-H8 plaster/mortar mixer, refereed to as WM700. This steel-drum machine mixes 7-cubic feet (193 liters) of material with an 8-horsepower Honda engine running at a slow speed. Other models of plaster/mortar mixers may be used if the speeds and mix times are qualified per section 3.5 and approved by the company.

d. A Heavy Duty Drum Vibrator/Packer(like McMaster-Carr, No. 5809K11, or Company approved equal) shall be used to clamp the Body Weldment, M2E-801580-A002 or Top Plug Weldment, M2E-801580-A008 upside down for vibration casting the Kaolite 1600™ into the welded stainless steel forms.

3.2 Mixing of Kaolite 1600™

Mixing shall be performed by operators qualified in accordance with requirements in Section 4.4.

The term batch is defined as a mixture of one bag of Kaolite 1600™ with the appropriate amount of water. The required mix ratio is 1.65 pounds of filtered water per pound of Kaolite 1600™.

The mixing activity shall be recorded on Attachment A, *Kaolite Mixing Control*. Each batch shall be given a mixture control number (MCN) and recorded upon its data Attachment. (A 10-digit control number is recommended consisting of the date and the time format using a 24-hour clock. Example: 1021041515 for October 21, 2004 at 3:15 pm.)

The Kaolite 1600™ mixing shall be performed as follows:

a. Record the weight of the bag of Kaolite 1600™ on the mixing Attachment.

b. The required mix ratio is 1.65 pounds of filtered water per pound of Kaolite 1600™. For a 50 pound bag of Kaolite 1600™, weigh and record 82.5 (±½) lbs. of filtered water generating an acceptable wet mix density of 56.2±5.8 lb/ft^3.

c. Start the mortar mixer motor and when ready to engage the moving vanes, pour the weighed filtered water, pour all of the 50-pound bag of Kaolite 1600™ over the water. Immediately start the WM700 moving vanes for 3.0 (±0.2) minutes.

3.3 Vibration Casting and Curing of Kaolite 1600™ into Assemblies

3.3.1 Body Weldment Casting Instructions

Casting operations shall be performed by operators and witnesses qualified in accordance with requirements listed in Section 4.4.

Use Attachment B, *Body Weldment Vibration Casting Control,* to record information gathered during this operation.

Complete the casting of the mixture in less than 70 minutes. This timed procedure starts when the first batch is poured into the vibrating component. The casting and vibrating procedure must be completed within 77 minutes from initial pour for each assembly.

Casting operations shall be performed as follows:

a. Weigh the Body Weldment clean and empty. Record the weight.

b. Fill the Body Weldment with potable water that has been filtered through a 20 micron filter and has a chlorine content of ≤ 4 ppm and weigh it. Record the weight.

c. Remove the water from the assembly as much as is practical.

d. Secure the assembly on the vibration table. Set the vibration table dial indicators to approximately 800 lb-force at 450 vibrations per minute (VPM). Assure that the Body Weldment is properly secured to the table and start the vibration table. The Body Weldment must be vibrated continuously throughout the casting operation.

e. The mixture shall then be poured directly into the assembly after mixing through the fill hole provided.

f. Repeat the mixing operation in Section 3.2 and continue pouring until the mixture overflows the fill hole by ½ to ¾ inch.

g. Mist the top surface of the mixture with a bottle water sprayer if necessary to get the mixture into a solution after the pouring is completed. Do not add more than 8 ounces of water.

h. Vibrate the filled assembly for 5 to 7 minutes after the casting is completed.

3.3.2 Body Weldment Curing Instructions

A designated area shall be set aside for curing the assemblies. The temperature of the curing area shall be controlled to 70°F (±25°F) and shall prevent the introduction of foreign materials into the mixture.

Curing operations shall be performed as follows:

a. Remove the Body Weldment from the vibration table and place it in the curing area. Let it rest uncovered for 2½ (±½) hours.

b. Weigh and record the Before Baking weight of the cast assembly. If the weight is outside of 330 to 386 lbs range it is recommended not to cure the casting but to clean out and recast the Kaolite. This Before Baking weight is a recommended process control for the finished baked density. The manufacture may continue with a part outside of this weight range but it has a high chance being rejected for not meeting the finished baked density.

c. After resting, scrape the excess mixture from the fill opening until the Kaolite surface has a circular concave of .32±.10 to match drawing M2E801580A002.

d. Weigh the cast assembly, and photograph the fill opening. Record the weight.

e. Cover the fill opening with plastic sheeting and let the assembly set undisturbed in the curing area for at least 24 hours.

3.3.3 Top Plug Assembly Casting Instructions

Use Attachment C, Top Plug Assembly Vibration Casting Control, to record information gathered during this operation.

Complete the casting of the mixture in less than 70 minutes. This timed procedure starts when the first batch is poured into the vibrating component. The casting and vibrating procedure must be completed within 77 minutes from initial pour for each assembly.

Casting operations shall be performed as follows:

a. Weigh the top plug assembly clean and empty. Record the weight.

b. Fill the top plug assembly with potable water that has been filtered through a 20-micron filter and has a chlorine content of ≤ 4 ppm and weigh it. Record the weight.

c. Remove the water from the assembly as much as practical.

d. Place the assembly on the vibration table. Assure that the assembly is properly secured to the table. Set the vibration table dial indicator to approximately 120 lb-force at 450 vibrations per minute and start the vibration table. The top plug assembly must be vibrated continuously throughout the casting operation.

e. The mixture shall then be poured directly into the assembly after mixing through the fill hole provided.

f. Repeat the mixing operation in Section 3.2 and continue pouring until the mixture overflows the fill hole by ½ to ¾ inch.

g. Mist the top surface of the mixture with a bottle water sprayer if necessary to get the mixture into a solution after the pouring is completed. Do not add more than 4 ounces of water.

h. Vibrate the filled assembly for 5 to 10 minutes after the casting is completed.

3.3.4 Top Plug Assembly Curing Instructions

Curing operations shall be performed as follows:

a. Remove the top plug assembly from the vibration table and place it in the curing area. Let it rest uncovered for 2½ (± ½) hours.

b. Weigh and record the Before Baking weight of the cast assembly. If the weight is outside of 29.2 to 34.2 lbs range it is recommended not to cure the casting but to clean out and recast the Kaolite. This Before Baking weight is a recommended process control for the finished baked density. The manufacture may continue with a part outside of this weight range but it has a high chance being rejected for not meeting the finished baked density.

c. After resting, scrape the excess Kaolite mixture from the fill opening until surfaces are a circular convex shape of .09±.06 before it is baked to match drawing M2E801580A008.

d. Weigh the cast assembly, and photograph the fill opening. Record the weight.

e. Cover the fill opening with plastic sheeting and let the assembly set undisturbed in the curing area for at least 24 hours.

3.4 Baking of Assemblies Cast and Cured with Kaolite 1600™ mixture

3.4.1 Baking Instructions

Several assemblies may be baked together during each furnace heating cycle. Once the furnace heating cycle has started, no additional assemblies may be inserted into the furnace. The furnace and temperature control requirements to perform the baking operation are as follows:

a. The furnace shall be a gas-fired or a forced convection fresh air circulating electric furnace.

b. The furnace heat zone shall be certified to ±25°F from the furnace set point temperature at each baking temperature process point.

c. Furnace time and temperature strip charts for each furnace heating cycle shall be provided with each completed Attachment D. Alternatively, an ASCII furnace time and temperature data file may be provided for each completed Attachment D.

3.4.2 Baking Documentation

Use Attachment D, *Furnace and Baking Control*, to record information gathered during this operation. An Attachment D identified by the Baking Control Number (BCN) shall be generated for each set of assemblies subjected to the furnace baking operations. Record the BCN from Attachment D for each assembly baked during this furnace heating cycle utilizing the proper assembly Casting Attachments B, C, and F. Qualified operators as indicated in Section 4.4 shall perform the baking of the cured assemblies. Movement of the cured assemblies before baking shall be minimized. The time and actual furnace exhaust air temperature shall be recorded at least every 15 minutes for baking control during a furnace heating cycle.

The baking furnace heating cycle shall be completed as follows:

a. Place the assemblies into the furnace.

b. Set the initial set point temperature to 200 (±10) °F.

c. Hold the temperature for 4 hours at a 200 (±10) °F steady state.

d. Increase the furnace set point temperature to 275 (±10) °F.

e. Hold the temperature for 1 hour at a 275 (±10) °F steady state.

f. Increase the furnace set point temperature to 350 (±10) °F.

g. Hold the temperature for 1 hour at a 350 (±10) °F steady state.

h. Increase the furnace set point temperature to 425 (±10) °F.

i. Hold the temperature for 1 hour at a 425 (±10) °F steady state.

j. Increase the furnace set point temperature to 500 (±10) °F.

k. Hold the temperature for 41 (±5) hours at a 500 (±10) °F steady state.

l. Remove assemblies and allow cooling in still air until they reach ambient temperature.

m. Weigh the assemblies after the baking process and record the weights upon the appropriate Attachment (Attachment B or C). Calculate the baked density of the cured mixture using the equation at the bottom of Attachment B or C and record.

Acceptance criteria:

An acceptable baking process is defined as the process in which the density of the baked mixture in an assembly is within the acceptance range of 22.4 ±3 lb/ft^3 as defined on Attachments B or C. If the density is less than the allowable value, contact the Company for disposition. If the density is greater than the allowable level, then re-bake the assembly using Section 3.4.5.a through k, with the exception of the final hold time which shall be 5 (±0.5) hours. Remove assemblies and allow cooling in still air until they reach ambient temperature. Recalculate and record the density on the appropriate Attachment. If the density still is greater than the allowable level, contact the Company for disposition.

n. Photograph the surface of the baked mixture (digital images are preferred).

o. Following the acceptable baking process, weld the cover plate onto the assemblies in accordance with the appropriate engineering drawing within 24 hours.

p. Weigh the final assembly and record on the appropriate Attachment (Attachment B or C).

3.5 Mixer Qualification for Kaolite 1600™ Casting Placement

The mixer qualification process shall verify that the mixer speed and mix time are properly set to mix the Kaolite 1600™. The end result of the mixer qualification is the as-baked density of 22.4±1 lb/ft^3 in the Baked Mixer Qualification Samples. This baked density can be estimated by monitoring the wet density. The baked density is approximately 41% of the wet density; therefore, the Target Wet Density is 56.2 lb/ft^3 for an average baked density of 22.4±1 lb/ft^3. The longer the Kaolite 1600™ is mixed the denser it becomes. The mixer qualification process shall verify the mix time required at a fixed and repeatable speed. The operators shall use the mixer to determine a repeatable speed to operate the mixer for all of the tests. Record the speed setting and assure that the speed setting is repeatable. The mixer qualification tests are a two step process: first is a Wet Density Mixer Time Vibration Casting test used to determine the range of mix time versus wet density; second is the mixer Baked Density Qualification Sample Vibration Casting. It is recommended that a 4-gallon or larger metal pail be used for the testing like the 4-1/2 gallon Tin-Plated Steel Pail (McMaster-Carr 4243T16 or equivalent), 9" Top Dia, 19-3/8" Height.

3.5.1 Wet Density Mixing Test

Use Attachment E, *Wet Density Mixer Time Vibration Casting*, to record information gathered during this operation.

Prepare the Kaolite 1600™ and water for mixing per section 3.2 except for the mix time. A digital stop watch shall be used to monitor the running mix time. The mix time shall vary per Form F from 1 to 15 minutes in 1 minute intervals. Use a quick release attachment to affix the two metal pails (at least 4 gallon) to the vibration table. Start the mixer and run it for one minute, start the vibration table and pour the Kaolite 1600™ into the two pails after filling let them vibrate for 2 minutes, stop the vibration table, scrape them flush, and remove the pails and weigh them. Record the weight, dump the Kaolite 1600™ back into the mixer and start the mixer for another minute and repeat the process.

Plot the wet mix density of the two pails versus the mix time in an Excel file. An Excel file generated by the Company can be provided for this task upon request. Curve fit the data

using a third order polynomial curve and show the equation. Plot the target density of 56.2 lb/ft^3 on a chart in Excel along with the wet mix density. Where the curves intersect the target density line is the mixer's target mix time. Consult the Company for verification of this data. Use the Company verified mix time for the Mixer Baked Density Qualification Castings in Section 3.5.2.

3.5.2 Mixer Baked Density Qualification Castings

Use Attachment F, *Baked Qualification Density Sample Vibration Casting*, to record information gathered during this operation.

Prepare the Kaolite 1600™ and water for mixing per section 3.2.1 except for the mix time. A digital stop watch shall be used to obtain the Company verified mix time. Start mixer and run it for the Company verified mix time. Start the vibration table and pour the Kaolite 1600™ into the two pails. After filling, let them vibrate for 5 to 7 minutes then stop the vibration table.

Remove the two pails from the vibration table. Place the filled two pails in the curing area, and let them sit uncovered for 2½ (±½) hours. After sitting 2½ (±½) hours, scrape the excess mixture from the fill opening until surfaces are flush. Cover the fill opening with plastic sheeting or a metal lid and let the assembly sit undisturbed in the curing area for at least 24 hours before weighing. Remove the two pails and weigh the cured qualification samples to an accuracy ±1 pounds. Record the as-cured and after-baking weights and follow the baking instructions in section 3.4.

4. Quality Assurance Requirements

4.1 General

4.1.1 The Seller shall have a quality assurance program that meets the applicable requirements of Title 10 CFR Part 71, Subpart H for packaging and transportation of radioactive material. The quality assurance plan shall be in accordance with the requirements identified in the ES-3100 procurement specification. The Seller shall submit an approved quality assurance program plan that describes the quality assurance policies and practices to be implemented in identifying, controlling and verifying quality of the Kaolite 1600™ processes (weighing, mixing, pouring, vibrating, curing, and baking).

4.1.2 The Seller shall submit a Manufacturing Plan as defined in procurement specification, and shall describe how the Seller will comply with the instructions in this specification. If subcontractors are utilized for any of the processing of the Kaolite 1600™, the Seller shall ensure that the requirements of this specification (including quality assurance requirements) are met by all suppliers and subcontractors. The subcontractor's procedures, approved by the Seller, shall be included in the procedures submitted to the Company for review and approval.

4.1.3 The Seller's quality assurance program plan shall include the requirements for the process controls for the operations, operator and witness' qualifications, and verification records. Operator qualification requirements are identified in Section 4.4.

4.1.4 The Seller shall generate the documentation necessary to show compliance with the approved quality assurance program plan. All records shall be identified based on the assembly serial numbers. The Seller shall maintain quality-related documentation in accordance with requirements in the procurement specification. The Company reserves the right to request any

such documentation and to witness all aspects of the fabrication process in accordance with this specification. The Seller shall ensure that the specified manufacturing and inspection records are generated and supplied to the Company as part of the certification package.

4.1.5 The Seller must ensure all operators are aware of and comply with the quality assurance requirements identified in this specification. The Seller must ensure all operators use and follow written procedures for the respective processes. The Seller shall ensure operators and witnesses are aware of the operational requirements for the common industrial equipment (material handling equipment, mixers, vibration tables, ovens/furnace) used for the processes.

4.2 Material and Equipment Certification

4.2.1 Material certification for the Kaolite 1600™ must be provided by the supplier as defined in Section 8.0 of the procurement specification. Bags of Kaolite 1600™ must be identified with the product name and unique lot number. The material certification will be incorporated into the quality assurance records of the certification package.

4.2.3 All weighting, mixing, casting, curing, and baking processes shall be controlled and performed by qualified personnel (see Section 4.4). Written procedures shall be utilized by the operator at each operation and shall identify process hold points where required by the Company.

4.2.4 All process equipment used for mixing, casting, and baking of the Kaolite 1600™ and water mixture must be the model type identified in this specification, and must be in good working condition. Equipment used for measurements must be certified to traceable NIST standards or similar agency. Variation from specified equipment (vibration table, mixer, and furnace) is not allowed without the written approval of the Company before implementation.

4.3 Nonconformance Control

4.3.1 The Seller shall have an approved procedure for the control of nonconformances, waivers, and deviation requests during the execution of this manufacturing specification.

4.3.2 Nonconforming components shall not be used unless it has been determined by analysis or assessment by the Company that the nonconformance does not impact the physical properties of the material.

4.2.3 The disposition of nonconforming components shall be documented. Any nonconforming component shall be clearly identified and all nonconformance reports shall be traceable to the actual component affected. Copies of all approved nonconformance reports, except for scrapped components shall be supplied by the Seller to the Company as part of the certification package.

4.4 Operator and Witness Qualifications

The Kaolite™ 1600 mixing and vibration casting qualification evaluations shall be sequential. Each operator must mix and cast at least one simulated drum. Mixing and casting operations shall be repeated as necessary to achieve fully cast mock drums. The simulated ES-3100 drums cast during qualification activities shall be baked according to procedure.

4.4.1 Kaolite 1600™ Mixing Process Qualifications

Each operator and witness performing Kaolite 1600™ mixing activities must be qualified to perform this activity. This qualification shall be documented. This qualification shall consist of the following:

a. Location and time.

b. Properly identifying a bag of Kaolite 1600™ the bag of material and associated certification data (such as lot numbers)

c. Inspection of the bag for observable damage (such as water damage)

d. Successfully weighing the bag of Kaolite 1600™ on an industrial scale

e. Successfully calculating the required amount of water to be mixed with the Kaolite 1600™ (1.65 pounds of water per pound of Kaolite 1600™)

f. Properly inspecting the mixing equipment for foreign materials (such as oil, grease, free liquids, trash, or evidence of non-Kaolite 1600™ material affixed to the inner surfaces.)

g. Successfully operating the mixing equipment while mixing a complete bag of Kaolite 1600™.

h. Successfully preparing a uniformly mixed batch of Kaolite 1600™. (Uniformly shall be defined as a thoroughly mixed material with no dry material and no free liquids remaining in the mixer.)

4.4.2 Kaolite 1600™ Vibration Casting Process Qualifications

Each operator and witness performing Kaolite 1600™ casting activities must be qualified by successfully performing a casting activity. This qualification shall consist of the following.

a. Properly inspecting the inner surfaces of an empty simulated ES-3100 drum body for residues (oil, grease, free liquids) and waste material. (A simulated ES-3100 drum body shall consist of a 55-gallon carbon steel open-head drum which has a 16-gallon carbon steel drum secured to the bottom center. The 16-gallon drum may be secured by tack welding or suitable fasteners. The lid of the 55-gallon drum must have an opening 15" in diameter through which the Kaolite 1600™ can be poured into the drum.)

b. Properly securing an empty simulated ES-3100 drum body to the vibration table.

c. Properly adjusting the vibration table controls to the specified values for drum assemblies.

d. Successfully transferring the Kaolite 1600™ from the mixer into the drum while the drum is vibrating.

4.4.3 Kaolite 1600™ Baking Process Qualifications

Each operator and witness performing Kaolite 1600™ baking operations shall review the procedure steps for calculating the as-baked density of the Kaolite 1600™ in the assemblies and perform a sample calculation.

Attachment A **EQUIPMENT SPECIFICATION** **ES-3100 Shipping Package** **Kaolite Mixing Control**	Specification Number JS-YMN3-801580-A003-1		Revision C
	Issue Date 11/24/03	Revision Date 6/1/06	
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Caster's Company Name			Supplier's Company Name		
Mixing Start Date	Time	Air Temp. °F	Thermal Ceramics Kaolite 1600™ Certificate of Conformance		
Kaolite 1600™ Mixing and Vibration Casting Information			Comments	Operator	Witness
50 lb. Bag ID Number					
Bag Wt.					
1.65 × Bag Wt.					
Mixing Control Number (MCN) [a]					
Water Wt. ±0.5 lbs. (1.65 times Kaolite Bag Wt.)					
Mix Finish Time					

[a] A 10-digit control number is recommended for the Mixing Control Number (MCN) consisting of the date and the time format using a 24-hour clock (i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.)

Caster's Company Name				Seller's Company Name			
Part Serial Number				Body Weldment Drawing Number M2E801580A002			
Measured Weights ±0.5 lb	Casting Information			Comments		Operator	Witness
	Weight		Date				
Clean and Empty							
Filled with Water [a]							
Before Baking [f]							
After Baking Cycle 5							
After Baking Cycle 5A [d]							
After Welding							
Water Information	Water Weight ±0.5 lb		Water Temp.	Comments		Operator	Witness
Water Conditions [a]	lb		°F				
Casting Start Date	Air Temp. °F	Vibration Settings [b] lbf	VPM				
Operation	MCN [c]		Time	Comments		Operator	Witness
Pour Start							
Pour Start							
Pour Start							
Vibration Start							
Vibration Stop							
Baking Cycle 5	Baking Control Num. [c]		Date	Time	Density [d]	Operator	Witness
Baking Cycle 5A [d]	Baking Control Num. [c]		Date	Time	Density [d]	Operator	Witness

[a] Record the water weight and water temperature within 10 minutes from completion of the weighing process.

[b] Recommended Vibration settings are at 450 VPM and twice the total vibrated weight. The total vibrated weight is the finish cast part and fixtures weight, for a setting of approximately 800 pound-force.

[c] A 10-digit Baking Control Number shall be used to define the date and the time of baking using the format with a 24-hour clock (i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.)

[d] Use the above weights to calculate the Density as shown below. If the density is greater, then 25.4 lb/ft^3 then proceed with the next Baking Cycle. If the density is less then 19.4 lb/ft^3 then contact the Company for disposition.

$$\text{Density} = \frac{(AfterBaking - CleanAndEmpty)}{(WithWater - CleanAndEmpty)} \times 62.3\ \text{lb/ft}^3 \quad @\ 70°\text{F}$$

[f] Recommend Before Baking weight is to be 330 to 386 lb range.

Attachment C **EQUIPMENT SPECIFICATION** **ES-3100 Shipping Package** **Top Plug Assembly Vibration Casting Control**	Specification Number JS-YMN3-801580-A003-3		Revision C
	Issue Date 11/24/03	Revision Date 6/1/06	
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Caster's Company Name			Seller's Company Name			
Part Serial Number			Top Plug Assembly Drawing Number M2E801580A008			
Measured Weights ±0.5 lb	Casting Information Weight	 Date	Comments		Operator	Witness
Clean and Empty						
Filled with Water[a]						
Before Baking[f]						
After Baking Cycle 5						
After Baking Cycle 5A[d]						
After Welding						
Water Information	Water Weight ±0.5 lb	Water Temp.	Comments		Operator	Witness
Water Conditions[a]	lb	°F				
Casting Start Date	Air Temp. °F	Vibration Settings[b] lbf VPM				
Operation	MCN	Time	Comments		Operator	Witness
Pour Start						
Pour Start						
Vibration Start						
Vibration Stop						
Baking Cycle 5	Baking Control Num.[c]	Date	Time	Density[d]	Operator	Witness
Baking Cycle 5A[d]	Baking Control Num.[c]	Date	Time	Density[d]	Operator	Witness

[a] Record the water weight and water temperature within 10 minutes from completion of the weighing process.

[b] Recommended Vibration settings are at 450 VPM and twice the total vibrated weight. The total vibrated weight is the finish cast part and fixtures weight, for a setting of approximately 120 pound-force.

[c] A 10-digit Baking Control Number shall be used to define the date and the time of baking using the format with a 24-hour clock (i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.)

[d] Use the above weights to calculate the Density as shown below. If the density is greater than 25.4 lb/ft^3 then proceed with Baking Cycle 1A. If the density is, less then 19.4 lb/ft^3 then contact the Company for disposition.

$$\text{Density} = \frac{(AfterBaking - CleanAndEmpty)}{(WithWater - CleanAndEmpty)} \times 62.3 \text{ lb/ft}^3 \quad @ \, 70°\text{F}$$

[f] Recommend Before Baking weight is to be 29.2 to 34.2 lb range.

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Attachment D **EQUIPMENT SPECIFICATION** **ES-3100 Shipping Package** **Furnace and Baking Control**	Specification Number JS-YMN3-801580-A003-4		Revision C
	Issue Date 11/24/03	Revision Date 6/1/06	
	Plant Y-12	Page 1 of 1	

Baking Company Name				Seller's Company Name			
Baking Control Number [a]				Furnace Serial Number			
Bake Start Date		Air Temp. °F		Computer Data File Name [b]			
Baking Process Control	Furnace Check or NA	Start Time	Start Date	Stop Time	Stop Date	Operator	Witness
Baking Cycle (1) 200°F for 4 hrs.							
Baking Cycle (2) 275°F for 1 hrs.							
Baking Cycle (3) 350°F for 1 hrs.							
Baking Cycle (4) 425°F for 1 hrs.							
Baking Cycle (5) 500°F for 36 to 46 hrs. [c]							
Baking Cycle (1A) 200°F for 4 hrs.							
Baking Cycle (2A) 275°F for 1 hrs.							
Baking Cycle (3A) 350°F for 1 hrs.							
Baking Cycle (4A) 425°F for 1 hrs.							
Baking Cycle (5A) 500°F for 4.5 to 5.5 hrs. [c]							

[a] Record the Baking Control Number in MMDDYYTIME (with time the 24 hour format i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.) on Casting Forms B, C, and F for each part baked under this furnace heating cycle.

[b] The sample baking cycle time and temperature data could be presented both in a digital and graphical form. For example, an Excel file showing the original data and time verses temperature plots shall be acceptable.

[c] Calculate the density as shown on Forms B or C following this furnace heating cycle phase. If the part density is greater than 25.4 lb/ft^3, then proceed with the remaining furnace phases.

EXEMPT FROM IO-155

Attachment E EQUIPMENT SPECIFICATION ES-3100 Shipping Package Wet Density Mixer Time Vibration Casting	Specification Number JS-YMN3-801580-A003-5		Revision C
	Issue Date 11/24/03	Revision Date 6/1/06	
	Plant Y-12	Page 1	of 1

Caster's Company Name			Seller's Company Name		
Mixer Make and Model					
Wet Mix Density Qualification Number [a]			Mix Control Number [a]		
Measured Weights ±0.5 lb	Casting Information		Comments	Operator	Witness
	Weight [c, b] (lb)	Date			
Clean and Empty					
Filled with Water [b]					
Water Information	Water Weight [c, b] ±0.5 lb	Water Temp.	Comments	Operator	Witness
Water Conditions		°F			
Casting Start Date	Air Temp. °F	Vibration Settings [c] lbf / VPM	Mixer Speed Setting		
Operation	Weight [c,b] (lb)	Time (min)	Wet Density [d] (lb/ft^3)	Operator	Witness
Wet Cast [c]		1.0			
Wet Cast [c]		2.0			
Wet Cast [c]		3.0			
Wet Cast [c]		4.0			
Wet Cast [c]		5.0			
Wet Cast [c]		6.0			
Wet Cast [c]		7.0			
Wet Cast [c]		8.0			
Wet Cast [c]		9.0			
Wet Cast [c]		10.0			
Wet Cast [c]		11.0			
Wet Cast [c]		12.0			
Wet Cast [c]		13.0			
Wet Cast [c]		14.0			
Wet Cast [c]		15.0			
Curve fit the Time required to generate the target density and contact the Company for confirmation.			Target Density 56.2 lb/ft^3		

[a] Record the Wet Mix Density Qualification Number and the Mix Control Number in MMDDYYTIME (with time the 24 hour format i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.).

[b] Record water weight and water temperature within 10 minutes from completion of the weighing process.

[c] Use both steel pails to calculate the weights and density.

[d] Recommended Vibration settings are at 450 VPM and twice the total vibrated weight. The total vibrated weight is the finish cast part and fixtures weight, for a setting of approximately 120 pound-force.

[e] Use the above weights to calculate the Wet Density as shown below.

$$\text{Wet Density} = \frac{(WetCast - CleanAndEmpty)}{(WithWater - CleanAndEmpty)} \times 62.3 \text{ lb/ft}^3 \quad @ \ 70°F$$

EXEMPT FROM IO-155

Caster's Company Name			Seller's Company Name			
Mixer Make and Model						
Baked Qualification Density Number [a]			Mix Control Number [a]			

Measured Weights ±0.5 lb	Casting Information		Comments		Operator	Witness
	Weight ±0.5 lb	Date				
Clean and Empty						
Filled with Water [c]						
Before Baking						
After Baking Cycle 5						
Water Information	Water Weight ±0.5 lb	Water Temp.	Comments		Operator	Witness
Water Conditions [c]		°F				
Casting Start Date	Air Temp. °F	Vibration Settings [b] lbf VPM				
Operation	MCN	Time	Comments		Operator	Witness
Pour Start						
Vibration Start						
Vibration Stop						
Baking Cycle 5	Baking Control Num.	Date	Time	Density [d]	Operator	Witness

[a] Record the Baked Qualification Density Number and the Mix Control Number in MMDDYYTIME (with time the 24 hour format i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.).

[b] Recommended Vibration settings are at 450 VPM and twice the total vibrated weight. The total vibrated weight is the finish cast part and fixtures weight, for a setting of approximately 120 pound-force.

[c] Record water weight and water temperature within 10 minutes from completion of the weighing process

[d] Use the above weights to calculate the Qualification Sample Density as shown below. If the density is greater then 23.4 lb/ft^3 or less then 21.4 lb/ft^3 contact the Company for disposition.

$$\text{Qualification Density} = \frac{(AfterBaking - CleanAndEmpty)}{(WithWater - CleanAndEmpty)} \times 62.3 \text{ lb/ft}^3 \quad @\ 70°\text{F}$$

EXEMPT FROM IO-155

Appendix 1.4.5

EQUIPMENT SPECIFICATION, JS-YMN3-801580-A005, *CASTING CATALOG NO. 277-4 NEUTRON ABSORBER FOR THE ES-3100 SHIPPING PACKAGE*

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EQUIPMENT SPECIFICATION APPROVAL/REVISION PAGE

SPECIFICATION NO. JS-YMN3-801580-A005	REV. G	ISSUE DATE 02-18-05
PAGE i of ii	REVISION DATE 08/31/2009	
PROCURED BY BWXT Y-12 L.L.C.	INSTALLED BY B&W Y-12 L.L.C.	
PLANT Y-12	BUILDING AREA	
W.O. OR E.S.O. 7ADDEQ01	RECORD NUMBER Y2003-0328	
SSC IDENTIFICATION NUMBER NA		

PROJECT TITLE: ES-3100 Shipping Package

JOB TITLE: Production Design Definition

SPECIFICATION FOR: Casting Catalog No. 277-4 Neutron Absorber For The ES-3100 Shipping Package

APPROVALS

	SIGNATURE	DATE		SIGNATURE	DATE
PREPARED BY	G. A. Byington /s/	2/18/05	PROJECT ENGINEER	G. A. Byington /s/	2/18/05
DESIGN VERIFICATION	M. L. Goins /s/	2/18/05	CRITICALITY SAFETY	D. A. T. J. F. DeClue /s/	2/18/05
DISCIPLINE MANAGER	D. P. Sooter /s/	11 Feb 05			

REVISIONS/APPROVALS

REV. NO.	DESCRIPTION OF REVISION
A	Issued for Procurement.
B	Changed the minimum LOD from 25.3% to 30.1% at three locations on page 13 section 4.7.3 and one location on page 23 Form D.
C	General changes. Went from an off the shelf item to a two part system of boron carbide plus high alumina cement.
D	General revision. Reformatted sections and attachments. Deleted references to drawing numbers.
E	The mass limits were changed to account for volume tolerances in the 277-4 annulus. Section 3.3.8, Item I, "inner liner" was replaced with "can". A.3.1 was separated into two sections; the second part of A.3.1 became A.3.1.a with the title "Net Count Rate Time Determination". Section A.6.3 was modified by adding "Define the repeatable accuracy for" before the first sentence. JS-YMN3-801580-A005-5 was expanded to include more approval data requirements. A typo was fixed on JS-YMN3-801580-A005-6. Added Rev level to Forms and headers.
F	In Section 3.3.9.3, added maximum and minimum LOD% table based upon cured density and made reference to table on Form F.
G	Shieldwerx, supplier of 277-0 was Thermo Electron Corporation. Added Figures 9, 10, & 11 to represent design and procurement changes made to the ES-3100 Heavy Spacer Can Assembly, see drawing M2E801580A043 Rev. 0 for supplementary details. Added additional reference to M2E801580A043.

	SIGNATURE	DATE		SIGNATURE	DATE
PREPARED BY	Michael Ensley /s/	09/10/09	PROJECT ENGINEER	Larry Roberson /s/	09/10/09
DESIGN VERIFICATION	Drew Winder /s/	09/10/09	CRITICALITY SAFETY	John DeClue /s/	09/10/09
DISCIPLINE MANAGER	Walter North /s/	09/10/09			

This document has been reviewed by a Y-12 DC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: Roger D. Aigner /s/ Date: 09/10/09

EXEMPT FROM IO-155 (8-02)

CONTENTS

ATTACHMENTS

1.0 Scope

1.1 This specification describes the requirements for the procurement, preparation, casting, and verification of a neutron absorber material into the ES–3100 shipping package. The neutron absorber material shall be cast into ES–3100 Body Weldment (Figure 1), Neutron Absorber Form (Figures 4 and 5), Heavy Can Spacer Assembly (Figure 6 and 9), and 10 oz. double friction can (Figures 7, 8, 10 and 11) with tooling, i.e., Neutron Absorber Casting Funnel Assembly (Figure 2), and Body Weldment and Casting Funnel Assembly (Figure 3).

1.2 Definitions

277-0 - Shieldwerx Catalog No. SWX-277-0 or equivalent, Heat Resistant Shielding "Non-Borated" high alumina cement.

277-4 - A mixture of 277-0 and boron carbide (B_4C) powder to form a neutron absorber material.

Companion Sample Cans - The 10 oz. double friction cans in Figures 7 and 8 or 10 oz. crimp style cans in Figures 10 and 11 used for sampling.

Company – B&W Y-12 L.L.C.

Dry Batch - A dry mix of batch size of 277-4.

Dry Blend Batch - A thoroughly mixed Dry Batch.

Heavy Can Spacer Assembly - The 10 oz. double friction can in Figure 6 or 10 oz. crimp style can in Figure 9.

Overcast – Additional cast material required to achieve the fill requirements.

PGNAA Subcontractor – Independent testing firm that performs the Prompt Gamma-ray Neutron Analysis on the companion sample cans for the Company.

Process Procedures - Dry mixing, wet mixing, casting, sampling, and inspection procedures.

Subcontractor - The manufacturer of the ES-3100 Drum Assembly per JS-YMN3-801580-A001.

Vibration Casting – Vibration during casting to remove the air bubbles.

Wet Mix Batch - A wet mix of Dry Blend Batch and water.

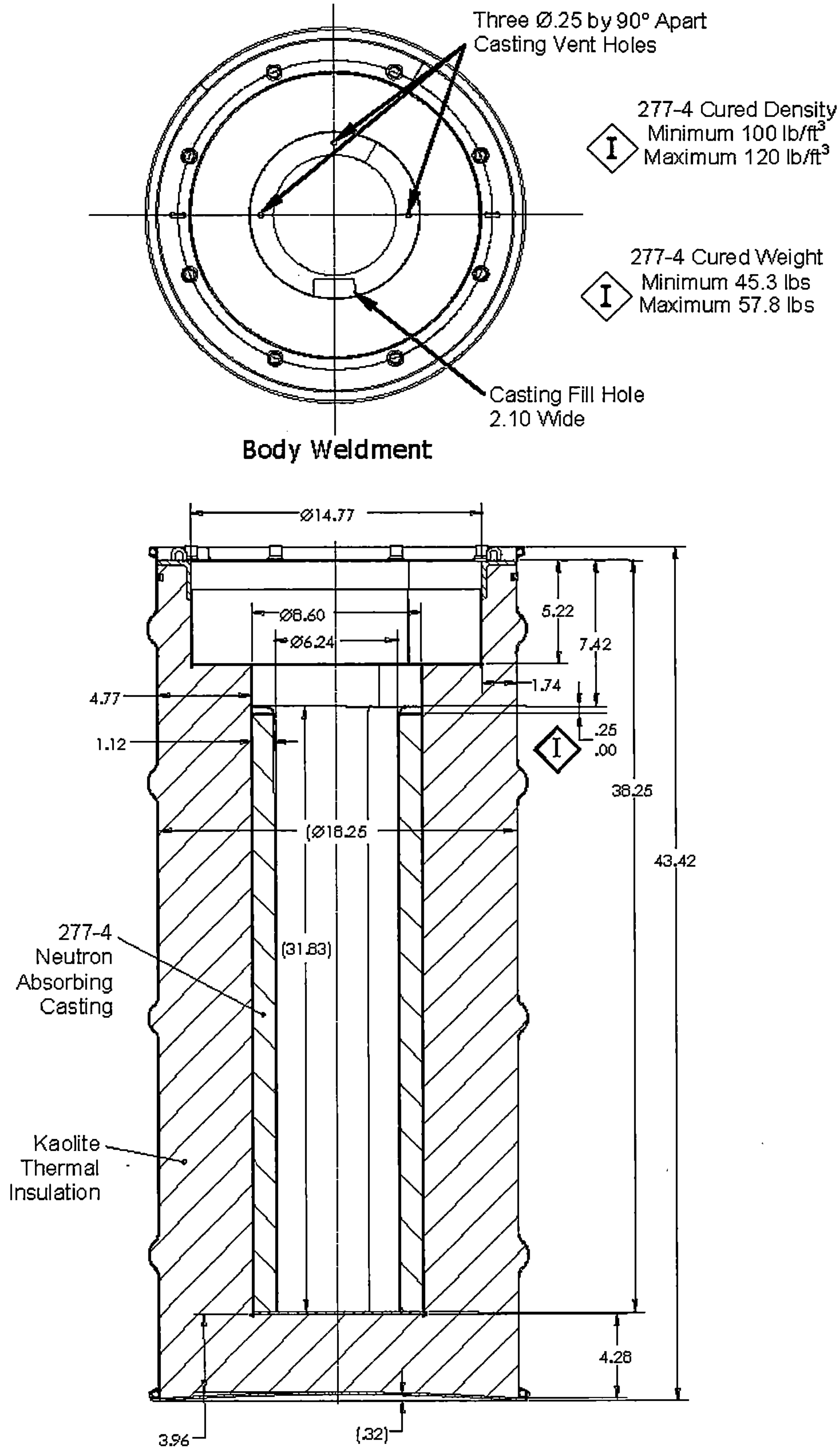
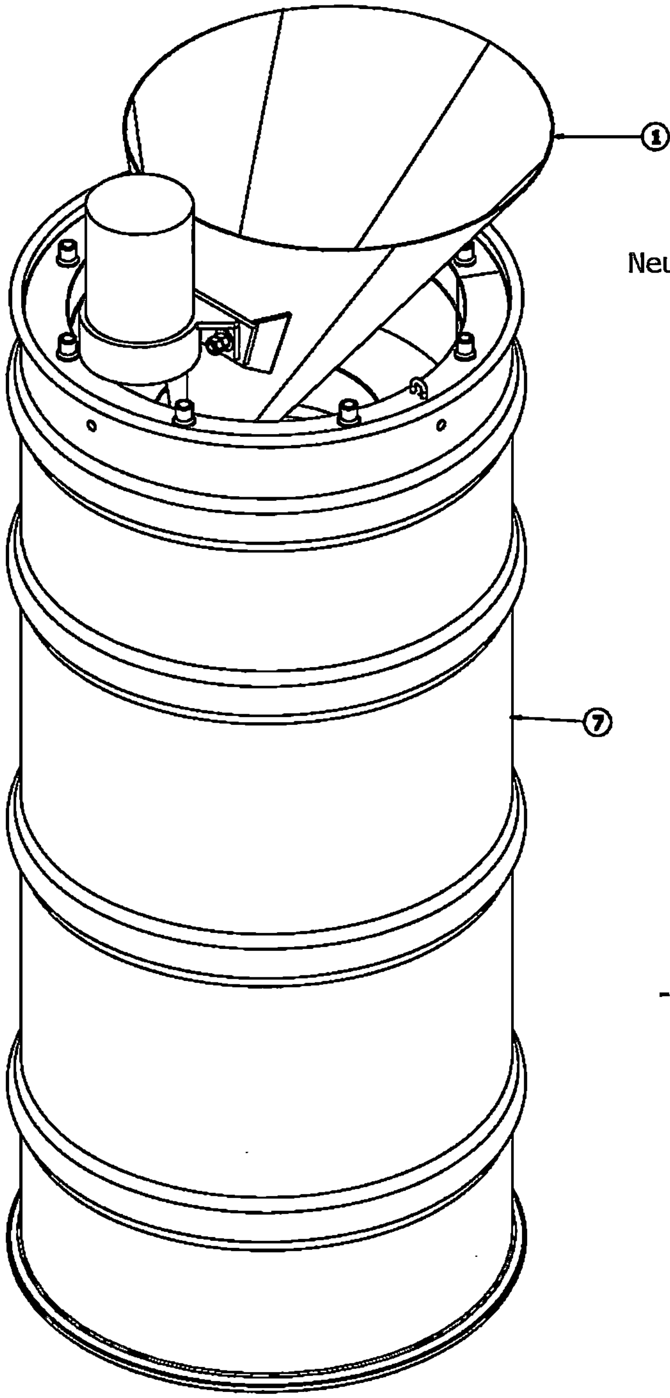
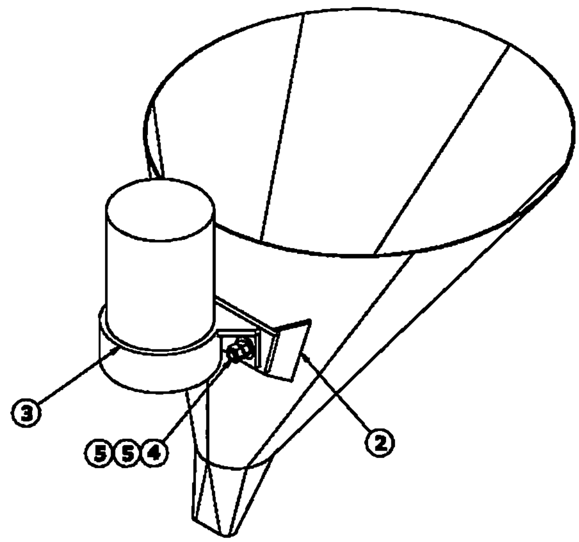


Figure 1 ES-3100 Neutron Absorbing Casting



Neutron Absorber Casting Funnel Assembly



-1 NEUTRON ABSORBER CASTING FUNNEL ASSEMBLY

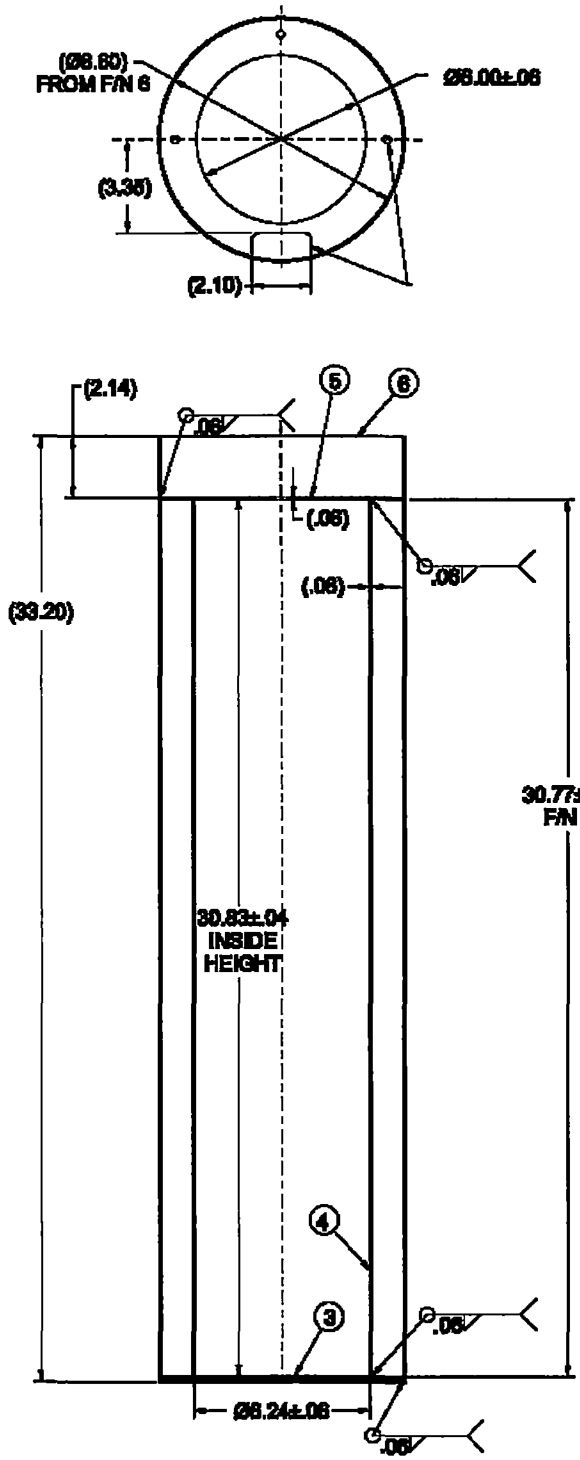
VIBRATOR POWERED CASTING FUNNEL

Figure 2

-6 BODY WELDMENT AND CASTING FUNNEL ASSEMBLY

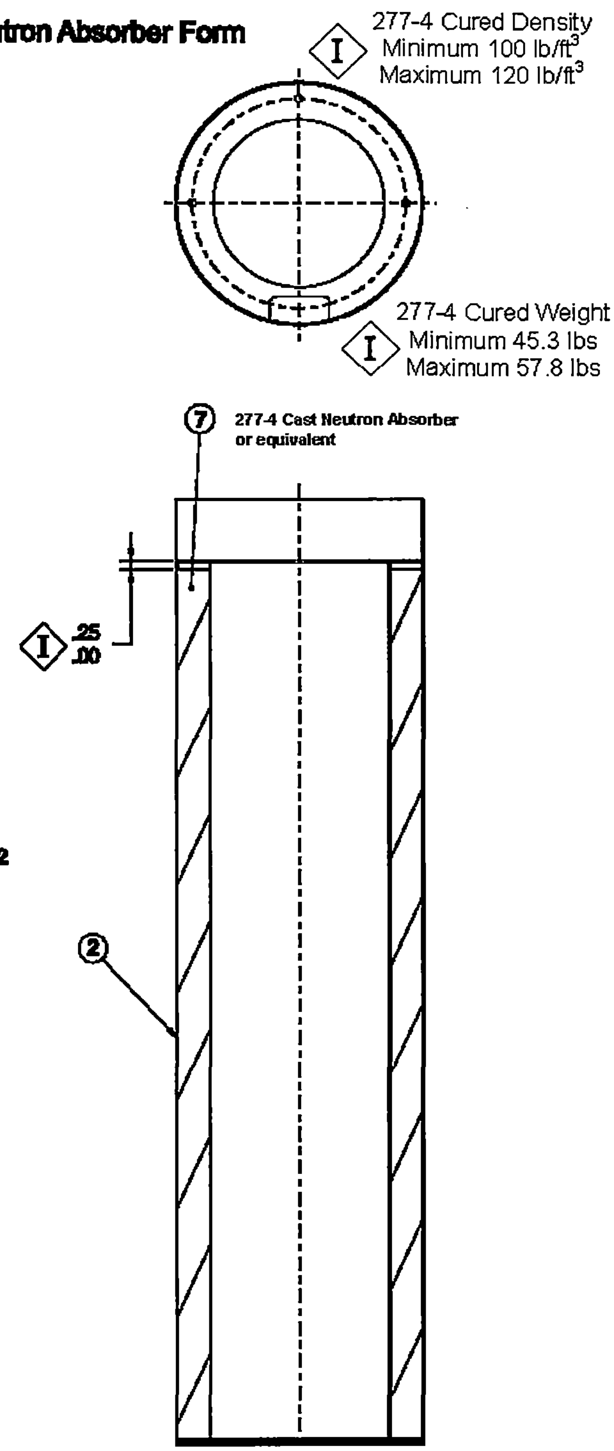
Figure 3

Neutron Absorber Form



-2 NEUTRON ABSORBER FORM WELDMENT

Figure 4



-1 NEUTRON ABSORBER FORM ASSEMBLY

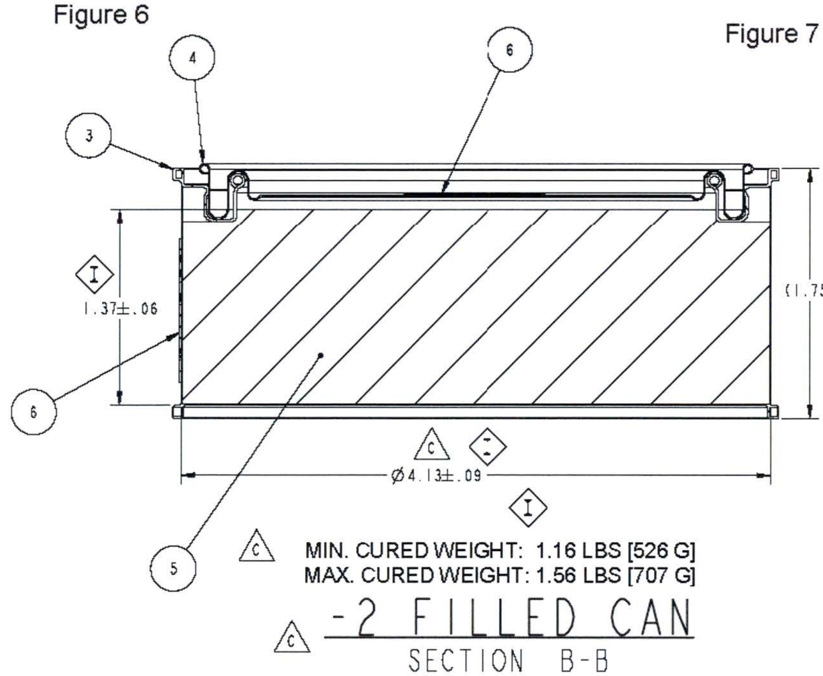
Figure 5

HEAVY CAN SPACER ASSEMBLY

Figure 6

10oz DOUBLE FRICTION CAN
FILLED WITH 277-4

Figure 7



10oz DOUBLE FRICTION CAN
FILLED WITH 277-4

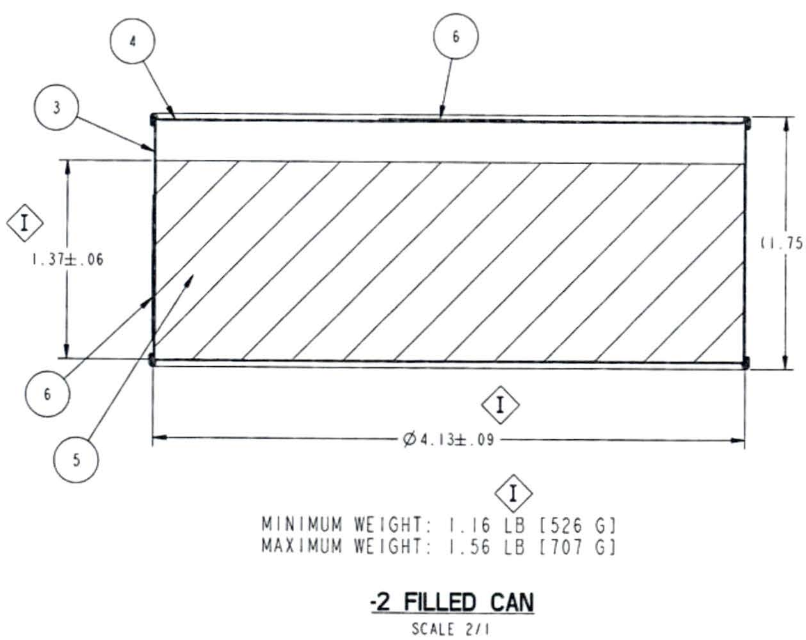
Figure 8

HEAVY CAN SPACER ASSEMBLY

Figure 9

10oz CRIMP STYLE CAN
FILLED WITH 277-4

Figure 10



10oz CRIMP STYLE CAN
FILLED WITH 277-4

Figure 11

2.0 Applicable Documents

2.1 The following documents are a part of this specification. When there is a conflict between the specification and the applicable documents, the Subcontractor shall bring it to the attention of the Company for resolution.

2.2 Standards

ASTM A 380-99	*Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment and Systems*
ASTM C 750-03	*Specification for Nuclear-Grade Boron Carbide Powder*
ASTM C 791-04	*Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Boron Carbide*
ASTM E 11-04	*Standard Specification for Wire Cloth and Sieves for Testing Purposes*
10 CFR 71 Subpart H	*Code of Federal Regulations - Energy - Packaging and Transportation of Radioactive Material - Quality Assurance*

2.3 Company Documents

JS-YMN3-801580-A002	*ES-3100 Drum Assembly*
JS-YMN3-801580-A003	*Manufacturing Process Specification for Casting Kaolite ™ Into the ES-3100 Shipping Package*
M2E801580A026 and M2E801580A043	*Heavy Can Spacer Assemblies*

2.4 Referenced Documents (Not Provided with Request for Proposal)

DAC-PKG-801624-A001	*Mixing Weights And Elemental Composition of 277-4 Neutron Poison used in the ES-3100*
Ltr. No. COR-NDA-04-93	Canberra Oak Ridge, LLC, January 5, 2005, *Results of Prompt Gamma-ray Neutron Activation Analysis and Neutron Transmission Measurements on Prototype Confinement Vessel Inner Liners and Spacers.*
Ltr. No.: COR-NDA-05-015	Canberra Oak Ridge, LLC November 3, 2005, *Results of Prompt Gamma-ray Neutron Activation Analysis On 20 Slip Fit Spacer Cans.*

3.0 Requirements

3.1 General Requirements

The Subcontractor shall be responsible for supplying all materials, services, facilities, and equipment to meet the requirements of this specification unless otherwise noted. Items needed to meet the requirements of this specification that are not identified in this specification shall be specified by the Subcontractor and submitted as Approval Data.

3.2 Equipment Requirements

3.2.1 Certified Scales

All weighing operations of assemblies and materials shall be conducted on certified scales with a minimum accuracy of ±1% of the required measurement or as specified by the measurement tolerance. Scale certification shall be submitted as Approval Data.

3.2.2 Dry Blending the 277-0 and B_4C

A small parts tumbler shall be used to dry blend the ingredients. The small parts tumbler shall be a Multi-Barrel Small Parts Tumbler Benchtop Base (McMaster-Carr No. 44235A11) with Multi-Barrel Small Parts Tumbler 8 Gallon Barrel, 15-3/4" Dia X 14-3/4" W (McMaster-Carr No. 44235A24) or Company approved equal.

3.2.3 Mortar or Plaster Mixer

A mortar or plaster type mixer with moving vanes to shear the wet mix shall be used. The batch volume is approximately 0.5 ft^3 (15 quarts or 3.8 gallons). Therefore, it is recommended that the mixer volume should be 1.5 to 2 times the mix volume or around 0.75 to 1.0 ft^3 (22.5 to 30 quarts, ~6 to 8 gallons). The 277-4 wet mix is thixotropic when mixed and it is recommended that a heavy duty adjustable vibrator mounted to the mixer for both mixing and pouring is used.

3.2.4 Small Plaster Mixer

A drill-powered mortar or plaster mixer and a 5-gallon plastic bucket may be used on small batches of 277-4 instead of the mortar or plaster type mixer. The 5-gallon plastic bucket shall be placed upon the Heavy Duty Drum Vibrator (see Section 3.2.6).

3.2.5 Vibration Powered Funnel Assembly

The Neutron Absorber Casting Funnel Assembly with a vibration- powered funnel (Figures 2 and 3) shall fill both the Body Weldment (Figure 1) and the Neutron Absorber Form (Figure 4). The Casting Funnel Assembly may be modified as required by the Subcontractor to get the wet mix to flow.

3.2.6 Heavy Duty Drum Vibrator

A Heavy Duty Drum Vibrator/Packer shall be used to hold the Body Weldment (Figure 1) or Neutron Absorber Form (Figure 4) for vibration casting the 277-4 into the stainless steel forms. The Heavy Duty Drum Vibrator/Packer shall be McMaster-Carr No. 5809K11, or Company approved equal.

3.2.7 Bench Vibrator

A bench vibrator shall be used during the mixing of the companion sample cans and Heavy Spacer Can Assemblies. The bench vibrator shall be Tabletop Vibration/Mixing Table 10-in. by 7-in. Platform, 10-lb Capacity Continuous Use (McMaster-Carr No. 5714K61) or Company approved equal.

3.3 277-4 Neutron Absorber

3.3.1 Raw Casting Material Requirements and Inspection

3.3.1.1 277-0

Shieldwerx Catalog No. SWX-277-0 Heat Resistant Shielding "Non-Borated" shall be procured. The manufacturer model or catalog number and expiration date shall be clearly indicated on the container. A Certificate of Conformance shall be provided with each lot or batch. The Certificate of Conformance shall include the lot or batch number and the expiration date. The 277-0 shall be sealed and stored in a dry place.

3.3.1.2 Type 1 Nuclear-Grade Boron Carbide Powder

B_4C powder shall be procured as Type 1 Nuclear-Grade Boron Carbide Powder per ASTM C 750. 100% of the powder shall pass through a No. 140 Sieve per ASTM E 11. A Certificate of Conformance and a copy of the chemical and elemental analysis purity in accordance with ASTM C 791 shall be provided.

3.3.1.3 Water

The water shall be potable, filtered through a 20-micron filter and an activated charcoal filter, have a chlorine content of less than 4 ppm, and have a temperature of 65±15°F. Unfiltered potable water may be used for the cleaning of equipment used to cast the neutron absorber system.

3.3.2 Dry Blending Process

3.3.2.1 Dry Batch

A dry batch of 277-4 shall be a mixture of 93.6 wt% 277-0 and 6.4 wt% B_4C. It shall be of sufficient quantity to fill one ES-3100 Body Weldment or Neutron Absorber Form, i.e., approximately 0.55 ft^3 poured volume and 50 lbs. of dry 277-4 weight. The batch size may be adjusted as necessary based on experience for the ES-3100 Body Weldment or Neutron Absorber Form. The tolerance for 277-0 and B_4C weighting shall be the following:

277-4 Dry Batch Size	277-0	B_4C
Equal to or greater than 30 lbs.	±.2 lbs.	±.01 lbs.
Less than 30 lbs	±.01 lbs.	±.01 lbs.

The data shall be recorded on Form A.

3.3.2.2 Blended Dry Batch

The dry batch of 277-4 shall be thoroughly blended. The data shall be recorded on Form A.

If the blended dry batch is not used immediately, the blended dry batch shall be sealed and stored in a dry place with a Blended Dry Batch control number attached to the container.

The Blended Dry Batch shall not be used if the 277-0 expiration date has expired.

3.3.3 Wet Mixing

The weight of the dry mix and water shall be to the following weight proportions of 100% dry mix and 27±1% water. The 277-4 is thixotropic when mixed. It is recommended to have a heavy duty adjustable vibrator mounted to the mixer for both mixing and pouring. Place the water in the mixer and add the dry mix into the water. Before casting, mix the dry powder and water for at least 3 minutes and less than 60 minutes. Any material in the mixer after 60 minutes shall be discarded. Mix only in a room with a temperature range of 70±25°F.

The data shall be recorded on the appropriate form, i.e., Form B for overcast, Form C for Body Weldment, Form D for Neutron Absorber Form, and Form E for Heavy Can Spacer Assembly/PGNAA Acceptance Standards.

3.3.4 Body Weldment and Neutron Absorber Form Vibration Casting

3.3.4.1 Vibration Casting Requirements for Body Weldment and Neutron Absorber Form

During the vibration casting of the 277-4, record the Body Weldment (Figure 1) casting data on Form C and the Neutron Absorber Form (Figure 5) casting data on Form D. A stainless steel vibration powered funnel (i.e., Neutron Absorber Funnel Assembly shown in Figure 3) fits inside the 2.10-in. wide slotted fill hole shown in Body Weldment and in Neutron Absorber Form.

a. Weigh and record the data on Form C or on Form D.
b. Weigh and record the water weight and temperature data when filled with water to within .25 in. of the top metal surface.
c. Remove the water.
d. Secure the part on the drum vibrator.
e. Plug the 6.24 in. diameter cavity to keep the wet mix from falling into the liner bottom.
f. Place the Neutron Absorber Funnel Assembly in the slot and secure in place. If required, additional vibrators may be added.
g. Prepare the Wet Mix per Section 3.3.3.
h. Start the drum vibrator.
i. Scoop the wet mix into the Neutron Absorber Funnel Assembly.
j. Turn on the vibrating funnel and adjust the vibration force until the wet mix flows.
k. About half way through filling the wet mix in either the Body Weldment or Neutron Absorber Form, cast two companion samples for Section 3.3.7. Record the companion sample data on Form F and either Form C or Form D.
l. Continue filling the wet mix until the part will take no more.
m. After filling is complete, vibrate the container for 45±15 seconds to remove air bubbles.

3.3.4.2 Overcast Requirements for Body Weldment and Neutron Absorber Form

A few hours after casting, the 277-4 will settle in the vertical direction and leave a layer of watery fluid on the top of the casting. Remove this fluid and overcast the top between 4 and 24 hours from the first casting. After the overcast has cured for between 4 and 24 hours inspect the depth of casting to the top metal surface and verify that it is within 0.25 in. If not within the 0.25 in., cast additional 277-4 material and perform the following:

a. Remove the water.
b. Secure the Body Weldment or Neutron Absorber Form on the drum vibrator.
c. Plug the 6.24 in. diameter cavity to keep the wet mix from falling into the liner bottom.
d. Record the Overcast Wet Mix Control Number (WMCN) on the appropriate casting data form.
e. Prepare the Wet Mix per Section 3.3.3.
f. Start the drum vibrator.
g. Scoop the wet mix into the Body Weldment or Neutron Absorber Form Assembly until the vent hole is filled.

The final shrinkage of the 277-4 shall be within 0.25 in. of the metal surface as shown in Figures 1 and 5.

3.3.4.3 Curing Requirements Body Weldment and Neutron Absorber Form

Cover the newly cast wet component with plastic or metal for 7 days. Do not store the cast 277-4 castings in temperatures below 35°F for the first 30 days after casting.

After 7 days, remove the plastic or metal cover and dehydrated using either or both vacuum and heat to create an acceptable density and weight. If heat is used, the maximum temperature of the inner liner shall not exceed 250°F.

Record the diamond I measurements shown on Figures 1 and 5 on the appropriate casting data forms. The acceptable cured height measurement shall be less than 0.25 inches. The acceptable cured casting weight shall be between 45.3 and 57.8 lbs. Cured casting weights shall be used to calculate the cured density. If the cured casting density is greater than 120 lb/ft^3, continue the dehydration process. If the cured casting density is less than 100 lb/ft^3, the casting shall be unacceptable, the appropriate form shall be completed, and a copy of the form shall be sent to the Company.

3.3.5 Heavy Can Spacer Assembly

The Heavy Can Spacer Assembly shown in Figure 6 or 9 shall be the 10-oz. double friction metal can as shown in Figures 7 and 8, or 10-oz. crimp style metal can as shown in Figures 10 and 11. The cured casting weight for each can shall be measured and the cured casting density recorded on Form E. A cured cast density of 100 to 120 lb/ft^3 and a cured weight range of 1.16 to 1.56 lbs shall be acceptable. If the cured casting density is outside the acceptable range, a copy of the form shall be sent to the Company.

Two cans from the middle of the lot on Form E, i.e., a maximum lot of 22 cans, shall be selected and identified as companion sample cans. Cans that are not from the middle of the lot on Form may be selected with Company approval.

3.3.6 PGNAA Acceptance Standards

The PGNAA Acceptance Standards shall be made with a Company representative witnessing the manufacturing processes of weighing, blending, wet mixing, and casting. The PGNAA Acceptance Standards shall be the 10-oz. double friction metal can as shown in Figures 7 and 8, or 10-oz. crimp style metal cans as shown in Figures 10 and 11. The cured casting weight for each can shall be measured and the cured casting density recorded on Form E. A cured casting density of 100 to 120 lb/ft^3 and a cured casting weight of 1.16 to 1.56 lbs shall be acceptable. If the cured casting density is outside the acceptable range, a copy of the form shall be sent to the Company.

One can from the middle of the lot on Form E, i.e., a maximum lot of 22 cans, shall be selected and identified as a companion sample can for Loss On Drying (LOD) testing. The remainder of the lot shall be sent to the PGNAA Subcontractor.

3.3.7 Companion Sample Cans

In addition to the companion sample cans selected in Sections 3.3.5 and 3.3.6, two companion sample cans shall be made half way through the casting process for the Body Weldment and the Neutron Absorber Form per Section 3.3.4.1. Companion sample can data shall be recorded on Test Form F.

a. The cured casting density of all companion sample cans shall be calculated per Section 3.3.9.2 and recorded on Form F. If the cured casting density is outside the acceptable range, a copy of the form shall be sent to the Company. A low cured casting density of a companion sample can shall not be a reason to reject the Body Weldment, Neutron Absorber Form, Heavy Can Spacer Assembly casting lot, or PGNAA Acceptance Standards casting lot.
b. The odd serial number companion sample cans for the Body Weldment, Neutron Absorber Form, Heavy Can Spacer Assembly casting lot, or PGNAA Acceptance Standards casting lot shall be LOD tested to verify the hydrogen content per Section 3.3.9.3.
c. The even serial number companion sample cans for the Body Weldment, Neutron Absorber Form, or Heavy Can Spacer Assembly casting lot shall be PGNAA tested to verify the ^{10}B content per Section 3.3.9.4.

3.3.8 Casting the 10 oz. Double Friction Metal Cans or 10 oz. Crimp Style Cans

a. Select a labeled can which has a drawing and serial number per drawings M2E801580A026 or M2E801580A043.
b. Weigh the empty labeled can and lid and record the casting can data on Forms C, D, or E. It is acceptable to weigh ten cans with ten lids for each purchase order of cans and to use the average can and lid weight on each form.
c. Weigh the water and measure the water temperature. Record this data on Form C, D, or E. Fill with water only up to the bottom of the inside rim. The can lid shall be on the scale. It is acceptable to weigh the water weight of the first ten cans with ten lids of the same lot of cans and to use the average water weight for each of the following cans if the measurements are consistent.
d. Remove the water from the cans.
e. Prepare the Wet Mix Batch following Section 3.3.3.
f. Hold the can on the bench vibrator during filling with the 277-4 wet mix. Quickly vibrate and continue to add wet mix to the can lip.
g. Once all of the cans are full of wet mix, return the first can back to the vibrator for at least 3 minute at a high frequency setting. During the 3 minutes of vibration, continue to add 277-4 wet mix until the can stays full. Repeat this process for all the cans in the casting lot.
h. Between 1 to 24 hours after casting, scrape the top of the casting to meet 1.37±0.06 dimension from bottom of can noted on Figures 8 and 11.

i. Clean the can rim around the edge per Section 3.4.2.
j. Perform an in-process measurement of the scraped casting height to ensure that the casting height parameters are met shown in Figures 8 and 11.
k. Cover the casting by placing the properly labeled can lid on the can for 7 days.
l. Remove the can lid and let the can air dry or use either or both vacuum and heat to create an acceptable density and weight. If heat is used, the maximum temperature of the can shall not exceed 250°F.
m. Measure casting height and weigh the can with lid. Record this data on Forms C, D, or E.
n. Record the final Companion Sample Can casting density, weight, or casting height measurements data on Form F.
o. Crimp lid onto crimp style can, as applicable.

3.3.9 Verification

All verification shall be completed after the casting is cured.

3.3.9.1 Cured Casting Density Verification

The density of cured casting in the Body Weldment, Neutron Absorber Form, Heavy Can Spacer Assembly, and PGNAA Acceptance Standards shall be determined by weighing the casting container before casting, while filled with water, after casting, and when cured.

Since the density of water is known, a simple relationship between the weight differences shall determine the cured casting density.

$$Density = \left(\frac{Cured - Empty}{WithWater - Empty} \right) \times 62.3 \text{ lb/ft}^3$$

3.3.9.2 Companion Sample Can Cured Casting Density Verification

The density of cured casting in each companion sample can shall be determined by weighing the can before casting, while filled with water, after casting, and when cured.

Since the density of water is known, a simple relationship between the weight differences shall determine the cured casting density.

$$Density = \left(\frac{Cured - Empty}{WithWater - Empty} \right) \times 62.3 \text{ lb/ft}^3$$

3.3.9.3 Companion Sample LOD Verification

The companion sample cans identified in Section 3.3.7.b shall be LOD tested. The acceptable LOD percent range shall be based upon the companion sample can cured casting density in Section 3.3.9.2. The Acceptable Maximum and Minimum LOD% at Density is in this table developed from data in DAC-PKG-801624-A001 Table 7, 277-4 Composition @ Extreme Densities and LOD% and compared to the average values as manufactured.

Acceptable Maximum and Minimum LOD% at Density		
Density (lb/ft^3)	Maximum LOD%	Minimum LOD%
100	31.80%	28.61%
101	32.47%	28.33%
102	33.12%	28.06%
103	33.77%	27.79%
104	34.40%	27.52%
105	35.03%	27.26%
106	35.64%	27.00%
107	36.25%	26.75%
108	36.84%	26.50%
109	37.42%	26.25%
110	37.99%	26.01%
111	38.56%	25.78%
112	39.11%	25.55%
113	39.65%	25.32%
114	40.18%	25.10%
115	40.70%	24.88%
116	41.21%	24.66%
117	41.71%	24.45%
118	42.20%	24.25%
119	42.68%	24.05%
120	43.15%	23.85%

a. The lid shall have the serial number permanently transferred by vibro etch or other method.
b. The lid shall have a small vent hole in it. It is recommended that a nail be used to punch a hole 0.12±0.06 in. diameter in the metal lid from the inside surface of the lid.
c. Match the can serial numbers and place the lid on the can.
d. The weight of the can shall be recorded on Form F.
e. The cans shall be placed in an oven at 1500±150°F (800°C) for 4 hours.
f. The weight of the can shall be recorded on Form F with the can temperature not below 100°F.
g. Calculate the LOD% using the equation below and record it on Form F. Due to can oxidizing and gaining weight during the heating cycle, a 0.024 lb correction factor is included in the following LOD% calculation.

$$\text{LOD\%} = \left[1 - \frac{(LODWeight - Empty - 0.024lb)}{(Cured \,\&\, Clean - Empty)}\right] \times 100\%$$

h. Verify that the LOD% is within the acceptable range. If water content is outside the acceptable range, a copy of the form shall be sent to the Company.

3.3.9.4 PGNAA Verification

The companion sample cans identified testing in Section 3.3.7.c shall be sent to the PGNAA Subcontractor. The PGNAA Subcontractor will test to the requirements in Appendix A and record the data on Forms AA to AD. The PGNAA Subcontractor will send copies of the completed Forms AC and AD to the Subcontractor and Company.

The PGNAA testing acceptance results on From AD shall be transferred to Form F.

3.4 Cleaning Requirements

3.4.1 Contact with Chlorides or Fluorides

The stainless steel material shall be protected from contact with chlorides in accordance with ASTM A380, paragraph 8.5, during all operations including packaging. The Material Safety Data Sheet (MSDS) for all cleaning solutions or products used on the ES-3100 shall be submitted as Approval Data to verify that no chlorides or fluorides are present.

3.4.2 Satisfactory Cleanliness

Cleaning procedures for the stainless steel per Section 3.4 of equipment specification JS-YMN3-801580-A002 shall be submitted as Approval Data. Only non-chloride-bearing chemicals shall be used for cleaning (e.g., trisodium phosphate detergent or acetone). Water used in cleaning shall have a maximum chlorine content of 4 parts per million.

After casting but prior to packaging, stainless steel components of the forms and cans shall be cleaned per the approved cleaning procedures. Satisfactory cleanliness shall be determined by visual inspection as can be observed by a person with normal visual acuity (natural or corrected) and without magnification. Light intensity of at least 100 ft-candles shall be provided on the surface to be inspected.

4.0 <u>Quality Assurance</u>

4.1 Quality Assurance Program

The subcontractors shall have in place and maintain a Quality Assurance (QA) Program and inspection system that meets the requirements of 10 CFR 71 Subpart H. If not previously submitted, an uncontrolled copy of the subcontractor's QA Program shall be submitted as Offer Appraisal Data.

4.2 ES–3100 Casting Quality Assurance Requirements

4.2.1 ES–3100 Documentation Package

All records shall be identified based on the ES–3100 serial numbers. The ES-3100 Documentation Package shall be provided as Certified Data with each ES-3100 casting. The ES-3100 Documentation Package shall be complete, legible, indexed, and traceable to the material supplied and include the following:

a. Material measuring, dry blending, wet mixing, casting, sampling, and inspection forms, i.e, Forms A through F.
b. A Certificate of Compliance for each lot of the 277-0 Heat Resistant Shielding "Non-Borated" dry mix documentation with the expiration date identified on each container.

c. A Certificate of Compliances for B_4C powder to Type 1 Nuclear-Grade Boron Carbide Powder per ASTM C 750, chemical and elemental analysis per ASTM C 791, and 100% of the powder passes through a No. 140 Sieve per ASTM E 11.

d. A Certificate of Compliance signed by an officer of the Subcontractor confirming that the cast neutron absorber in ES−3100 shipping package meets the subcontract requirements.

4.2.2 Batch Processes

Batch processes such as mixing, pouring, curing, sampling, inspection, etc., shall be performed in accordance with detailed written procedures. These procedures shall specifically describe the exact manner in which these processes are to be performed. All records shall be traceable to the ES−3100 Shipping Package, Neutron Absorber Form, Heavy Spacer Can Assembly, PGNAA Acceptance Stands or Companion can serial numbers.

4.2.3 Materials Traceability

A manufacturing lot or batch number shall identify material furnished to make up the neutron absorber system. Materials shall be identified by material type; applicable specification and revision number, and be traceable to their lot numbers. Traceability records shall be available for review by the Company's representative.

4.2.4 Procedures

Preparation, installation, sample collection, and inspection processes shall be controlled and performed by qualified personnel. The procedures must incorporate a mechanism to identify process step completion. Procedures shall be submitted as Approval Data. The approved procedures shall be provided as Certified Data prior to the start of casting.

4.2.5 Training and Qualification of Personnel

The Subcontractor shall provide for the training and qualification of personnel to ensure their competence in the use of process procedures and specifications. Records of personnel qualifications shall be made available to the Company upon request. Only those personnel who have been qualified to perform a specific batch process used in the casting of Kaolite per equipment specification JS-YMN3-801580-A003 shall be used to perform work in this process.

4.2.6 The Company reserves the right to request any documentation and to witness any of the processes performed in accordance with this specification.

5.0 Preparation for Delivery

After cleaning of stainless steel surfaces per Section 3.4, aluminum foil duct tape shall be applied over the fill and vent holes in the Body Weldment (Figure 1) and the Neutron Absorber Form (Figure 5).

6.0 Manufacturer's Data

6.1 Offer Appraisal Data shall be submitted with the offer. This data shall become part of the subcontract requirements.

6.2 Approval Data will be reviewed and approved by the Company. Subcontractor shall not proceed with the casting activity until Company approval is given for all the Approval Data. The Approval Data shall be transmitted to the Company by the dates agreed to by the Subcontractor and the Company Subcontractor Administrator.

6.3 Certified Data will be used by the Company as the record for the ES-3100 shipping packages. The Certified Data shall be transmitted as noted.

6.4 A request for Company approved equal shall be submitted as Approval Data. Adequate information shall be provided with the request for Company approved equal so that the Company can determine if the item is equivalent.

ATTACHMENT A -
Prompt Gamma-ray Neutron Activation Analysis Testing Setup & Tooling
(Page 1 of 4)

A.1 Prompt Gamma-ray Neutron Activation Analysis Can Testing

Prompt Gamma-ray Neutron Activation Analysis (PGNAA) of boron performs one of the acceptances of the ES-3100 277-4 casting. Specifically, ^{10}B gives rise to a 478-keV gamma-ray produced by the recoil of the lithium nucleus from the neutrons captured in ^{10}B. The gamma-ray is Doppler broadened by 10–15 keV. The PGNAA shall be performed upon a companion sample can cast made during the drum casting in accordance with JS-YMN3-801580-A005 and Body Weldment (Figure 1), Neutron Absorber Form (Figure 5), Heavy Can Spacer Assembly (Figure 6 or 9), and the cast companion samples in the same 10-oz. double friction metal can on (Figures 7 and 8), or 10-oz. crimp style metal cans as shown in (Figures 10 and 11). PGNAA is a relative measurement therefore daily baselines are required to define the acceptance values.

Canberra Industries to perform the PGNAA testing.

Canberra Industries, Inc.
Linda C. Ostrowski
1133-C Oak Ridge Turnpike Suite 260
Oak Ridge, TN 37830-6442
865-241-3963 fax 865-241-3965

A.2 PGNAA Quality Assurances

The equipment and software used in the PGNAA shall be certified to a national standard.

A.3 PGNAA Measurements Setup

A PGNAA measurement setup number shall be required for each unique setup recording the pertinent data of the setup on Form AA. A new setup is required from previous prototypical work. Several setups may be tried to determine the most efficient testing setup. These changes shall be documented using Form AA. Once the setup is defined on Form AA reference the setup number each time it is used. Measure the PGNAA acceptance standards using the defined setup to verify the setup distances are repeatable within ±0.13-in.

A.3.1 Net Count Rate Measurements

Time shall be consistently applied throughout all of the PGNAA testing. For the prototype system setup, a time of at least 15 minutes (900 seconds) for each spectrum measurement was found to be satisfactory. A net count rate (NCR) in counts per second shall be used throughout with a set target standard time limit of around 900 seconds. Record both the count and time in seconds for that count on Form AA and calculate the count rate to three decimal places (i.e., 34.245 counts/sec).

A.3.1.a Net Count Rate Time Determination

The time of the measurement shall be determined by performing the Tooling Setup on Form AA at different times like 300, 600, 900, 1800, and 72000 seconds. Determine the accuracy effect of the total counting time on the counting statistics, based upon at least a 72000 seconds (20 hour) count. The testing time shall be re-evaluated when a significant change in the source system occurs.

A.3.2 Neutron Source

A spontaneous fission neutron source similar to the 1.8-μg ^{252}Cf prototype shall be used to perform the tests. This source was rated at 4.4×10^6 neutrons/sec on November 15, 2004. The neutron source is sealed in a 32.5-mm-long, 9.4-mm-diameter stainless steel cylinder and placed in a collimator.

ATTACHMENT A
(Page 2 of 4)

A.3.3 Collimator and Neutron Source Setup

A collimator similar to the prototype collimator shall be used to hold the source. The prototype collimator was a 3-in. cube of high-density polyethylene covered on five sides with 2 mm of cadmium as a neutron shield with at least 0.5-in. of lead on six sides as a gamma shield. The center of the sixth side of the polyethylene cube has a 9.5-mm hole into which the source was pressed. The sixth side is covered with cadmium except for a 1-in. square in the center. A 1-in. diameter hole in the cadmium at the source location shall be provided in the collimator to generate a better shaped neutron source for the sample can tests. The location of the collimator and source shall be defined in a fixture and shall be inspected to be repeatable to within ±0.13-in. to locate the collimator, can, detector, and other materials, e.g., polyethylene.

Record the setup and the results in the net detector count rate on Form AA. Record the setup source distance (SD) ±0.13-in. from the sample can lid. Move the filled sample can further away from the source, and repeat the process, increasing the distance in increments to identify the setup distance that maximizes the NCR for that source arrangement. Record the setup information on Form AA.

A.3.4 Detector

A detector system similar to the prototype shall be used. The prototype was a Canberra Model BE3825 Broad Energy Germanium (BEGe) detector, which was a gamma-ray detector, in a 2-in. thick lead shield with a Canberra Model 7935SL-7 cryostat and Canberra Model 2002CSL preamplifier to capture the gamma spectrum for the PGNAA measurements. This detector has a side lead shield but no shielding in the front to collimate the field-of-view. An Inspector 2000 along with the Genie2K gamma-ray analysis software package from Canberra was used for distinguishing the ^{10}B peak from the rest of the gamma-ray spectrum. It is recommended that a fixture be made to locate the collimator, can, and detector. Document the method used to determine the Compton boundary end points.

A.3.5 Detector Net Count Rate Determination

Use software equivalent to the Genie2K gamma-ray analysis software package from Canberra for performing the gamma-ray spectrum collection and analysis. The peak fitting routine in Genie2K does not expect a peak as broad as 10–15 keV; therefore, a region-of-interest (ROI) was set around the broad boron neutron activation peak of 478 keV. The data gathered has three components. The gross count is the total count of the gamma-rays detected with an energy that falls within the ROI. The Compton background is the portion of the gross count that is caused by scattered gamma-rays. The NCR is the portion of the total count that is from the boron in a period of time. The NCR is the difference between the gross and the Compton counts.

A.3.6 Detector Location Setup

The setup distance of the prototype detector setup was as close as possible using about 1-in. thick lead as a gamma shield to keep the detector noise signal low. This thickness was applied during the PGNAA documented in Ltr. No.: COR-NDA-05-015; Canberra Oak Ridge, LLC November 3, 2005, *Results of Prompt Gamma-ray Neutron Activation Analysis On 20 Slip Fit Spacer Cans*. Figure A.1 shows the direction this development work was heading. Document and verify that the detector setup distance (DD) from the sample can generates a maximum NCR by adjusting the detector setup distance and repeating this test. It is recommended that a fixture be made to locate the collimator, can, and detector.

ATTACHMENT A
(Page 3 of 4)

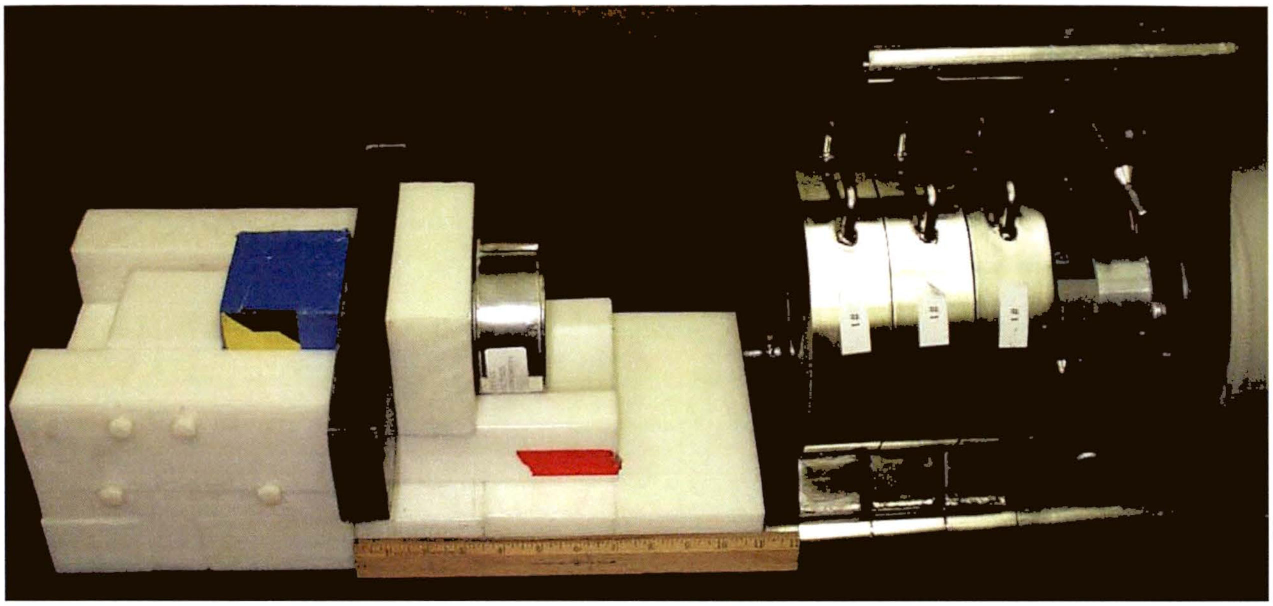


Figure A.1 Preliminary Tooling Generated for PGNAA

A.3.7 Detector Operation Setup

Set the detector setup distance (DD) ±0.13-in. and the setup source distance (SD) ±0.13-in. from the filled sample can. Record the set detector setup distance, setup source distance, 277-4 sample serial number, NCR value, and the day and time of the measurement in the setup form. Repeat this final test measurement in 30 minutes to verify the stability of the detector and this shall become the setup standard test measurement on Form AA. The repeatable measurement tolerances shall be part of the testing fixture certification inspection.

A.3.8 Net Count Rate Baseline Measurements

Once the setup is completed and the fixture dimensions are certified, Form AB shall be used to record the NCR for the twenty acceptance standards using the 10-oz. double friction metal cans or 10 oz. crimp style cans. The baseline acceptance 277-4 NCR shall be set daily using five of the twenty acceptance standards using the 10-oz. double friction metal cans or 10 oz. crimp style cans and recorded on Form AC. The twenty acceptance standards cans shall be inspected with a Company representative as a witness.

Select five PGNAA acceptance standards from Form AB as the Daily Standard Setup that generate approximately the same average and standard deviation as on Form AB. The baseline acceptance 277-4 NCR shall be set daily using five of the twenty acceptance standards using the 10-oz. double friction metal cans or 10 oz. crimp style cans and recorded on Form AC. Verify the Daily Standard cans selection with the Company. The Body Weldment (Drum), Neutron Absorber Form (From), and Heavy Can Spacer Assembly (Lot) acceptance criteria for the ^{10}B interaction is based upon this test. The Minimum acceptable standard NCR shall be set daily using the following formula.

Minimum Acceptable NCR = Can Five NCR Average − 3 × Standard Deviation Can Five NCR

ATTACHMENT A
(Page 4 of 4)

A.4 Net Count Rate Acceptance Measurements
The NCR acceptance measurement shall be made following the Daily Standard Setup using Form AC and calculating a Pass Rate. Record the PGNAA setup number, day and start time of the measurement, the associated Body Weldment, Neutron Absorber Form, Heavy Can Spacer Assembly Lot's serial number, companion sample can serial number, actual net count, acceptable net count, and testing results on the inspection form. For the testing results, if the actual NCR is equal or above the Pass Rate, then record a PASS; if less than, enter FAIL in the test Form AD. It is acceptable to group the test results for several sample cans on one form following one testing setup.

Once a 277-4 sample can NCR failure has occurred verify that the setup has not shifted by rerunning the Daily Standard Setup using Form AC and calculate a new Pass Rate. If the Pass Rate has changed more then 1% than perform a new detector operation setup and NCR baseline measurements and verify the test failure rate by retesting the failed can. If the companion sample can receives two failures in a row, the associated parts shall be rejected from service, the Company Subcontract Administrator notified, and the testing continued.

A.5 Documentation of the Acceptance or Rejection Measurements
Documentation of the acceptance or rejection NCR measurements shall be made with the Forms AA through AD plus a detailed description of the active NCR measurement hardware and software that was used.

A.6 Results

A.6.1 Equipment and Software Quality Assurances
The national standard used in the PGNAA (see Section A.2) shall be provided as Certified Data.

A.6.2 Certified Tooling Setup and Repeatable Dimensions
The final tooling setup shall be manufactured and certified that the placement of the source, detector, sample can, and tooling materials are dimensional stable and repeatable to ±0.13-in.

A.6.3 Measurement Time and Repeatable Accuracy
Define the repeatable accuracy for the Nate Rate Count time selection for the production certification inspections. The Nate Rate Count time justification (see Section A.3.1.a) shall be submitted as Approval Data.

A.6.4 Measurement Software and Methodology
For the final setup the measurement software and methodology method used to generate the net counts (see Section A.3.4) shall be documented and provided as Certified Data.

A.6.5 Forms AA through AD
Forms AA, AB, and AC shall be submitted as Approval Data.

After the process is approved, filled-in Forms AC and AD shall be provided as Certified Data to the Company and the casting company.

A.6.6 Can Disposition
After PGNAA testing is completed on a lot of companion sample can lot, the cans shall be returned to the Company. The PGNAA Acceptance Standards cans shall be stored for the life of the subcontract.

FORM A 277-4 Dry Blend Batch Control **Rev G** **Page 1 of 1**

Casting Company Name	Certificate of Conformance of the 277-0 dry mix		
Blended Dry Batch Control Number [a]	Record the expiration date of the 277-0 dry mix [b]		
Certificate of Conformance of the B_4C dry mix	277-0 Heat Resistant Shielding Drum ID Number		
Planning	277-4 Weight	Units	Operator
Batch Size		lb	
Operation	Measurement	Units	Operator
277-0 Weight (Target = 277-4 Weight x 93.6 wt%)		lb	
B_4C Weight (Target = 277-4 Weight x 6.4 wt%)		lb	
Dry Blending Time		min.	
Comments			

[a] A 10-digit Blended Dry Batch Control Number shall be used to define the date and the time of mixing the casting batch using the format with a 24-hour clock (i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.)

[b] Record the expiration date of the Blended Dry Batch and confirm that it is still acceptable to be cast following this specification.

FORM B 277-4 Wet Mix Control (Overcast or Special Batch) Rev G Page 1 of 1

Casting Company Name		Blended Dry Batch Control Number		
Wet Mix Control Number (WMCN) [a]		Record the expiration date of the Dry Blend Batch		
Water Temperature °F	Air Temperature °F	Measurement	Units	Operator
277-4 Weight			lb	
Water Weight (Target = 277-4 Weight × 27±1 wt%)			lb	
Mix Time			min.	
Mix Finish Time			min.	
Comments				

[a] A 10-digit Wet Mix Control Number (WMCN) shall be used to define the date and the time of mixing the casting batch using the format with a 24-hour clock (i.e. 1021041515 is used for October 21, 2004 at 3:15 pm.)

Casting Company Name	Body Weldment Casting Control # [a]
Part Serial Number	Drawing Number M2E801580A002

Measured Weights ±0.5 lb	Casting Information			Comments	Operator
	Weight	Date			
Clean and Empty					
Filled with Water [b]					
Water Information	Water Weight ±0.5 lb	Water Temp. [b]		Comments	Operator
Water Conditions [b]	lb	°F			
Vibration Settings [c]	lbf	VPM			
Wet Mix Control	Blended Dry Batch Control No.		Dry Blend Batch Expiration Date		
(Target Water = 277-4 Weight × 27±1 wt%)	277-4 Weight	lb	Water Weight	lb	
	Air Temperature	°F	Water Temperature	°F	
	Mix Time		Mix Finish Time		
Companion Samples [d]	−1		−2		
	Time	Date		Comments	Operator
Vibration Start					
Vibration Stop					
Overcast WMCN					
After Casting	lb	Date			
After Cured and Clean	lb	Date			

Measurements ⟨I⟩	Height [e] (in)	Pass or Fail Height	Cured Weight (lb)	Pass or Fail Cured Weight [e]	Cured Density [f] (lb/ft^3)	Pass or Fail 100–120 (lb/ft^3)
Body Weldment						

[a] A 10-digit Body Weldment Casting Control Number shall be used to define the date and the time of mixing the casting batch using the format with a 24-hour clock (i.e., 1021041515 is used for October 21, 2004 at 3:15 pm).

[b] Record the water weight and water temperature within 10 minutes from completion of the weighing process.

[c] Recommended vibration settings are at 450 VPM and three times the total vibrated weight. The total vibrated weight is the finish cast part and fixtures weight, for a setting of approximately 800 pound-force.

[d] Use Form F, for ES-3100 Companion Sample Casting Control and Tests to control the companion sample castings.

[e] The acceptable cured height measurement is less than 0.25 inches. The Body Weldment cured casting weight shall be between 45.3 and 57.8 lbs.

[f] Use the above weights to calculate the density as shown below. $Density = \left(\frac{Cured - Empty}{WithWater - Empty} \right) \times 62.3 \text{ lb/ft}^3$

FORM D **ES-3100 Neutron Absorber Form Casting Control** **Rev G** **Page 1 of 1**

Casting Company Name				Body Weldment Casting Control #[a]		
Part Serial Number				Drawing Number M2E801580A034		
Measured Weights ±0.5 lb	Casting Information			Comments		Operator
	Weight		Date			
Clean and Empty						
Filled with Water[b]						
Water Information	Water Weight ±0.5 lb		Water Temp.[b]	Comments		Operator
Water Conditions[b]	lb		°F			
Vibration Settings[c]	lbf		VPM			
Wet Mix Control	Blended Dry Batch Control No.			Dry Blend Batch Expiration Date		
(Target Water = 277-4 Weight × 27±1 wt%)	277-4 Weight		lb	Water Weight	lb	
	Air Temperature		°F	Water Temperature	°F	
	Mix Time			Mix Finish Time		
Companion Samples[d]	−1			−2		
	Time		Date	Comments		Operator
Vibration Start						
Vibration Stop						
Overcast WMCN						
After Casting	lb		Date			
After Cured and Clean	lb		Date			
Measurements (I)	Height[e] (in)	Pass or Fail Height	Cured Weight (lb)	Pass or Fail Cured Weight[e]	Cured Density[f] (lb/ft^3)	Pass or Fail 100–120 (lb/ft^3)
Neutron Absorber Form						

[a] A 10-digit Body Weldment Casting Control Number shall be used to define the date and the time of mixing the casting batch using the format with a 24-hour clock (i.e., 1021041515 is used for October 21, 2004 at 3:15 pm).

[b] Record the water weight and water temperature within 10 minutes from completion of the weighing process.

[c] Recommended vibration settings are at 450 VPM and three times the total vibrated weight. The total vibrated weight is the finish cast part and fixtures weight, for a setting of approximately 800 pound-force.

[d] Use Form F, for ES-3100 Companion Sample Casting Control and Tests to control the companion sample castings.

[e] The acceptable cured height measurement is less than 0.25 inches. The Neutron Absorber Form cured casting weight shall be between 45.3 and 57.8 lbs.

[f] Use the above weights to calculate the density as shown below. $Density = \left(\frac{Cured - Empty}{WithWater - Empty}\right) \times 62.3\ \text{lb/ft}^3$

FORM E ES-3100 Heavy Can Spacer Assembly Lot Casting Control Rev G

Casting Company Name	Can Lot Serial Number [a]	Drawing Number M2E801580A026 or M2E801580A043
Average 10 Can and Lid **Empty** Weight	Temperature of Water Weight (°F)	Average 10 Can and Lid **Water** Weight

Wet Mix Control	Blended Dry Batch Control No.		Dry Blend Batch Expiration Date	
(Target Water = 277-4 Weight × 27±1 wt%)	277-4 Weight	lb	Water Weight	lb
	Air Temperature	°F	Water Temperature	°F
	Mix Time		Mix Finish Time	
Wet Mix Control Number (Overcast), if required				

Can Serial #	After Casting Weight (lb)	Cured Weight (lb)	Pass or Fail Cured Weight [b]	Cured Height (in)	Pass or Fail Cured Height [b]	Cured Density (lb/ft^3)	Pass or Fail Cured Density [c]
Companion Samples [d]		–1			–2		

Operator	Comments

[a] A 10-digit Can Lot Serial Number shall be used to define the date and the time of setup using the format with a 24-hour clock (i.e., 1021041515 is used for October 21, 2004 at 3:15 pm).

[b] Heavy Can Spacer Assembly acceptable weight is 1.16 to 1.56 lbs and height 1.37±0.06 as shown in Figure 8.

[c] Use this equation for the; $Density = \left(\dfrac{Cured - Empty}{WithWater - Empty} \right) \times 62.3$ lb/ft^3 . Acceptable 100 to 120(lb/ft^3).

[d] Use Form F, for ES-3100 Companion Sample Casting Control and Tests for Heavy Can Spacer Assembly companion samples..

Casting Company Name	Ave. 10 Can and Lid Empty Weight [a]		Ave. 10 Can and Lid Water Wgt. [a]		Temp. of Water Weight (°F)		Drawing Number M2E801580A026 or M2E801580A043	
Serial Numbers		Can Measurement Weights ±0.01 (lb)			For Record Only	Loss On Drying (Odd Serial Numbered Cans)		PGNAA (Even Serial Numbered Cans)	
Part # or Can Lot#	Companion Sample Can [a]	After Casting Weight	Cured Weight	LOD Weight	Cured Density (lb/ft^3)	Calculated LOD%	Pass Or Fail per Sec. 3.3.9.3	PGNAA (PMN) [c]	Pass Or Fail
Complied by					Comments				

a For the same lot of sample cans, it is acceptable to use an average weight of ten can bodies and ten can lids.

b Recommended vibration settings are at 450 VPM and three times the total vibrated weight. The total vibrated weight is the finish cast part and fixtures weight, for a setting of approximately 5 pound-force.

c Record the PGNAA Measurement Number (PMN) from Form AD for each Companion Sample Can tested.

$$Density = \left(\frac{Cured - Empty}{WithWater - Empty}\right) \times 62.3 \text{ lb/ft}^3$$

$$\text{LOD\%} = \left[1 - \frac{(LODWeight - Empty - 0.024)}{(Cured \,\&\, Clean - Empty)}\right] \times 100\%$$

EXEMPT FROM IO-155 (8-02)

FORM AA PGNAA Tooling Setup Control **Rev G** **Page 1 of 1**

Inspecting Company Name	Casting Company Name
PGNAA Tooling Setup Number [a]	277-4 Baseline Can Serial Number

Setup Distance [b]			Counts			Count Time (sec)	Net Count Rate (Net Counts/Sec)
#	Collimator	Detector	Gross	Compton	Net		

Describe the source and the amount of cadmium, lead and polyethylene surrounding the source for each Setup Number.

Describe the Software used and method to generate the net counts.

Operator

[a] A 10-digit PGNAA Tooling Setup Number shall be used to define the date and the time of setup using the format with a 24-hour clock (i.e., 1021041515 is used for October 21, 2004 at 3:15 pm). A –# will define the setup used for testing.

[b] The 10-oz. double friction metal lid or crimp style can lid shall face the source. The setup distances shall be measured from the can lid to the collimator face and from the can lid to the detector front face and must be documented to be repeatable to ±0.13". Also define all thickness of lead and polyethylene surrounding the source measurement to ±0.13".

[c] Use one 277-4 cast 10-oz. double friction metal can per drawing M2E801580A026 or 10-oz. crimp style can per drawing M2E801580A043 as the PGNAA reference to verify the Tooling Setup.

Inspecting Company Name	Casting Company Name
PGNAA Standard Setup [a]	PGNAA Tooling Setup Number (with -#)

277-4 Standard Can Serial Numbers		Counts			Count Time (sec)	Net Count Rate (Net Counts/Sec)
		Gross	Compton	Net		
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Average Values						

Comments
Operator

a A 10-digit PGNAA Standard Setup Number shall be used to define the date and the time of setup using the format with a 24-hour clock (i.e., 1021041515 is used for October 21, 2004 at 3:15 pm).

b The 10-oz. double friction metal can lid or 10-oz. crimp style can lid shall face the source following the PGNAA Standard Setup.

Inspecting Company Name	Casting Company Name
PGNAA Daily Standard Setup [a]	PGNAA Tooling Setup Number (with –#)

277-4 Standard Can Serial Numbers [b]		Counts			Count Time (sec)	Net Count Rate (Net Counts/Sec)
		Gross	Compton	Net		
1						
2						
3						
4						
5						
Average Values						
Standard Deviation						
3 × Standard Deviation						
(Pass Rate) Minimum Acceptable Net Count Rate = Average − 3 × Standard Deviation =						

Comments

Operator

[a] A 10-digit PGNAA Daily Standard Setup (DSS) shall be used to define the date and the time of setup using the format with a 24-hour clock (i.e., 1021041515 is used for October 21, 2004 at 3:15 pm).

[b] Select five PGNAA acceptance standards from Form AB as the Daily Standard Setup that generate approximately the same average and standard deviation as on Form AB.

Inspecting Company Name			Casting Company Name				
PGNAA Measurement Number (PMN) [a]			PGNAA Daily Standard Setup Num.		PGNAA Pass Rate (Net Cnt/Sec)		
Even Serial Numbers [b]		Counts (Cnt)			Count Time (sec)	Net Cnt Rate (NetCnt/Sec)	Pass or Fail
Drum/Neutron Absorber Form/Lot#	Sample #	Gross	Compton	Net			
Comments							
Operator							

[a] A 10-digit PGNAA Measurement Number (PMN) shall be used to define the date and the time of setup using the format with a 24-hour clock (i.e., 1021041515 is used for October 21, 2004 at 3:15 pm).

[b] Record the Body Weldment, Neutron Absorber Form, or Heavy Can Spacer Assembly can lot with the Companion Sample Number.

EQUIPMENT SPECIFICATION	**Specification Number** JS-YMN3-801580-A005-1	**Revision** G
	Issue Date 2/17/2005	**Revision Date** 08/31/2009
		Page 1 of 1

MANUFACTURER'S DATA REQUIREMENTS

Item No.	Data Submittal—Purpose and Description	Specification or Reference	Number of Copies	Form[a]	
	OFFER APPRAISAL DATA - Subcontractor				
	The Offerer shall submit the following data with the offer.				
1	Subcontractor's quality assurance program manual	4.1	1	E	

[a]Indicate the following:

A—Full-size prints
B—Full-size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Subcontractor's standard form
F—Other (Specify) Specimen

EXEMPT FROM IO-155 (8-02)

# EQUIPMENT SPECIFICATION	Specification Number JS-YMN3-801580-A005-2		Revision G
	Issue Date 2/17/2005	Revision Date 08/31/2009	
		Page 1 of 1	

MANUFACTURER'S DATA REQUIREMENTS

Item No.	Data Submittal—Purpose and Description	Specification or Reference	Number of Copies	Form[a]	
	APPROVAL DATA - Subcontractor				
	The Subcontractor shall provide the following data prior to the start of production casting.				
1	Process equipment approval	3.1	1	E	
2	Scale Certifications	3.2.1	1	E	
3	Request for Company approved equal	3.2.2, 3.2.6, 3.2.7, 6.4	1	E	
4	MSDS for cleaning products	3.4.1	1	E	
5	Procedures	4.2.4	1	E	

[a]Indicate the following:

A—Full-size prints
B—Full-size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Subcontractor's standard form
F—Other (Specify)
S—Sample of Workmanship

EQUIPMENT SPECIFICATION	Specification Number JS-YMN3-801580-A005-3	Revision G
	Issue Date 2/17/2005	Revision Date 08/31/2009
		Page 1 of 1

MANUFACTURER'S DATA REQUIREMENTS

Item No.	Data Submittal—Purpose and Description	Specification or Reference	Number of Copies	Form[a]	
	CERTIFIED DATA - Subcontractor				
	Item 1 shall be provided prior to the start of production casting.				
1	Approved procedures	4.2.4	1	E	
	Item 2 shall be provided with each ES-3100 unit.				
2	ES–3100 Documentation Package	4.2.1	1	E	

[a]Indicate the following:

A—Full-size prints
B—Full-size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Subcontractor's standard form
F—Other (Specify)
S—Sample of Workmanship

EQUIPMENT SPECIFICATION	Specification Number JS-YMN3-801580-A005-4	Revision G
	Issue Date 2/17/2005	Revision Date 08/31/2009
		Page 1 of 1

MANUFACTURER'S DATA REQUIREMENTS

Item No.	Data Submittal—Purpose and Description	Specification or Reference	Number of Copies	Form[a]	
	OFFER APPRAISAL DATA – PGNAA Subcontractor				
	The Offerer shall submit the following data with the offer.				
1	Subcontractor's quality assurance program manual	4.1	1	E	

[a]Indicate the following:

A—Full-size prints
B—Full-size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Subcontractor's standard form
F—Other (Specify) Specimen

EQUIPMENT SPECIFICATION

Specification Number	Revision
JS-YMN3-801580-A005-5	G
Issue Date 2/17/2005	**Revision Date** 08/31/2009
	Page 1 of 1

MANUFACTURER'S DATA REQUIREMENTS

Item No.	Data Submittal—Purpose and Description	Specification or Reference	Number of Copies	Form[a]	
	APPROVAL DATA – PGNAA Subcontractor				
	The Subcontractor shall provide the following data prior to the start of production inspection.				
1	Source, detector, and software must be certified to a national standard.	A.6.1	1	E	
2	Final tooling setup shall be manufactured - Results of final tooling setup dimensional inspection shall be provided showing repeatability to +/- 0.13" - As built drawing of final tooling setup that was manufactured shall be provided showing setup distances and materials of construction	A.6.2	1	E	
3	Results of Net Count Rate Measurements performed on manufactured final tooling setup per section A.3.1.a of specification, based upon at least a 20 hour PGNAA measurement count and time justification.	A.6.3	1	E	
4	Software used to determine net count rate and methodology used to determine net count rate shall be identified and documented	A.6.4	1	E	
5	Completed Forms AA	A.6.5	1	E	
6	Completed Forms AB, and AC	A.6.5	1	E	

[a]Indicate the following:

A—Full-size prints
B—Full-size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Subcontractor's standard form
F—Other (Specify)
S—Sample of Workmanship

EXEMPT FROM IO-155 (8-02)

EQUIPMENT SPECIFICATION	Specification Number JS-YMN3-801580-A005-6		Revision G
	Issue Date 2/17/2005	Revision Date 08/31/2009	
		Page 1 of 1	

MANUFACTURER'S DATA REQUIREMENTS

Item No.	Data Submittal—Purpose and Description	Specification or Reference	Number of Copies	Form[a]	
	CERTIFIED DATA - PGNAA Subcontractor				
	Item 1 and 2 shall be provided prior to the start of production PGNAA inspection.				
1	PGNAA national standard	A.6.1	1	E	
2	PGNAA measurement software and methodology	A.6.4	1	E	
	Item 3 shall be provided after each companion can lot is inspected.				
3	Forms AC and AD	A.6.5	2 (1 copy going to Casting Company)	E	

[a]Indicate the following:

A—Full-size prints
B—Full-size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Subcontractor's standard form
F—Other (Specify)
S—Sample of Workmanship

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Appendix 1.4.6

PACKAGE CATEGORY DETERMINATION

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Appendix 1.4.6

PACKAGE CATEGORY DETERMINATION

The ES-3100 with HEU content package has a maximum activity of 0.3243 TBq (8.76 Ci) at 10 y after initial fabrication; the maximum number of A_2s carried is 294.00 at 70 y after initial fabrication (Table 4.4). Based on the guidance from Regulatory Guide 7.11, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)*, this package is classified in Table 1.1 of NUREG-1609 as a Category II package.

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Appendix 1.4.7

HEU OXIDE MATERIAL SPECIFICATION AS PROVIDED BY Y-12 HIGHLY ENRICHED URANIUM DISPOSITION PROGRAM OFFICE

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Uranium oxide material limits

Specified item	Units	Limit	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Chemical form [a]			UO_x	UO_x	UO_x	U_3O_8	UO_x	UO_x	U_3O_8
Physical form			Dense, loose powder, may contain lumps						
Uranium content									
Uranium purity	gU/gSmpl	≥	0.830	0.200	0.830	0.830	0.200	0.200	0.845
U-235	g/gU	≤	97.7%	97.7%	97.7%	97.7%	97.7%	97.7%	93.2%
U-238	g/gU	≤	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
U-232	μg/gU	≤	0.040	0.040	0.040	0.040	0.040	0.040	0.040
U-233	μg/gU	≤	50	50	50	50	50	200	50
U-234	g/gU	≤	1.4%	1.4%	1.4%	1.4%	1.4%	2.0%	1.4%
U-236	g/gU	≤	1.0%	1.0%	1.0%	1.0%	1.0%	40.0%	1.0%
Transuranics (Np, Pu, Am, etc.)									
Concentration limit	μg/gU	≤	0.2	0.2	40.0	0.2	0.5	0.5	0.2
Activity limit	Bq/gU	≤	50	50	600,000	3,000	5,000	1,000	3,000
Unspecified beta emitters									
Activity limit	Bq/gU	≤	200	200	200	200	1,000,000[c]	10,000	200
Moisture	g/gSmpl	≤	6%	6%	6%	6%	6%	6%	6%
Carbon	μg/gU	≤	600	1,000	600	600	1,000	1,000	[d]
EBC [b]	μgEBC/gU	≤	4	10,000	4	4	10,000	10,000	4

[a] UO_x may be UO_2 or UO_3.

[b] EBC = equivalent boron content, as defined in ASTM standard C1233-98.

[c] The oxide contents of the ES-3100 were characterized with the beta emitters as an "unspecified" feature in order to establish one group limit for these nuclides rather than limits on each (of many) individual nuclides. The beta emitters are either daughter products from the decay of uranium isotopes, or activation and fission products from reprocessed material. The beta nuclides most often seen in this material are Tc-99, Sr-90, and Cs-137. Table 1.4.7-1 gives a complete list of the beta-emitting nuclides that have been observed in various oxides intended for shipment in the ES-3100. The maximum mass concentration allowable by the 1,000,000 Bq/gU activity limit is for Group 5 oxides.

[d] In this case, the total carbon allowed per ES-3100 container is 921 g.

Table 1.4.7-1

Radionuclide Reference Data - Beta Nuclides

Isotope				Specific Activity Calculation			Rad	Mass Conc at 10^6 Bq/gU
Element	Sym	At #	Iso	Mass	T½, Yr	SA, Bq/g	Type	µg/gU
Cobalt	Co	27	58	57.935755	0.194	1.177E+15	ß+	8.500E-04
Cobalt	Co	27	60	59.933819	5.271	4.187E+13	ß-	0.024
Strontium	Sr	38	90	89.907738	29.100	5.056E+12	ß-	0.198
Zirconium	Zr	40	95	94.908042	0.175	7.951E+14	ß-	0.001
Niobium	Nb	41	95	94.906835	0.096	1.456E+15	ß-	6.870E-04
Technetium	Tc	43	99	98.906254	2.130E+05	6.279E+08	ß-	1,592.656
Ruthenium	Ru	44	103	102.906323	0.108	1.196E+15	ß-	8.365E-04
Ruthenium	Ru	44	106	105.907321	1.020	1.224E+14	ß-	0.008
Antimony	Sb	51	125	124.905252	2.758	3.840E+13	ß-	0.026
Cesium	Cs	55	134	133.906696	2.065	4.784E+13	ß-	0.021
Cesium	Cs	55	137	136.907073	30.300	3.189E+12	ß-	0.314
Cerium	Ce	58	141	140.908271	0.089	1.055E+15	ß-	9.479E-04
Cerium	Ce	58	144	143.913643	0.779	1.180E+14	ß-	0.008
Europium	Eu	63	155	154.922889	4.710	1.813E+13	ß-	0.055
Thallium	Tl	81	208	207.981988	5.805E-06	1.096E+19	ß-	9.127E-08
Thallium	Tl	81	209	208.985334	4.183E-06	1.513E+19	ß-	6.609E-08
Lead	Pb	82	209	208.981065	3.708E-04	1.707E+17	ß-	5.858E-06
Lead	Pb	82	210	209.984163	22.600	2.787E+12	ß-	0.359
Lead	Pb	82	211	210.988735	6.864E-05	9.134E+17	ß-	1.095E-06
Lead	Pb	82	212	211.991871	0.001	5.141E+16	ß-	1.945E-05
Lead	Pb	82	214	213.999798	5.134E-05	1.204E+18	ß-	8.305E-07
Bismuth	Bi	83	210	209.984095	0.014	4.592E+15	ß-	2.178E-04
Bismuth	Bi	83	211	210.987255	4.069E-06	1.541E+19	ß-,a	6.490E-08
Bismuth	Bi	83	212	211.991255	1.151E-04	5.421E+17	ß-,a	1.845E-06
Bismuth	Bi	83	213	212.994359	8.670E-05	7.163E+17	ß-,a	1.396E-06
Bismuth	Bi	83	214	213.998691	3.784E-05	1.634E+18	ß-	6.121E-07
Thorium	Th	90	231	231.036298	0.003	1.967E+16	ß-	5.083E-05
Thorium	Th	90	234	234.043593	0.066	8.565E+14	ß-	0.001
Protactinium	Pa	91	234m	234.043303	2.225E-06	2.541E+19	ß-	3.936E-08

Appendix 1.4.8

DETAILED ENGINEERING DRAWINGS

Drawing No.	Rev.	Title
M2E801580A001	C	Drum Assembly
M2E801580A002	B	Body Weldment
M2E801580A003	B	Inner Liner Weldment (2 sheets)
M2E801580A004	B	Double Open Head Reinforced Drum
M2E801580A005	E	Misc. Details
M2E801580A006	B	Drum Lid Weldment
M2E801580A007	B	18.25" Diameter Drum Lid
M2E801580A008	B	Top Plug Weldment
M2E801580A009	D	Pad Details
M2E801580A010	D	Data Plate Details
M2E801580A011	C	Containment Vessel Assembly
M2E801580A012	C	Containment Vessel Body Assembly (2 sheets)
M2E801580A013	D	Containment Vessel O-ring Details
M2E801580A014	B	Containment Vessel Lid Assembly
M2E801580A015	C	Containment Vessel Sealing Lid
M2E801580A016	B	Containment Vessel Closure Nut
M2E801580A024	C	Containment Vessel Vibration Absorbing Silicone 4.25" Can Pad
M2E801580A031	D	Main Assembly
M2E801580A043	B	Heavy Can Spacer Assembly (SST)

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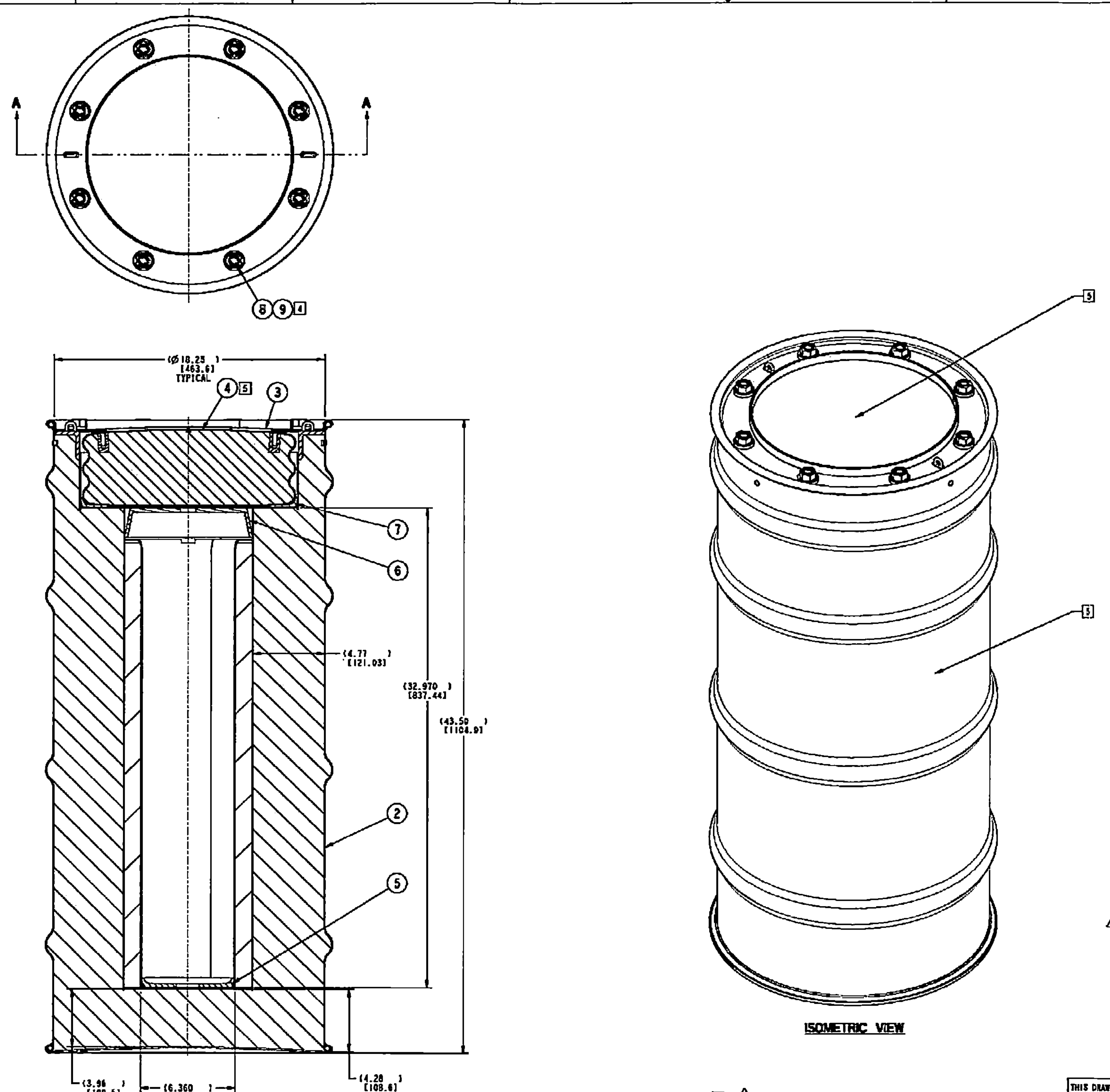

SECTION A-A

ISOMETRIC VIEW

-1 DRUM ASSEMBLY 8 C
SCALE 3/8

NOTES

1 INTERPRET DRAWING PER ENGINEERING DRAFTING STANDARD ES-3.1.

2 INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.

3 DIMENSIONS ARE IN INCHES [mm]. THE [mm] ARE ONLY FOR REFERENCE.

[4] TORQUE HEX NUTS TO 30±5 ft-lb AT ASSEMBLY.

[5] IN APPROXIMATE LOCATIONS SHOWN, USING BLACK ENAMEL PAINT (F/N 10), PAINT DRAWING NUMBER, REVISION LETTER AND FIVE DIGIT SERIAL NUMBER IN 1.00" HIGH CHARACTERS ON F/N 2, F/N 3, AND F/N 4.

6. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002.

7 FOR REF. ONLY APPROXIMATE WEIGHT: 289.2 LBS [131.2 Kg].

(C) [8] REFERENCE CONFIGURATION CONTROL EQUIPMENT DATA SHEET DS-PKG-801580-A001.

[5]		AR		PAINT, BLACK ENAMEL		FED SPEC 595B-17038	10
[4]		8	M2E801580A005-3	DRUM HEX NUT			9
		8	M2E801580A005-4	DRUM WASHER			8
		1	M2E801580A009-3	PLUG PAD			7
		1	M2E801580A009-2	CV FLANGE PAD			6
		1	M2E801580A009-1	CV BOTTOM PAD			5
		1	M2E801580A008-1	TOP PLUG WELDMENT			4
		1	M2E801580A006-1	DRUM LID WELDMENT			3
		1	M2E801580A002-1	BODY WELDMENT			2
(C) [8]	AR	X	-1	DRUM ASSEMBLY			1
	M2E801580 A001	-1	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
			← QTY REQ'D NEXT ASSEMBLY	PARTS LIST			

REV	DESCRIPTION	DRN	CHKD	ME	DE	QA	DATE	PE	DATE	PM	DATE
C	ADDED REFERENCE NOTE 8.	MLE	JRJ	MLE	DEW	WIN	[illegible]	LR	[illegible]	JGA	[illegible]
B	GEN REV: TORQUE IN NOTE 4 WAS 10 +/- 1 REVISED NOTES 4 & 7: F/N 8 & 9 WAS VENDOR SUPPLIED MOVED NUT & WASHER DETAILS TO A005.	JRP	SMK	GAB	RDA	DPS	[illegible]	GAB	[illegible]	JGA	[illegible]
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW	[illegible]	MRF	[illegible]	DSM	[illegible]

REVISION OR ISSUE PURPOSE — REVISION APPROVALS

P THIS DRAWING PRODUCED ON PRO/ENGINEER

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY ANALYSIS ENGINEERING APPROVAL.

REVISION	DATE	SAE APPROVAL
C	09/10/09	J.F. DECLUE

This document has been reviewed by a Y-12 DC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: R.D. AIGNER Date: 09/10/09

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED

FRACTIONS, XX DECIMALS, XXX DECIMALS, ANGLES, BREAK SHARP EDGES .04 MAX, FINISH

DRN	JR JACKSON	[illegible]
CHKR	JS LOWERY	[illegible]
DE	GA BYINGTON	[illegible]
DWB	JL HECK	[illegible]
QA	JC WALLS	[illegible]
PE	MR FELDMAN	[illegible]
PM	DB MILLER	[illegible]

DRAWING APPROVALS — DATE

Y-12 National Security Complex managed by B&W Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800, Oak Ridge, Tennessee

PROJECT NAME: ES-3100 SHIPPING PACKAGE

DRUM ASSEMBLY

				PLANT	BLDG	FL	SH. OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1 1	A	U
CM	PKG	IN	M2E801580A001						REV C

M2E801580A001

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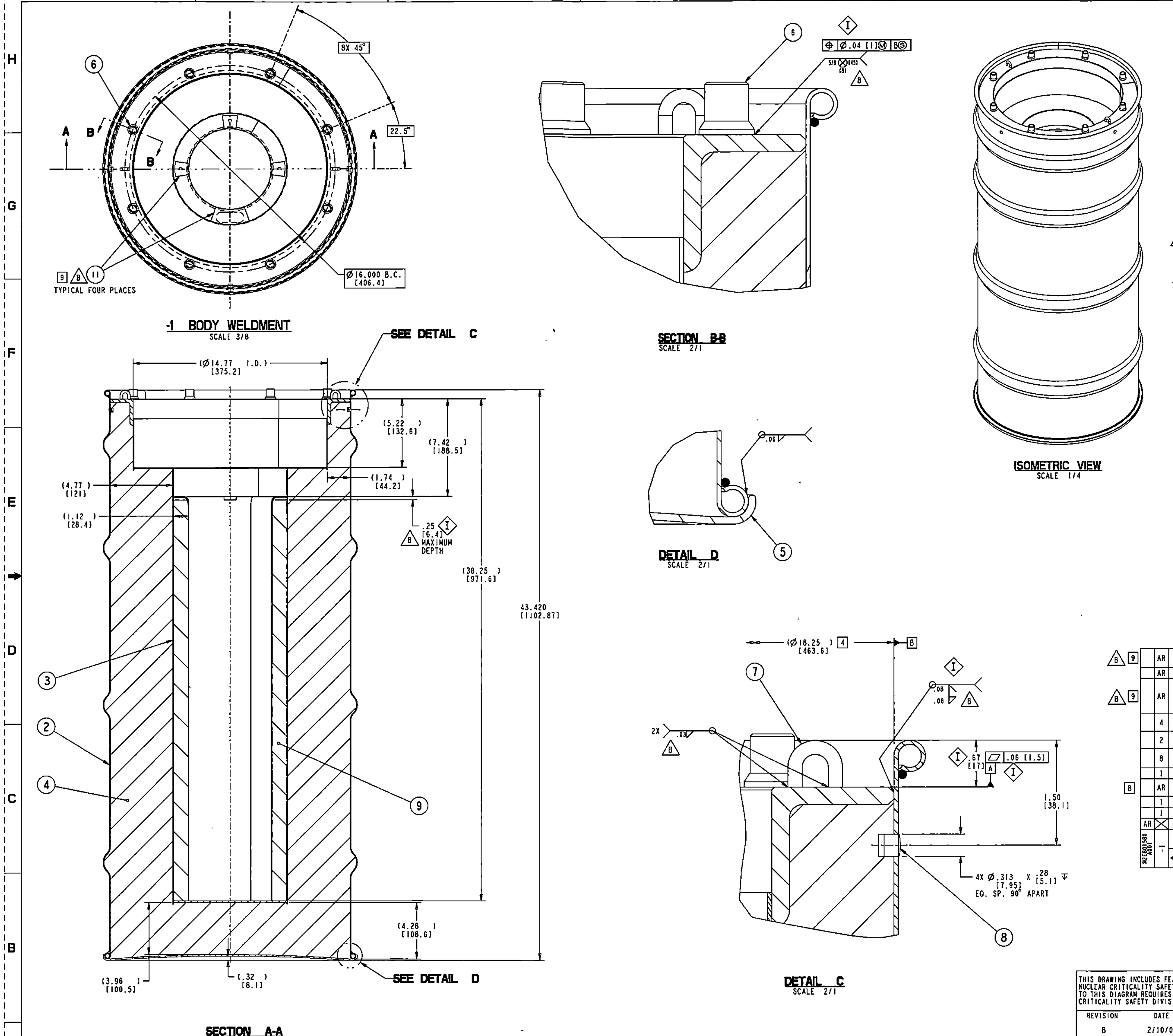

NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES [mm].
4. OD OF ANGLE TURNED TO ID OF DRUM AT ASSEMBLY.
5. WELDING SYMBOLS SHALL BE INTERPRETED IN ACCORDANCE WITH AWS A2.4.
6. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002.
7. DIMENSIONS AND FEATURES FLAGGED BY A ◇I SYMBOL SHALL BE INSPECTED AND DOCUMENTED.
8. SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A003 FOR REQUIREMENTS OF KAOLITE PROCESSING.
9. SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A005 FOR REQUIREMENTS OF CATALOG 277-4 PROCESSING AND APPLYING THE F/N 11 OVER FILL/VENT HOLES.
10. FOR REFERENCE ONLY APPROXIMATE WEIGHT: 259.7 LBS [117.8 Kg]

KAOLITE:
VOLUME: 4.82 CU. FT.
DENSITY: 22.4 LBS/CU. FT.
WEIGHT: 108.0 LBS [49.0 Kg]

CATALOG 277-4:
VOLUME: 0.466 CU. FT.
DENSITY: 105.0 LBS/CU. FT.
WEIGHT: 48.89 LBS [22.18 Kg]

	QTY REQ'D	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
B 9	AR	7616A21 OR EQUAL	LOW TEMPERATURE (-40° to +250°F)	ALUMINUM FOIL DUCT TAPE 2" WIDE	McMASTER- CARR ATLANTA, GA	11
	AR		WELD FILLER METAL	PER WELD PROCEDURES		10
B 9	AR	-9	CATALOG NO. 277-4	THERMO ELECTRON CORP., THERMOREAX, 504 AIRPORT ROAD, SANTA FE, NM 87507 PHONE 505-428-3508, FAX 505-428-3535		9
	4	62MP0312 OR EQUAL	PLUG, NYLON 6/6	MICRO PLASTIC INC. FLIPPIN, AR 72634		8
	2	M2E801580A005-2	TID LUG			7
	8	ARC FT 5/8-11 X 7/8 LG	ARC WELD STUD	304 / 304L SST	ASTM A493 OR ASTM F593	6
	1	M2E801580A005-1	DRUM FLAT COVER			5
8	AR	-4	KAOLITE 1600 VIBRATED CAST	THERMAL CERAMICS AUGUSTA, GA 30903-0923		4
	1	M2E801580A003-1	INNER LINER WELDMENT			3
	1	M2E801580A004-1	DOUBLE OPEN HEAD REINFORCED DRUM			2
AR	X	-1	BODY WELDMENT			1

M2E801580 A001 — QTY REQ'D NEXT ASSEMBLY — PARTS LIST

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
B	2/10/05	JF DECLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: ROGER D. AIGNER Date: 2/10/05

REV	DESCRIPTION
B	GEN REV ADDED F/N 11, 5/8 WAS 1/2, F/N 9 WAS BOROBOND 4; MOD. GEN. NOTE 9; MOD. WELD SYMS. IN DET. C; MOD. WTS AND VOLS. IN NOTE 10
A	ISSUED FOR PROTOTYPE PROCUREMENT

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONS; XX DECIMALS ±.03; XXX DECIMALS ±.005; ANGLES ±0.5°; BREAK SHARP EDGES .06 MAX; FINISH 125 RMS

DRAWING APPROVALS		DATE
DRW	J.R. JACKSON	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

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PROJECT NAME: ES-3100 SHIPPING PACKAGE

BODY WELDMENT

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	A	U

51 CM | 52 PKG | 53 IN | M2E801580A002 | REV B

P THIS DRAWING PRODUCED ON PRO/ENGINEER

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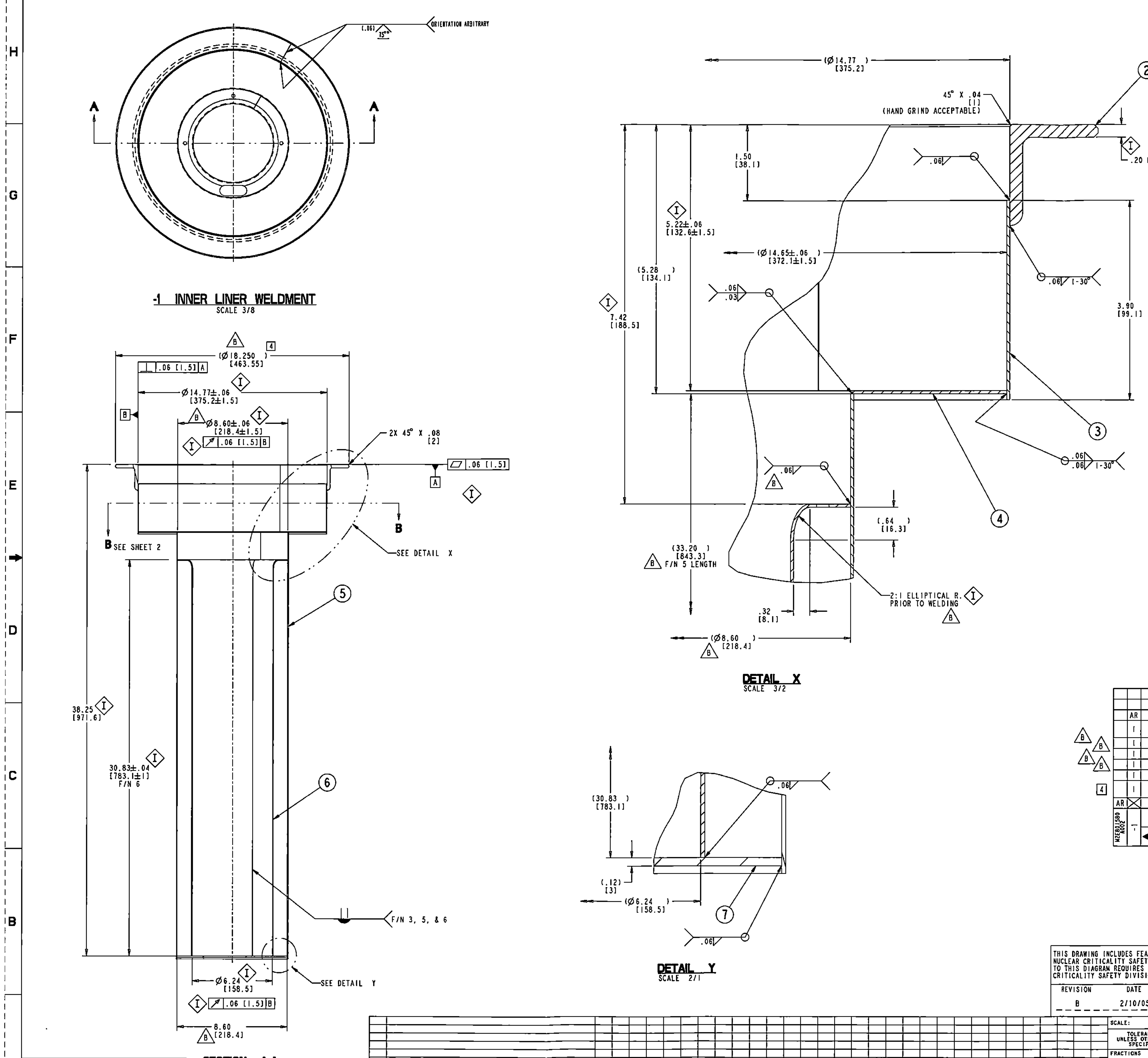

NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES [mm].
4. FINAL DIAMETER SET BY DRUM INSIDE DIAMETER, -.01 TO -.06 TOLERANCE.
5. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002.
6. DIMENSIONS AND FEATURES FLAGGED BY A ⟨I⟩ SYMBOL SHALL BE INSPECTED AND DOCUMENTED.
7. WELDING SYMBOLS SHALL BE INTERPRETED IN ACCORDANCE WITH AWS A2.4.

QTY REQ'D -1	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
AR		WELD FILLER METAL			8
1	-7	BOTTOM PLATE	11 GAGE SHEET 304/304L SST	ASME SA240	7
1	-6	LOWER INNER RING	16 GAGE SHEET 304/304L SST	ASME SA240	6
1	-5	LOWER OUTER RING	16 GAGE SHEET 304/304L SST	ASME SA240	5
1	-4	UPPER FLOOR PLATE	16 GAGE SHEET 304/304L SST	ASME SA240	4
1	-3	UPPER OUTER RING	16 GAGE SHEET 304/304L SST	ASME SA240	3
1	-2	2 X 2 X 1/4 ANGLE MODIFIED	304/304L SST	ASME SA479	2
AR (X)	-1	INNER LINER WELDMENT			1

M2E801580 A002 — QTY REQ'D NEXT ASSEMBLY

PARTS LIST

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
B	2/10/05	JF DECLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: ROGER D. AIGNER Date: 2/10/05

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DM
B	DELETED F/N 7, RENUMBERED F/N 8 TO 7 AND F/N 9 TO 8. CHANGED F/N 5 Ø8.80 TO Ø8.60, LENGTH 2.14 TO 33.20. F/N 6 OD WAS Ø9.13 NOW Ø8.60. REMOVED NOTE #8	JRP	SMM	GAB	RDA	DPS
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW

REVISION OR ISSUE PURPOSE

NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, IS MADE AS TO THE ACCURACY, COMPLETENESS OR USEFULNESS OF THE INFORMATION OR STATEMENTS CONTAINED IN THESE DRAWINGS, OR THAT THE USE OR DISCLOSURE OF ANY INFORMATION, APPARATUS, METHOD, OR PROCESS DISCLOSED IN THESE DRAWINGS MAY NOT INFRINGE PRIVATE RIGHTS OF OTHERS. NO LIABILITY IS ASSUMED WITH RESPECT TO THE USE OF, OR FOR DAMAGES RESULTING FROM THE USE OF ANY INFORMATION, APPARATUS, METHOD OR PROCESS DISCLOSED IN THESE DRAWINGS. DRAWINGS MADE AVAILABLE FOR INFORMATION TO BIDDER ARE NOT TO BE USED FOR OTHER PURPOSES AND ARE TO BE RETURNED UPON REQUEST OF THE FORWARDING CONTRACTOR.

THIS DRAWING PRODUCED ON PRO/ENGINEER

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±.03
XXX DECIMALS ±.005
ANGLES ±0.5°
BREAK SHARP EDGES .06 MAX
FINISH 125 RMS

DRAWING APPROVALS		DATE
DRW	J.R. JACKSON	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800 • Oak Ridge, Tennessee •

PROJECT NAME: ES-3100 SHIPPING PACKAGE

INNER LINER WELDMENT

6	M	L	F	PLANT Y-12	BLDG NA	FL NA	SH. 1	OF 2	TYPE S	CLASS U
CM	PKG	IN	M2E801580A003						REV B	

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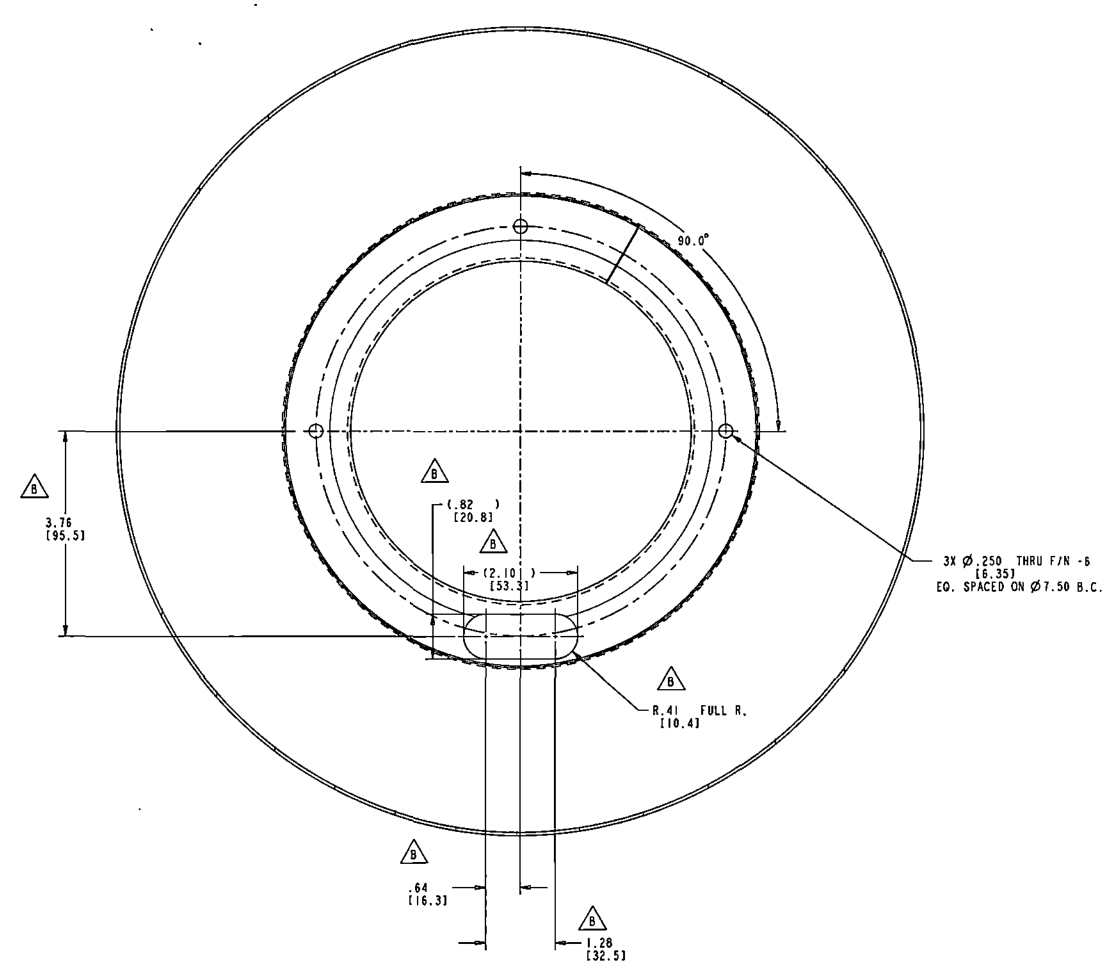

SECTION B-B
SCALE 1/1

NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, IS MADE AS TO THE ACCURACY, COMPLETENESS OR USEFULNESS OF THE INFORMATION OR STATEMENTS CONTAINED IN THESE DRAWINGS, OR THAT THE USE OR DISCLOSURE OF ANY INFORMATION, APPARATUS, METHOD, OR PROCESS DISCLOSED IN THESE DRAWINGS MAY NOT INFRINGE PRIVATE RIGHTS OF OTHERS. NO LIABILITY IS ASSUMED WITH RESPECT TO THE USE OF, OR FOR DAMAGES RESULTING FROM THE USE OF ANY INFORMATION, APPARATUS, METHOD OR PROCESS DISCLOSED IN THESE DRAWINGS. DRAWINGS MADE AVAILABLE FOR INFORMATION TO BIDDER ARE NOT TO BE USED FOR OTHER PURPOSES AND ARE TO BE RETURNED UPON REQUEST OF THE FORWARDING CONTRACTOR.

P THIS DRAWING PRODUCED ON PRO/ENGINEER

BWXT Y-12
Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800
Oak Ridge, Tennessee

PROJECT NAME
ES-3100 SHIPPING PACKAGE

INNER LINER WELDMENT

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	2	2	S	U

51	52	53		REV
CM	PKG	IN	M2E801580A003	B

M2E801580A003

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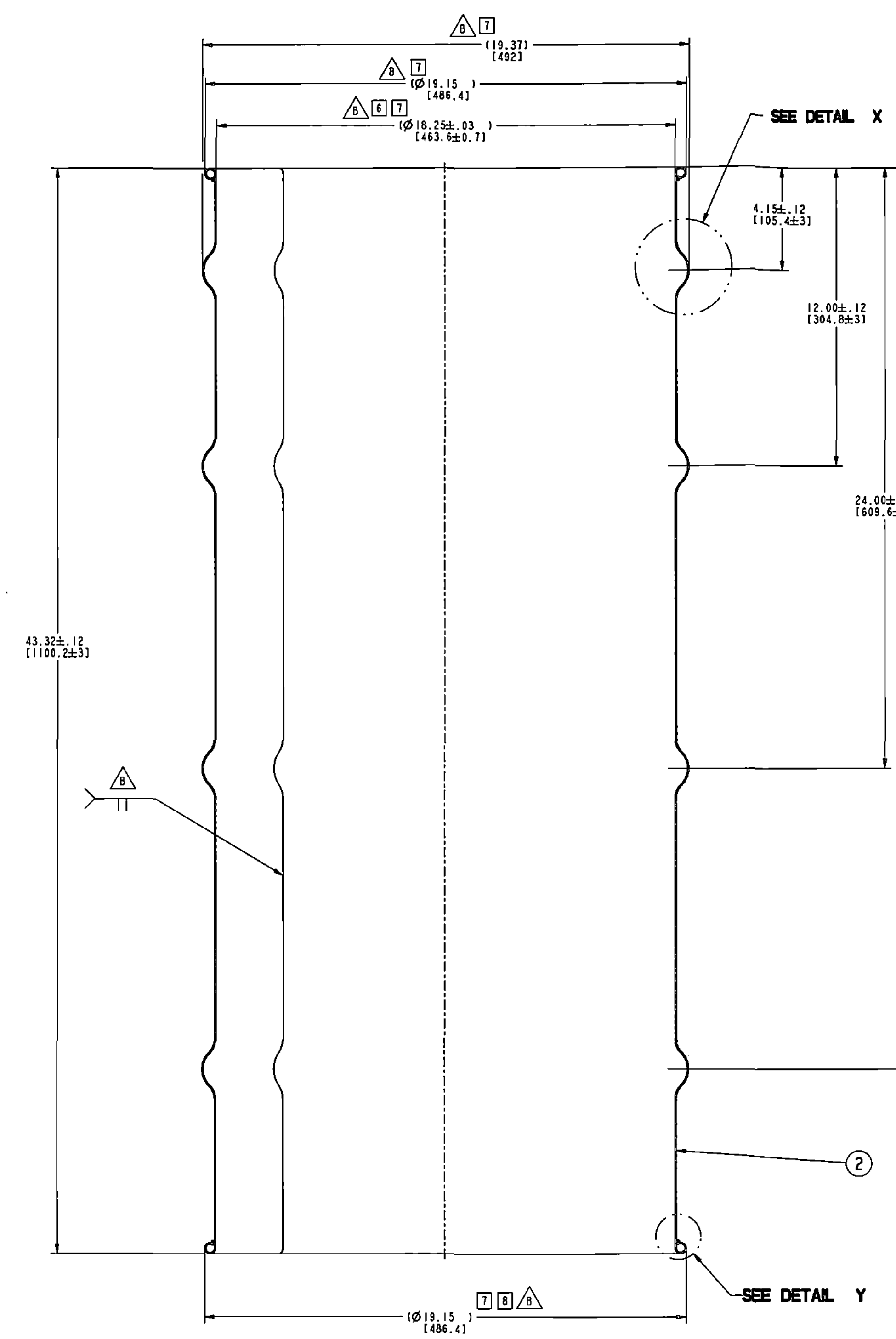
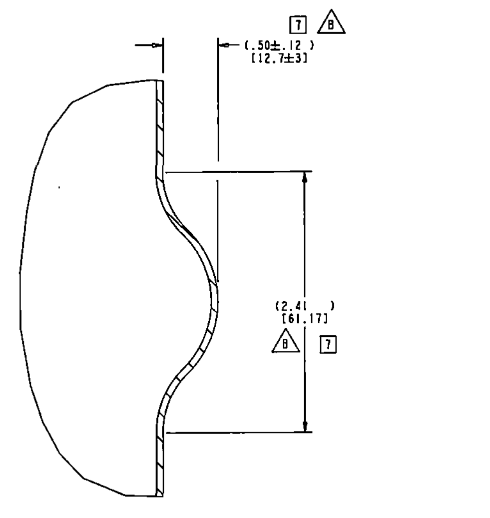
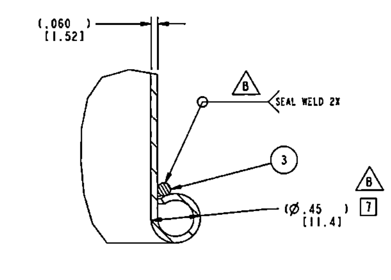


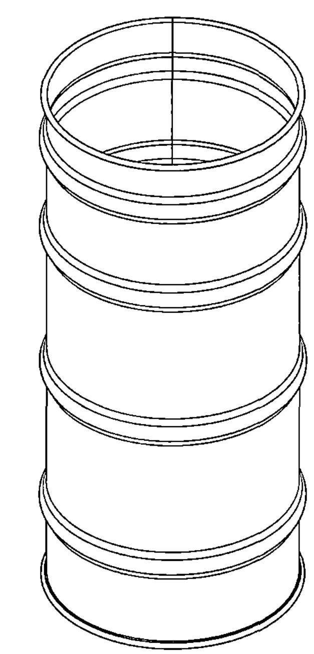
-1 DOUBLE OPEN HEAD REINFORCED DRUM
SCALE 1/2



DETAIL X
SCALE 2/1
(4X)



DETAIL Y
SCALE 2/1
(2 X)



ISOMETRIC VIEW
SCALE 1/4

NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES.[mm].
4. WELDING SYMBOLS SHALL BE INTERPRETED IN ACCORDANCE WITH AWS A2.4.
5. (B) FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002.
6. (B) INSPECT THE I.D. OF THE DRUM TO DETERMINE THE ACTUAL DIAMETER DIMENSION FOR FABRICATION INTERFACE WITH M2E801580A003. REFERENCE NOTE 4 ON DWG. M2E801580A002.
7. (B) DRUM DIAMETERS, CORRUGATIONS, AND MANUFACTURING SHALL MEET THE REQUIREMENTS OF MILITARY STANDARD, MS27683-7 (DRUM, METAL SHIPPING AND STORAGE 16 TO 80 GALLS). THE SEAM WELD OF THE DOUBLE OPEN-HEAD DRUM SHALL BE TESTED BY APPLYING AN INTERNAL AIR PRESSURE TO 10 PSIG (MIL-D-6054F, PARAGRAPH 4.6.1 PROCEDURE B) AND BY CONDUCTING A ROUGH HANDLING TEST (MIL-D-6054F, PARAGRAPH 4.6.2).
8. (B) INSPECT THE O.D. OF THE DRUM FOR INTERFACE DIMENSION WITH M2E801580A005-1, DRUM FLAT COVER. REFERENCE NOTE 5 ON DRAWING M2E801580A005.

M2E801580 A002	-	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
	AR		WELD FILLER METAL	PER WELD PROCEDURES		4
	AR	Ø1/8	WELD WIRE	ER308L	ASME SFA 5.9	3
	1	-2	DRUM 16 GA (.0595)	304/304L SST	ASME SA240	2
AR	X	-1	DOUBLE OPEN HEAD REINFORCED DRUM			1
		← QTY REQ'D NEXT ASSEMBLY	PARTS LIST			

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DM	DATE	PE	DATE	PM	DATE
B	GEN REV REMOVED TOL ON 18.25 DIA. REMOVED (I) ON 19.15 DIA. REMOVED BOX 9 DIM. UPDATED NOTE NUM. 6 TO 8. REVISED NOTE 7. MOD. WELD SYMBOLS, ADDED REF DIMENSIONS IN DETAIL X	JRP	SMM	GAB	RDA	DPS	11FEB05	GAB	2/10/05	JGA	2/10/05
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW	10/29/03	MRF	10/29/03	DBM	10/29/03

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK (WE, DATE, AR, CV, ST, HV, EM, FP, PD, EE, IE, M, MP)

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
B	2/10/05	JF DECLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: ROGER D. AIGNER Date: 2/10/05

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±.03
XXX DECIMALS ±.010
ANGLES ±0.5°
BREAK SHARP EDGES .06 MAX
FINISH 125 RMS

DRAWING APPROVALS		DATE
DRW	J.R. JACKSON	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

BWXT Y-12 — Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800 • Oak Ridge, Tennessee •

PROJECT NAME: ES-3100 SHIPPING PACKAGE

DOUBLE OPEN HEAD REINFORCED DRUM

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	S	U

51	52	53		REV
CM	PKG	IN	M2E801580A004	B

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P THIS DRAWING PRODUCED ON PRO/ENGINEER

M2E801580A004

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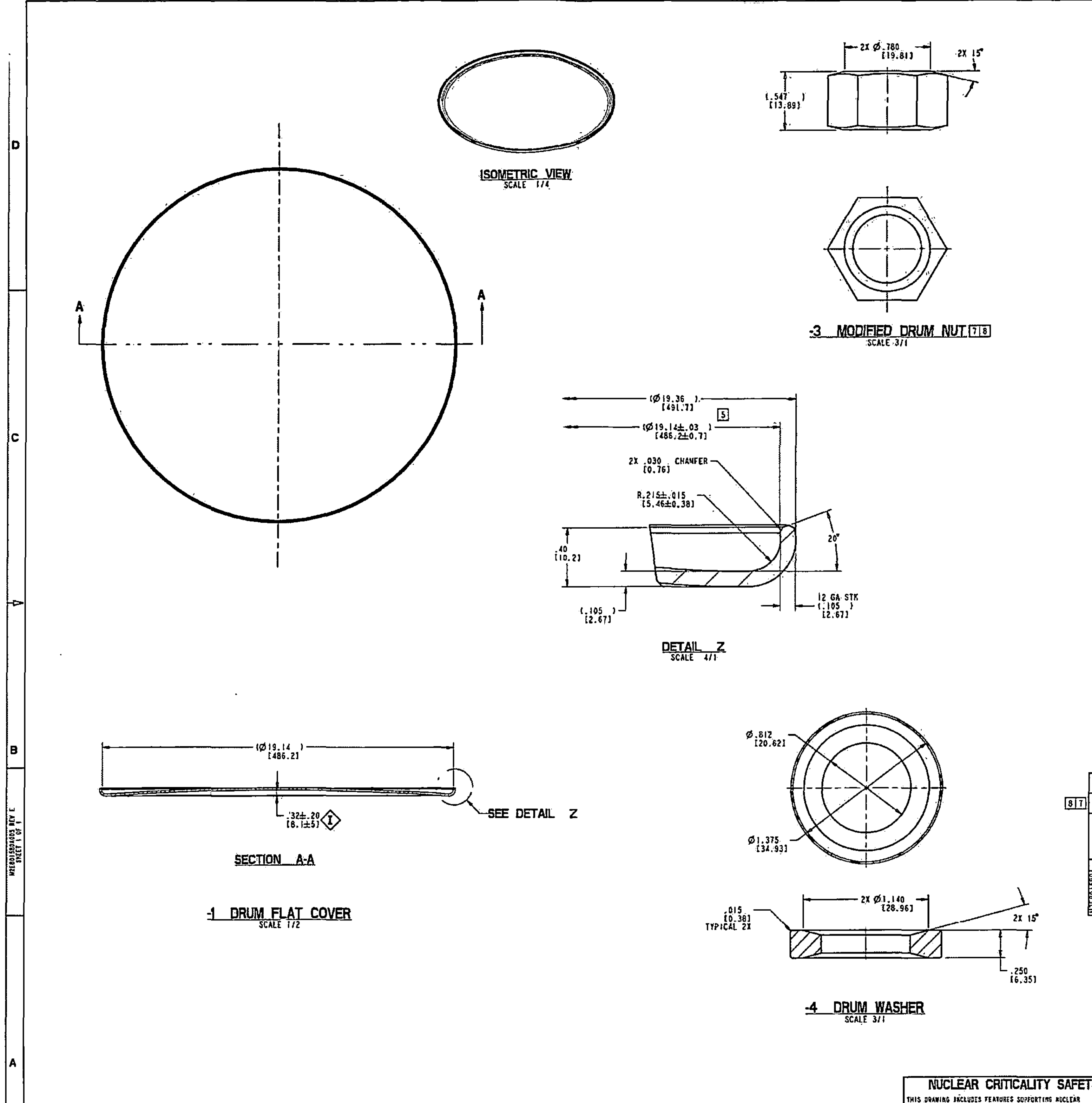
UNCLASSIFIED



NOTES

1. DELETED
2. DELETED
3. DELETED
4. DELETED
5. [5] DRUM FLAT COVER SHALL BE FABRICATED TO INTERFACE WITH DOUBLE OPEN HEAD REINFORCED DRUM DIMENSION. TOLERANCE SHALL BE -.01 TO -.04. REFERENCE NOTE 9 ON DRAWING M2E801580A004.
6. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002.
7. [7] THE MODIFIED DRUM NUT SHALL MEET THE REQUIREMENTS IN EQUIPMENT DATA SHEET DS-801580-0001.
8. [8] THE DRUM NUT MECHANICAL PROPERTY MARKING, F467K, SHALL BE FULLY VISIBLE AFTER MODIFICATION.

PARTS LIST

QTY REQD M2E801580 A001-1	QTY REQD M2E801580 A002-1	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
8		-4	DRUM WASHER	300 SERIES SST	ASTM A240 OR A276	4
8		-3	MODIFIED DRUM NUT [8][7]	C65100 SILICON BRONZE	ASTM F-467 ANSI B18.2.2	3
	2	MODIFIED 3392T51 OR EQUAL	TID-LUG	304L SST CHAIN 3/16" TRADE SIZE, .20 DIA. MATERIAL, INSIDE LINK SIZE .38 WD, .95L	McMASTER-CARR SUPPLY CO. ATLANTA, GA 30374	2
	1	-1	DRUM FLAT COVER	12 GA 304/304L SST	ASME SA240	1

REVISIONS

REV	DATE	REVISION DESCRIPTION
E	3/3/2016	UPDATED FORMAT, REVISED NOTE 7 & DELETED NOTES 1-4
D	3/17/10	ADDED NOTE 8, REVISED FORMAT
C	9/10/09	ADDED REFERENCE NOTE 7.
B	2/11/05	REVISED F/N 2; ADDED F/N 3 & 4 REMOVED TOL FROM DETAIL Z DIM.
A	10/29/03	ISSUED FOR PROTOTYPE PROCUREMENT

NEXT ASSEMBLY/ REFERENCE DOCUMENTS: N/A

SCALE: NOTED

SHEET SIZE REPRESENTATION: 1 INCH SQUARE AT FULL SIZE

SCALE PROVIDED FOR REFERENCE ONLY DO NOT SCALE

TOLERANCES UNLESS OTHERWISE SPECIFIED

FRACTIONS	
XX DECIMALS	±.01
XXX DECIMALS	±.005
ANGLES	±0.5°
BREAK SHARP EDGES	.01-.06
FINISH	125 RMS

THIRD ANGLE PROJECTION

(I) IMPORTANT TO FORM-FIT-FUNCTION INDEPENDENT VERIFICATION REQUIRED

(S) IMPORTANT TO SAFETY SHALL BE 100% INSPECTED AND NOT DEVIATED WITHOUT APPROVAL

NUCLEAR CRITICALITY SAFETY

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DRAWING REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

APPROXIMATE WEIGHT: N/A

DIMENSIONING AND TOLERANCING: ASME Y14.5M - 1994

ALL DIMENSIONS ARE IN INCHES

SOFTWARE: CREO 2.0

UNCLASSIFIED

THIS DOCUMENT HAS BEEN REVIEWED BY A Y-12 DC/UCNI-RO AND HAS BEEN DETERMINED TO BE UNCLASSIFIED AND CONTAINS NO UCNI. THIS REVIEW DOES NOT CONSTITUTE CLEARANCE FOR PUBLIC RELEASE.

NAME: STAN THOMAS

DATE: 03/01/16

TITLE: PKG. ENGR

ORGANIZATION: PACKAGING

CURRENT ISSUE APPROVALS

DES:	KW JOHNSON	RCS	AD WILKINSON
DE	GA BYINGTON		
CHKR	L ROBERSON		
DWR	ML GOINS		
SE	N/A		
PE	L ROBERSON		
DM	JC ANDERSON		

Y-12 NATIONAL SECURITY COMPLEX

CONSOLIDATED NUCLEAR SECURITY, LLC
P.O. BOX 2009 OAK RIDGE, TN 37831

US GOVERNMENT CONTRACT: DE-NA0001942

USERS MUST REFER TO THE TRANSMITTAL DOCUMENTS THAT ACCOMPANIED DELIVERY OF THIS DRAWING FOR ANY APPLICABLE DISCLAIMERS GOVERNING THE DRAWING.

PROJECT: ES-3100 SHIPPING PACKAGE

TITLE: MISC. DETAILS

DRAWING NUMBER: M2E801580A005 | PART: 000 | REV: E

RECORD NO: N/A | IDTS: N/A | STATE: AR | SHEET: 1 OF 1

UNCLASSIFIED

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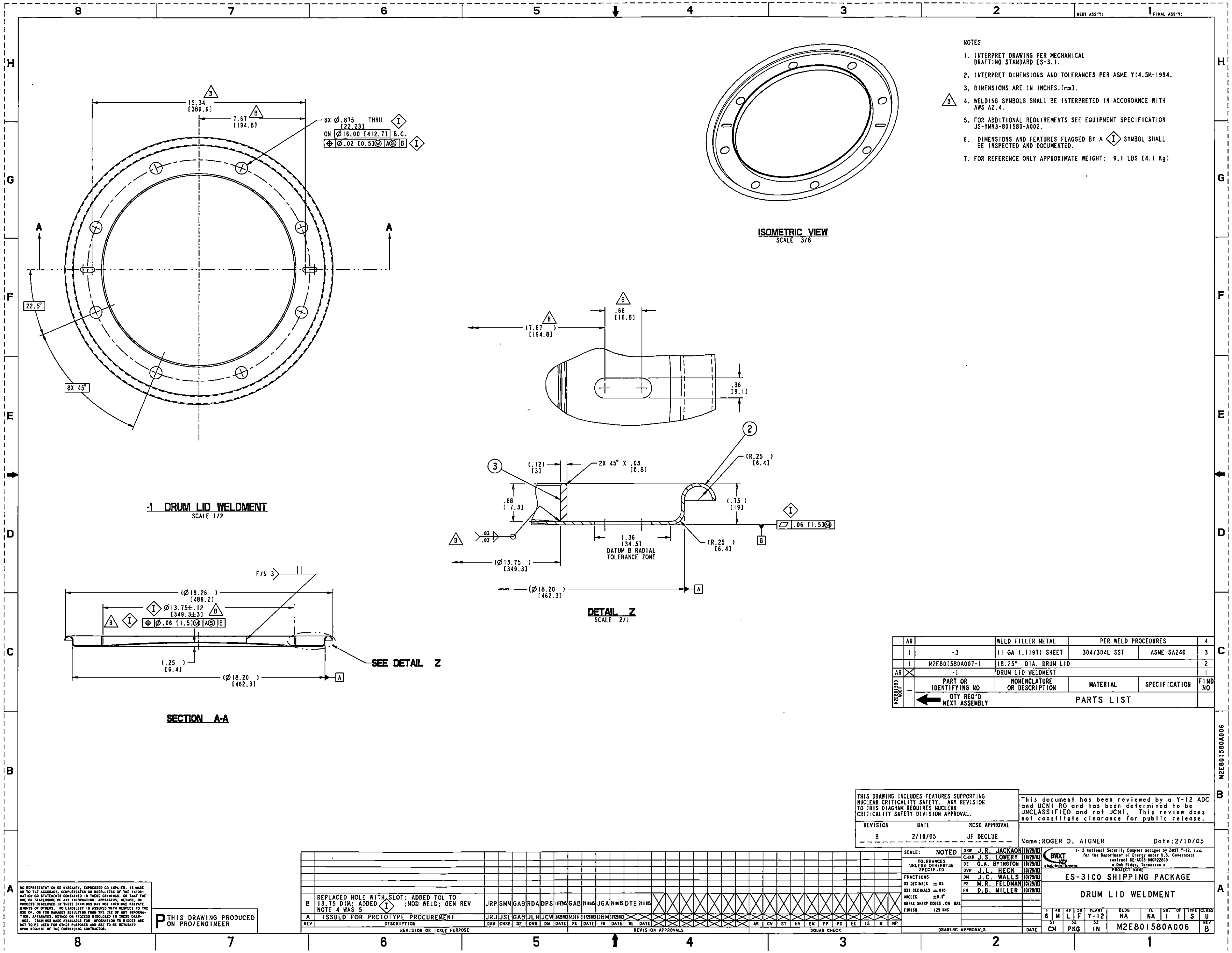
NOTES
1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES.[mm].
4. WELDING SYMBOLS SHALL BE INTERPRETED IN ACCORDANCE WITH AWS A2.4.
5. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002.
6. DIMENSIONS AND FEATURES FLAGGED BY A I SYMBOL SHALL BE INSPECTED AND DOCUMENTED.
7. FOR REFERENCE ONLY APPROXIMATE WEIGHT: 9.1 LBS [4.1 Kg]
ISOMETRIC VIEW
SCALE 3/8
-1 DRUM LID WELDMENT
SCALE 1/2
15.34
[389.6]
7.67
[194.8]
8X Ø.875 THRU
[22.23]
ON Ø16.00 [412.7] B.C.
22.5°
8X 45°
SECTION A-A
(Ø19.26)
[489.2]
Ø13.75±.12
[349.3±3]
(.25)
[6.4]
(Ø18.20)
[462.3]
F/N 3
SEE DETAIL Z
DETAIL Z
SCALE 2/1
.66
[16.8]
.36
[9.1]
2X 45° X .03
[0.8]
(R.25)
[6.4]
(.75)
[19]
.68
[17.3]
1.36
[34.5]
DATUM B RADIAL TOLERANCE ZONE
(Ø13.75)
[349.3]
(Ø18.20)
[462.3]
PARTS LIST
-3 | WELD FILLER METAL | PER WELD PROCEDURES | 4
1 | 11 GA (.1197) SHEET | 304/304L SST | ASME SA240 | 3
1 | M2E801580A007-1 | 18.25" DIA. DRUM LID | 2
-1 | DRUM LID WELDMENT | 1
PART OR IDENTIFYING NO | NOMENCLATURE OR DESCRIPTION | MATERIAL | SPECIFICATION | FIND NO
QTY REQ'D NEXT ASSEMBLY
THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.
REVISION B | DATE 2/10/05 | NCSD APPROVAL JF DECLUE
This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.
Name: ROGER D. AIGNER Date: 2/10/05
B | REPLACED HOLE WITH SLOT; ADDED TOL TO 13.75 DIM; ADDED I ; MOD WELD; GEN REV NOTE 4 WAS 5
A | ISSUED FOR PROTOTYPE PROCUREMENT
THIS DRAWING PRODUCED ON PRO/ENGINEER
DRW J.R. JACKSON
CHKR J.S. LOWERY
DE G.A. BYINGTON
DVR J.L. HECK
DM J.C. WALLS
PE M.R. FELDMAN
PM D.B. MILLER
ES-3100 SHIPPING PACKAGE
DRUM LID WELDMENT
M2E801580A006
B

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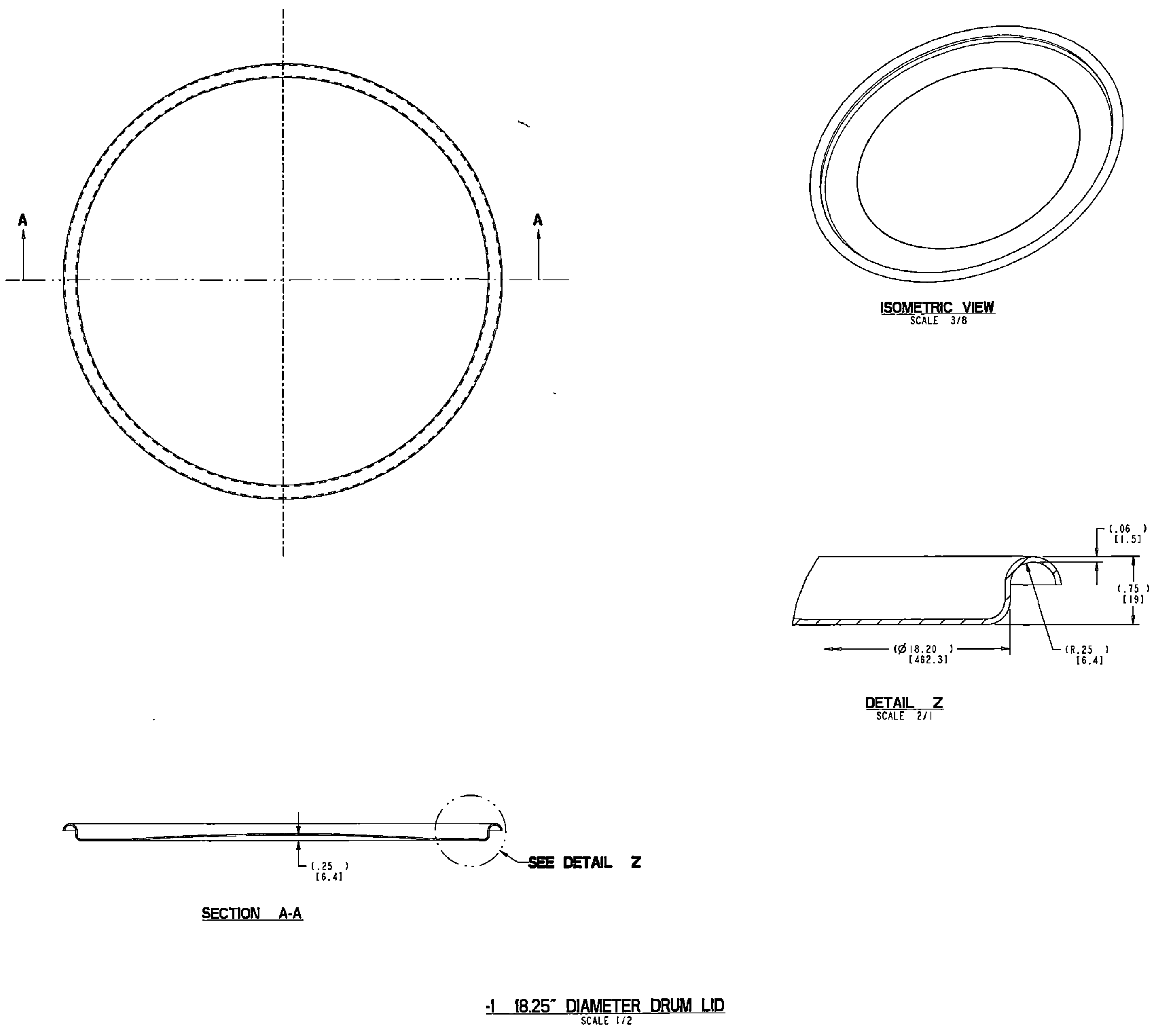

NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES.[mm].
4. FOR ADDITIONAL INFORMATION SEE EQUIPMENT SPECIFICATION DS-YMN3-801580A002.
5. LID SHALL BE FABRICATED IN ACCORDANCE WITH MILITARY SPECIFICATION MS27683-61, COVER STYLE 1.

AR	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
M2E801580 A006	-1	18.25" DIA. DRUM LID	16 GA 304/304L SST	ASME SA240	1
QTY REQ'D NEXT ASSEMBLY		PARTS LIST			

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REVISION	DATE	NCSD APPROVAL
B	2/10/05	JF DECLUE

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Name: ROGER D. AIGNER Date: 2/10/05

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DN	DATE	PE	DATE	PM	DATE
B	GENERAL REVISION.	JRP	SMM	GAB	RDA	DPS		GAB		JGA	
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW		MRF		DBM	

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK

DRAWING APPROVALS		DATE
DRW	J.R. JACKSON	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DN	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

SCALE: NOTED
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS
XXX DECIMALS
ANGLES
BREAK SHARP EDGES MAX
FINISH

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PROJECT NAME: ES-3100 SHIPPING PACKAGE

18.25" DIAMETER DRUM LID

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	S	U

51	52	53		REV
CM	PKG	IN	M2E801580A007	B

M2E801580A007

P THIS DRAWING PRODUCED ON PRO/ENGINEER

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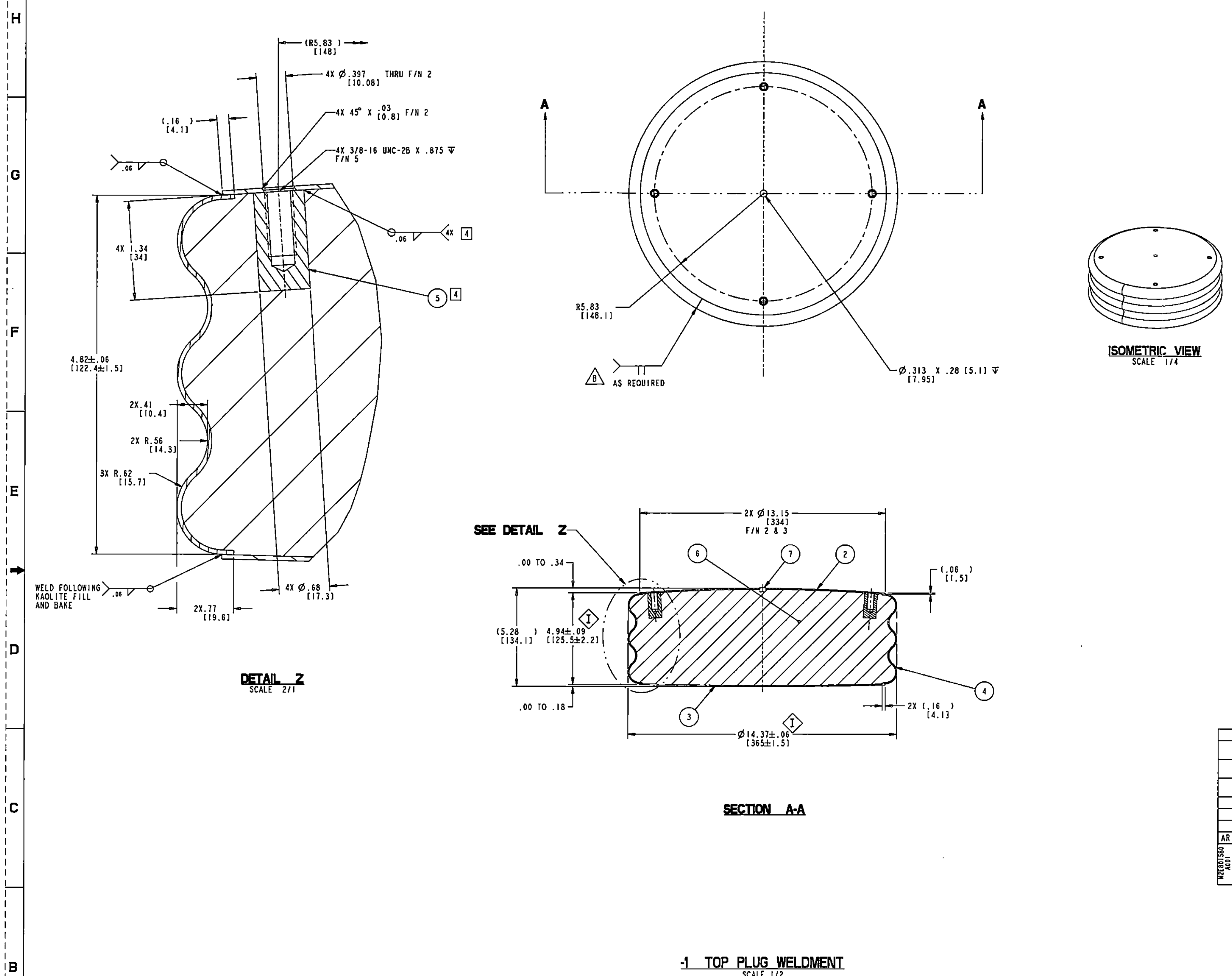

NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES.[mm].
4. WELD LIFTING INSERTS (F/N 5) IN PLACE BEFORE FILLING WITH KAOLITE (F/N 6).
5. WELDING SYMBOLS SHALL BE INTERPRETED IN ACCORDANCE WITH AWS A2.4.
6. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATIONS JS-YMN3-801580-A002 AND A003.
7. DIMENSIONS AND FEATURES FLAGGED BY A ⟨I⟩ SYMBOL SHALL BE INSPECTED AND DOCUMENTED.
8. FOR REFERENCE ONLY:
   APPROXIMATE WEIGHT 19.6 LBS [8.8 Kg] WITH KAOLITE VOLUME 0.43 CU.FT.
   KAOLITE DENSITY 22.4 LBS/CU. FT.
   KAOLITE WEIGHT: 9.6 LBS [4.7 Kg]

QTY REQ'D		PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
	AR		WELD FILLER METAL	PER WELD PROCEDURES		8
	1	62MP0312 OR EQUAL	PLUG, NYLON 6/6	MICRO PLASTIC INC. FLIPPIN, AR 72634		7
	1	-6	KAOLITE 1600 TM VIBRATED CAST	THERMAL CERAMICS AUGUSTA, GA 30903-0923		6
	4	-5	LIFTING INSERT	11/16 ROUND 304/304L SST	ASME SA479	5
	1	-4	PLUG RIM	16 GA SHT 304/304L SST	ASME SA240	4
	1	-3	BOTTOM SHEET	16 GA SHT 304/304L SST	ASME SA240	3
	1	-2	TOP SHEET	16 GA SHT 304/304L SST	ASME SA240	2
AR	X	-1	TOP PLUG WELDMENT			1
M2E801580 A001	-1	← QTY REQ'D NEXT ASSEMBLY				

PARTS LIST

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
B	2/10/05	JF DECLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: ROGER D. AIGNER Date: 2/10/05

REV	DESCRIPTION												
B	GENERAL REVISION ADDED WELD SYMBOL	JRP	SMM	GAB	RDA	DPS		JGA		GAB		DJE	
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW	10/29/03	MRF		DBM	10/29/03		

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±.03
XXX DECIMALS ±.005
ANGLES ±0.5°
BREAK SHARP EDGES .06 MAX
FINISH 125 RMS

DRW	J.R. JACKSON	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800 Oak Ridge, Tennessee

PROJECT NAME: ES-3100 SHIPPING PACKAGE

TOP PLUG WELDMENT

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	S	U

51	52	53		REV
CM	PKG	IN	M2E801580A008	B

PTHIS DRAWING PRODUCED ON PRO/ENGINEER

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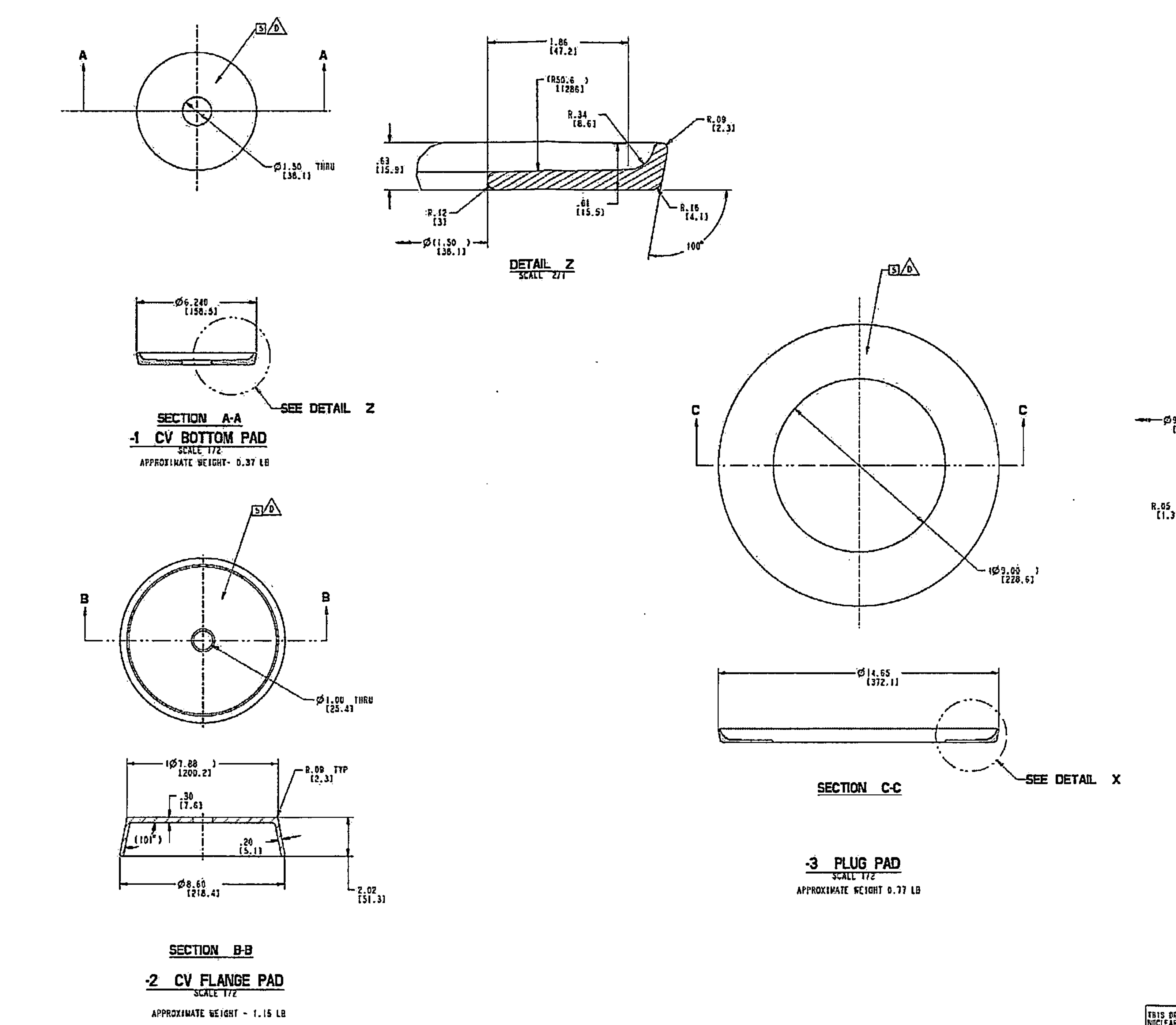
UNCLASSIFIED

NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER "RMA" RUBBER HANDBOOK (RMA-392) CLASS "A2 PRECISION."
3. DIMENSIONS ARE IN INCHES.
4. MANUFACTURER/SUPPLIER TO PROVIDE CERTIFICATE OF COMPLIANCE FOR ALL FEATURES OF THESE ITEMS.
5. (D) IN APPROXIMATE LOCATION SHOWN; ENGRAVE DRAWING NUMBER AND REVISION LETTER IN 1/4" HIGH CHARACTERS IN THE MOLD TO MAKE A LEGIBLE RAISED MARKINGS IN THE PART.
6. (D) FOR ADDITIONAL INFORMATION SEE EQUIPMENT DATA SHEET DS-801580-0002.



QTY REQ'D			PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
4	6	AR	-3	PLUG PAD	SILICONE RUBBER 22±5 SHORE A COLOR BLACK/GRAY	SEE NOTE 6	3
4	6	AR	-2	CV FLANGE PAD			2
4	6	AR	-1	CV BOTTOM PAD			1

PARTS LIST

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REVISION	DATE	SAE APPROVAL
D	6/05/2012	J.F. DeCLUE

This document has been reviewed by a Y-12 DC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: DREW WINDER Date: 06/05/12

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PART	REV	DESCRIPTION (REVISION OR ISSUE PURPOSE)
000	D	DELETED FIND NO 4, ADDED NOTE 6, CHANGED NOTE 5, REMOVED VENDOR FROM PARTS LIST
000	C	GEN REV; REDESIGNED F/N 1; ADDED APPROXIMATE WEIGHT TO F/N 1, 2 AND 3
000	B	MODIFIED DIMENSIONING ON -3
000	A	ISSUED FOR PROTOTYPE PROCUREMENT

SCALE: NOTED

DWN J.R. JACKSON; CHKD J.S. LOWERY; DE G.A. BYINGTON; DVG J.L. HECK; DM J.C. WALLS; PE M.R. FELDMAN; CWDO D.B. MILLER; WT N/R

Y-12 National Security Complex managed by B&W Technical Services Y-12, LLC for the Department of Energy

ES-3100 SHIPPING PACKAGE

PAD DETAILS

M2E801580A009 — SH 1 OF 1 — PART 000 — REV D

UNCLASSIFIED

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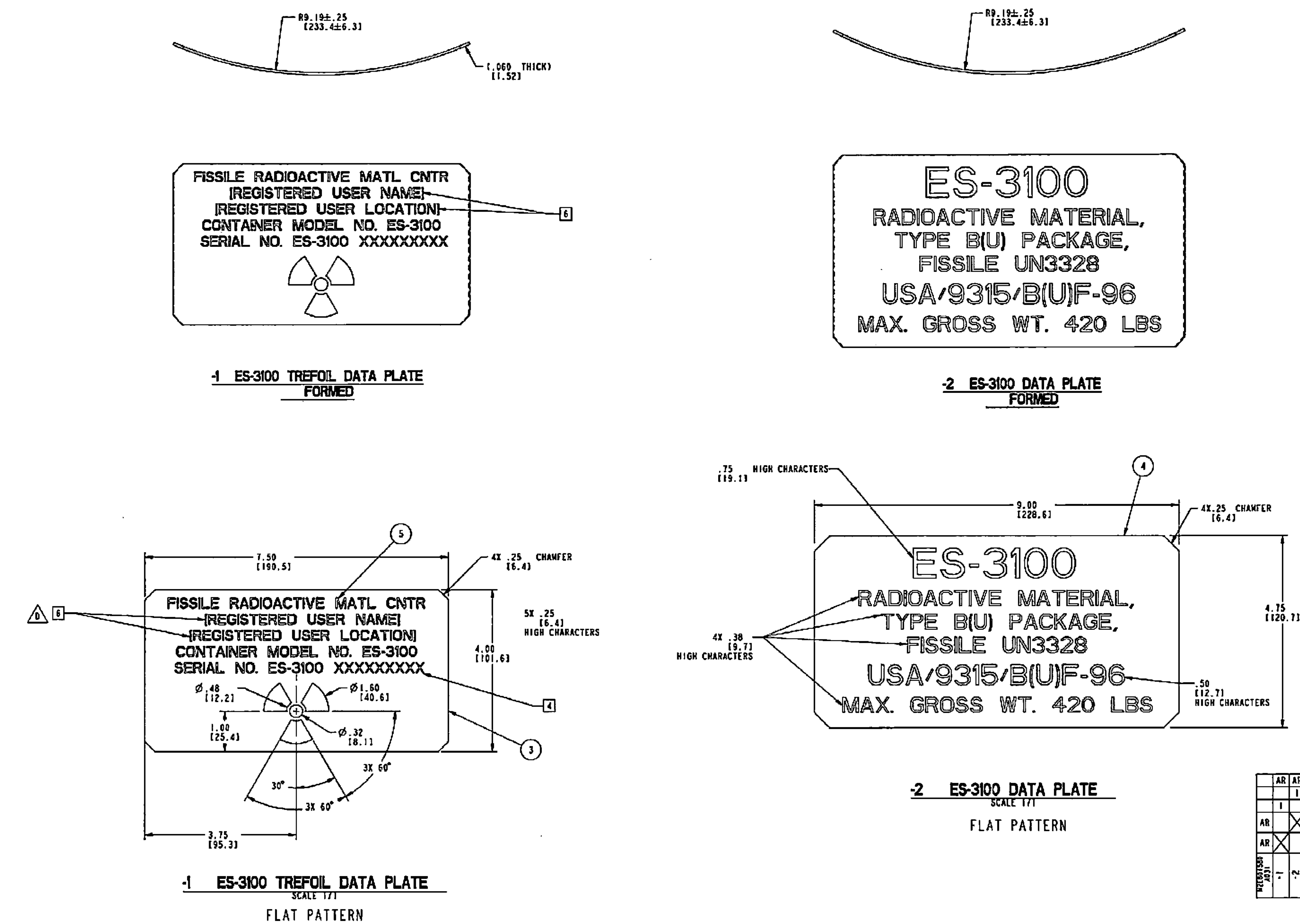

NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES [mm].
4. CONTAINER SERIAL NUMBER SHOWN "XXXXXXXXX" IS A GENERIC REPRESENTATION, ACTUAL SERIAL NUMBERS SHALL BE SPECIFIED IN PURCHASE ORDER, OR PROCUREMENT CONTRACT.
5. ALL CHARACTERS AND SYMBOLS SHALL BE ELECTROCHEMICALLY ETCHED .003-.005 DEEP AND FILLED WITH BLACK ENAMEL PAINT (F/N 5).
6. (D) SEE PROCUREMENT DOCUMENTS FOR PROPER REGISTERED USER NAME AND LOCATION.

M2E801580 A01	-1	-2	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
	AR	AR	-5	PAINT, BLACK ENAMEL		FED SPEC 595b-17038	5
		1	-4	16 GA, SHEET	304/304L SST	ASME SA240	4
	1		-3	16 GA, SHEET	304/304L SST	ASME SA240	3
AR		X	-2	ES-3100 DATA PLATE			2
AR	X		-1	ES-3100 TREFOIL DATA PLATE			1

QTY REQ'D NEXT ASSEMBLY — PARTS LIST

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REVISION	DATE	NCSD APPROVAL
D	09/10/08	J.F. DeCLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: R.D. AIGNER Date: 09/11/08

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DM	DATE	PE	DATE	PM	DATE
D	REVISED TREFOIL DATA PLATE, F/N 1, ADDED NOTE 6.	JRJ	RDA	LR	GAB	WIN	[illegible]	LR	[illegible]	JGA	[illegible]
C	REVISED TREFOIL DATA PLATE, F/N 1, AND NOTE 4	JRJ	RDA	JRJ	GAB	WIN	[illegible]	[illegible]	[illegible]	JGA	[illegible]
B	GEN REV: REMOVED RIVIT HOLES F/N 1 & 2; ADDED CHAMFERS F/N 1 & 2; ADDED NEW FLAT PATTERN VIEWS; REMOVED NOTE 5; CHANGED NOTE 6 TO NOTE 5; REMOVED NOTE 7; REMOVED INDEX NOTE BOX 5; CHANGED INDEX NOTE BOX 7 TO 4	JRP	SMM	GAB	RDA	DPS	[illegible]	GAB	[illegible]	JGA	[illegible]
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW	[illegible]	MRF	[illegible]	DBM	[illegible]

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK

THIS DRAWING PRODUCED ON PRO/ENGINEER

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONS; XX DECIMALS ±.03; XXX DECIMALS ±.005; ANGLES ±0.5°; BREAK SHARP EDGES .06 MAX; FINISH 125 RMS

DRAWING APPROVALS		DATE
DRW	J.R. JACKSON	10/21/03
CHKR	J.S. LOWERY	10/21/03
DE	G.A. BYINGTON	10/21/03
DVR	J.L. HECK	10/21/03
DM	J.C. WALLS	10/21/03
PE	M.R. FELDMAN	10/21/03
PM	D.B. MILLER	10/21/03

BWXT Y-12 — Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800, Oak Ridge, Tennessee

PROJECT NAME: ES-3100 SHIPPING PACKAGE

DATA PLATE DETAILS

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	S	U

51	52	53		REV
CM	PKG	IN	M2E801580A010	D

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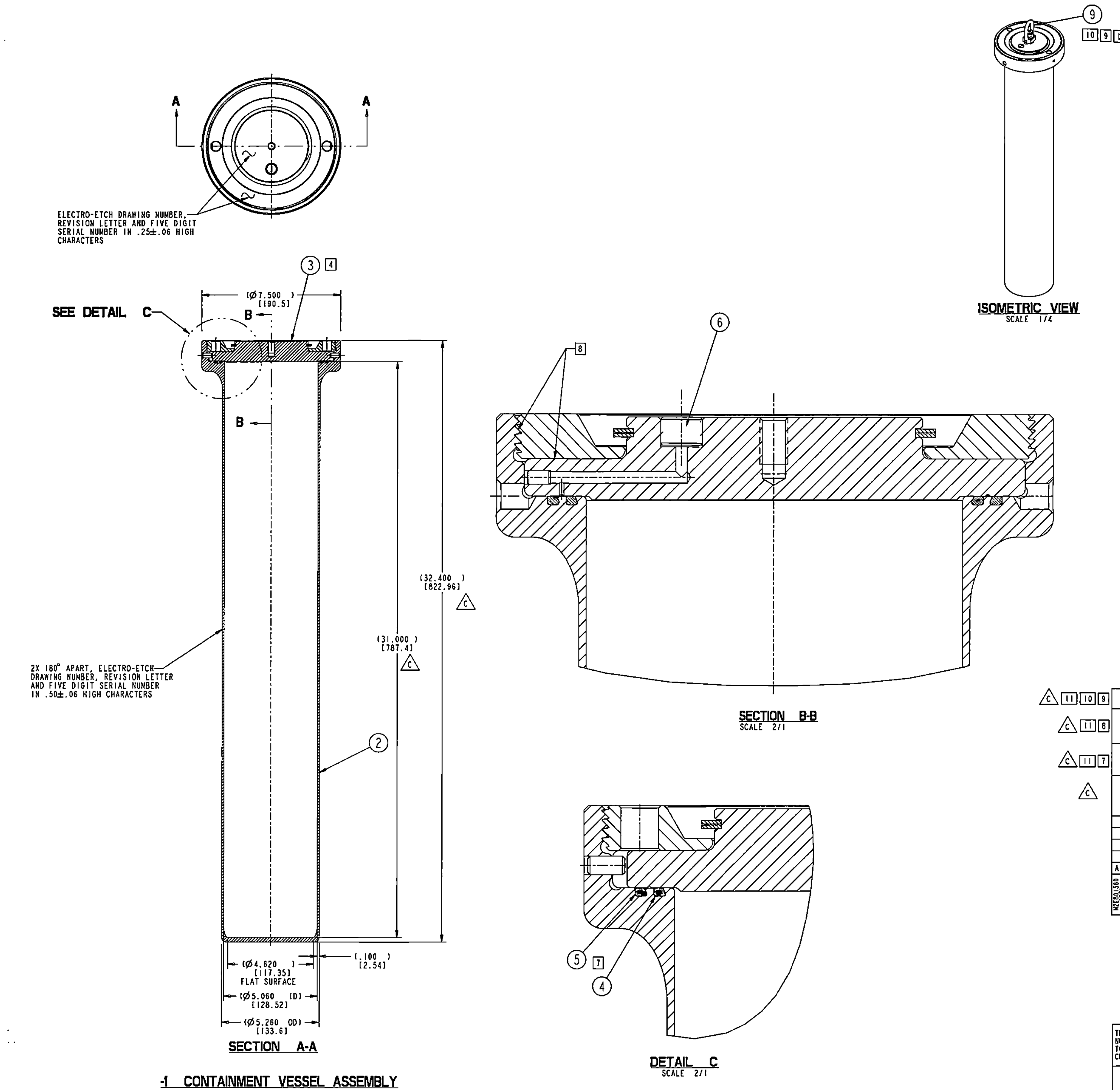

NOTES

1. INTERPRET DRAWING PER ENGINEERING DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994. PERFECT ORIENTATION AT MMC FOR INTERRELATED FEATURES REQUIRED.
3. DIMENSIONS ARE IN INCHES [mm].
4. (C) INSTALL THE LID NUT AND TORQUE TO 120 ±5 FT-LBS AS SHOWN ON M2E801580A020-3 AND A020-4.
5. APPROXIMATE WEIGHT: 32.98 LBS. [14.96 KG].
6. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPEC. DS-YMN3-801580-A001.
7. DURING INSTALLATION OF O-RINGS APPLY A THIN COAT OF SUPER-O-LUBE.
8. DURING INSTALLATION OF CONTAINER VESSEL LID ASSEMBLY, APPLY A LIGHT COAT OF KRYTOX GREASE TO THE THREADS AND UNDER THE NUT.
9. SWIVEL HOIST RING FOR USE WHEN LOADING AND UNLOADING CONTAINMENT VESSEL ONLY. NOT FOR SHIPMENT.
10. TORQUE SWIVEL HOIST RING TO 12 ±1 FT.LBS. PER MFGR'S SPEC.
11. (C) THE SWIVEL HOIST RING, THREAD LUBRICANT AND O-RING LUBRICANTS ARE REQUIRED AT EACH LOADING AND MAINTENANCE STATION.

PARTS LIST

		-1	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
(C) 11 10 9		AR	3052T56 OR EQUAL	SWIVEL HOIST RING	ALLOY STEEL	McMASTER- CARR ATLANTA, GA	9
(C) 11 8		AR	KRYTOX #240AC OR EQUAL	THREAD LUBRICANT	FLUORINATED GREASE	MILLER-STEPHENSON CHEMICAL CO. DANBURY, CT 06810	8
(C) 11 7		AR	SUPER-O-LUBE OR EQUAL	O-RING LUBRICANT	CLEAR DIMETHYL SILOXANE POLYMER	PARKER HANNIFIN CORP, O-RING DIV, PO BOX 11751 LEXINGTON, KY 40512	7
(C)		1	PART # 04-2126	MODIFIED VCO THREADED PLUG	BRASS	VOLUNTEER INDUSTRIAL P. O. BOX 30371 KNOXVILLE, TN 37930 PHONE 865-660-2617	6
		1	M2E801580A013-2	O-RING, OUTER			5
		1	M2E801580A013-1	O-RING, INNER			4
		1	M2E801580A014-1	CONTAINMENT VESSEL LID ASSEMBLY			3
		1	M2E801580A012-1 OR A012-4	CONTAINMENT VESSEL BODY ASSEMBLY			2
	AR	X	-1	CONTAINMENT VESSEL ASSEMBLY			1
	M2E801580 A031	QTY REQ'D	NEXT ASSEMBLY				

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REVISION	DATE	NCSD APPROVAL
C	2/10/05	JF DECLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: ROGER D. AIGNER Date: 2/10/05

REV	DESCRIPTION (REVISION OR ISSUE PURPOSE)	DRW	CHKR	DE	DVR	DM	DATE	PE	DATE	PM	DATE
C	GENERAL REVISION DELETED F/N 9; RENUMBERED F/N 10 TO NEW F/N 9; ADDED NOTE 11; NOTE 4 TORQUE WAS 100	JRP	SMM	GAB	RDA	DPS	[illegible]	GAB	[illegible]	JGA	[illegible]
B	-6 WAS A FABRICATED PART, ADDED A012-4 WELDED CV OPTION	GAB	RA	GAB	JLH	JCW	[illegible]	GAB	[illegible]	JGA	[illegible]
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW	[illegible]	MRF	[illegible]	DBM	[illegible]

REVISION APPROVALS — SQUAD CHECK: AR CV ST HV EM FP PD EE IE M NP

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±.01
XXX DECIMALS ±.005
ANGLES ±0.5°
BREAK SHARP EDGES .06 MAX
FINISH 125 RMS

DRAWING APPROVALS		DATE
DRW	JRJ for D.W. SPARKS	10/29/03
CHKR	D.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

BWXT Y-12 — Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800 • Oak Ridge, Tennessee •

PROJECT NAME: ES-3100 SHIPPING PACKAGE

CONTAINMENT VESSEL ASSEMBLY

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	A	U

51	52	53		REV
CM	PKG	IN	M2E801580A011	C

M2E801580A011

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THIS DRAWING PRODUCED ON PRO/ENGINEER

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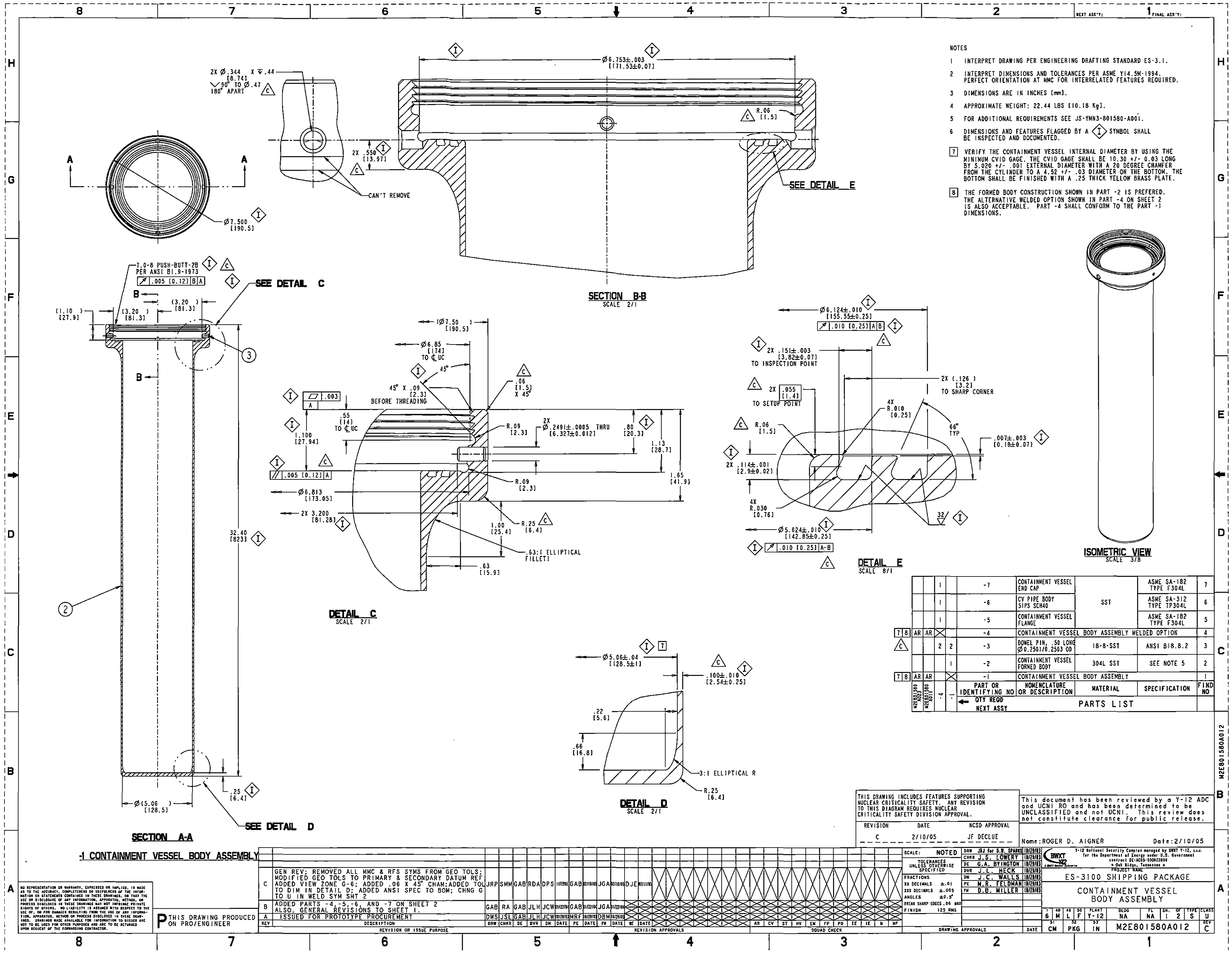

NOTES
1 INTERPRET DRAWING PER ENGINEERING DRAFTING STANDARD ES-3.1.
2 INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994. PERFECT ORIENTATION AT MMC FOR INTERRELATED FEATURES REQUIRED.
3 DIMENSIONS ARE IN INCHES [mm].
4 APPROXIMATE WEIGHT: 22.44 LBS [10.18 Kg].
5 FOR ADDITIONAL REQUIREMENTS SEE JS-YMN3-801580-A001.
6 DIMENSIONS AND FEATURES FLAGGED BY A (I) SYMBOL SHALL BE INSPECTED AND DOCUMENTED.
7 VERIFY THE CONTAINMENT VESSEL INTERNAL DIAMETER BY USING THE MINIMUM CVID GAGE. THE CVID GAGE SHALL BE 10.30 +/- 0.03 LONG BY 5.020 +/- .001 EXTERNAL DIAMETER WITH A 20 DEGREE CHAMFER FROM THE CYLINDER TO A 4.52 +/- .03 DIAMETER ON THE BOTTOM. THE BOTTOM SHALL BE FINISHED WITH A .25 THICK YELLOW BRASS PLATE.
8 THE FORMED BODY CONSTRUCTION SHOWN IN PART -2 IS PREFERED. THE ALTERNATIVE WELDED OPTION SHOWN IN PART -4 ON SHEET 2 IS ALSO ACCEPTABLE. PART -4 SHALL CONFORM TO THE PART -1 DIMENSIONS.
SECTION B-B
SCALE 2/1
SEE DETAIL E
CAN'T REMOVE
SECTION A-A
-1 CONTAINMENT VESSEL BODY ASSEMBLY
SEE DETAIL C
SEE DETAIL D
DETAIL C
SCALE 2/1
DETAIL D
SCALE 2/1
DETAIL E
SCALE 8/1
ISOMETRIC VIEW
SCALE 3/8
PARTS LIST
-7 CONTAINMENT VESSEL END CAP | SST | ASME SA-182 TYPE F304L | 7
-6 CV PIPE BODY 5IPS SCH40 | SST | ASME SA-312 TYPE TP304L | 6
-5 CONTAINMENT VESSEL FLANGE | SST | ASME SA-182 TYPE F304L | 5
-4 CONTAINMENT VESSEL BODY ASSEMBLY WELDED OPTION | 4
-3 DOWEL PIN, .50 LONG Ø0.2501/0.2503 OD | 18-8-SST | ANSI B18.8.2 | 3
-2 CONTAINMENT VESSEL FORMED BODY | 304L SST | SEE NOTE 5 | 2
-1 CONTAINMENT VESSEL BODY ASSEMBLY | 1
THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.
REVISION C DATE 2/10/05 NCSD APPROVAL JF DECLUE
This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.
Name: ROGER D. AIGNER Date: 2/10/05
Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800 Oak Ridge, Tennessee
ES-3100 SHIPPING PACKAGE
CONTAINMENT VESSEL BODY ASSEMBLY
M2E801580A012
THIS DRAWING PRODUCED ON PRO/ENGINEER

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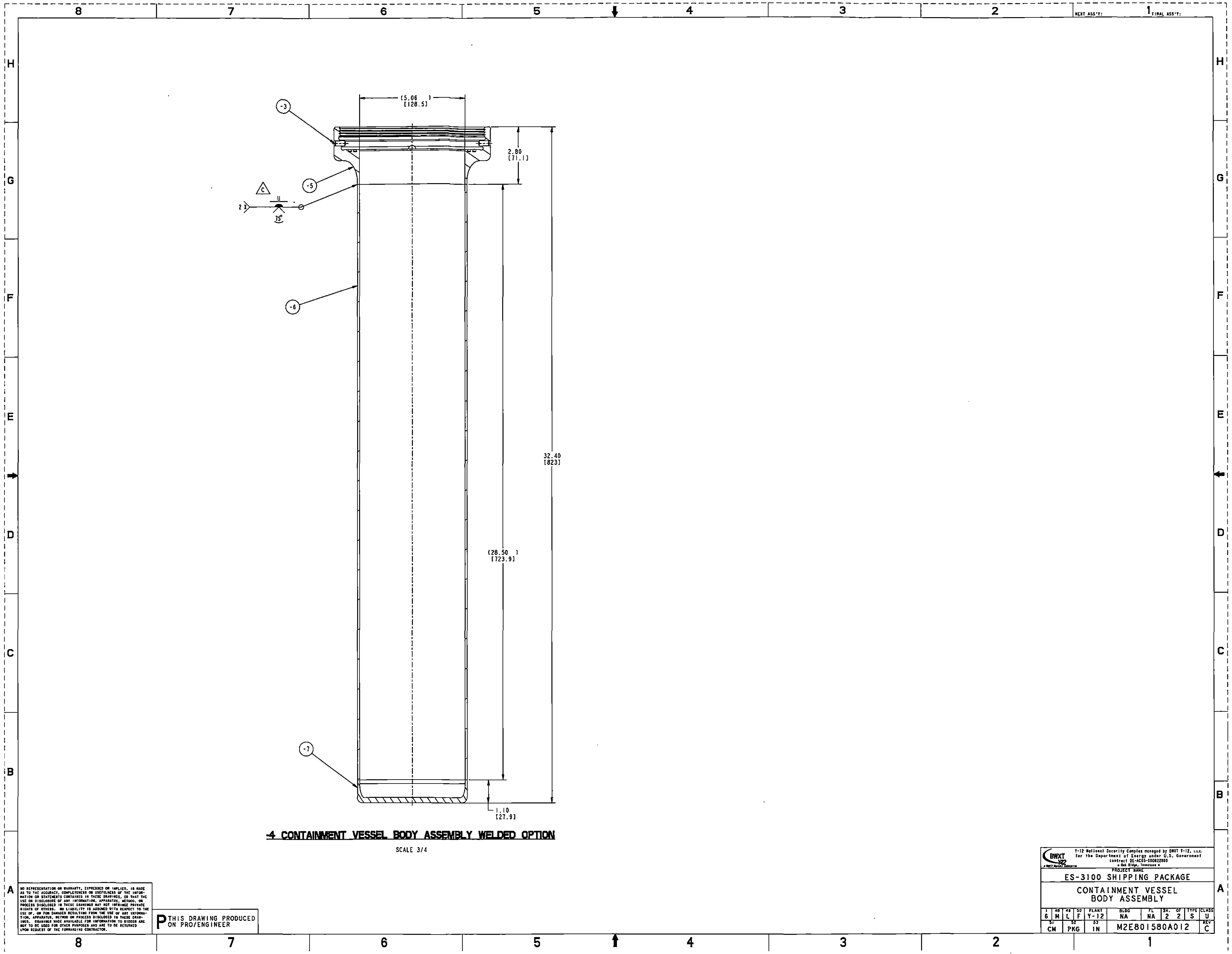
(5.06)
[128.5]
2.80
[71.1]
32.40
[823]
(28.50)
[723.9]
1.10
[27.9]
-3
-5
-6
-7
15°
-4 CONTAINMENT VESSEL BODY ASSEMBLY WELDED OPTION
SCALE 3/4
THIS DRAWING PRODUCED ON PRO/ENGINEER
Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800
Oak Ridge, Tennessee
PROJECT NAME
ES-3100 SHIPPING PACKAGE
CONTAINMENT VESSEL
BODY ASSEMBLY
PLANT Y-12
BLDG NA
FL NA
SH. 2 OF 2
TYPE S
CLASS U
CM
PKG
IN
M2E801580A012
REV C

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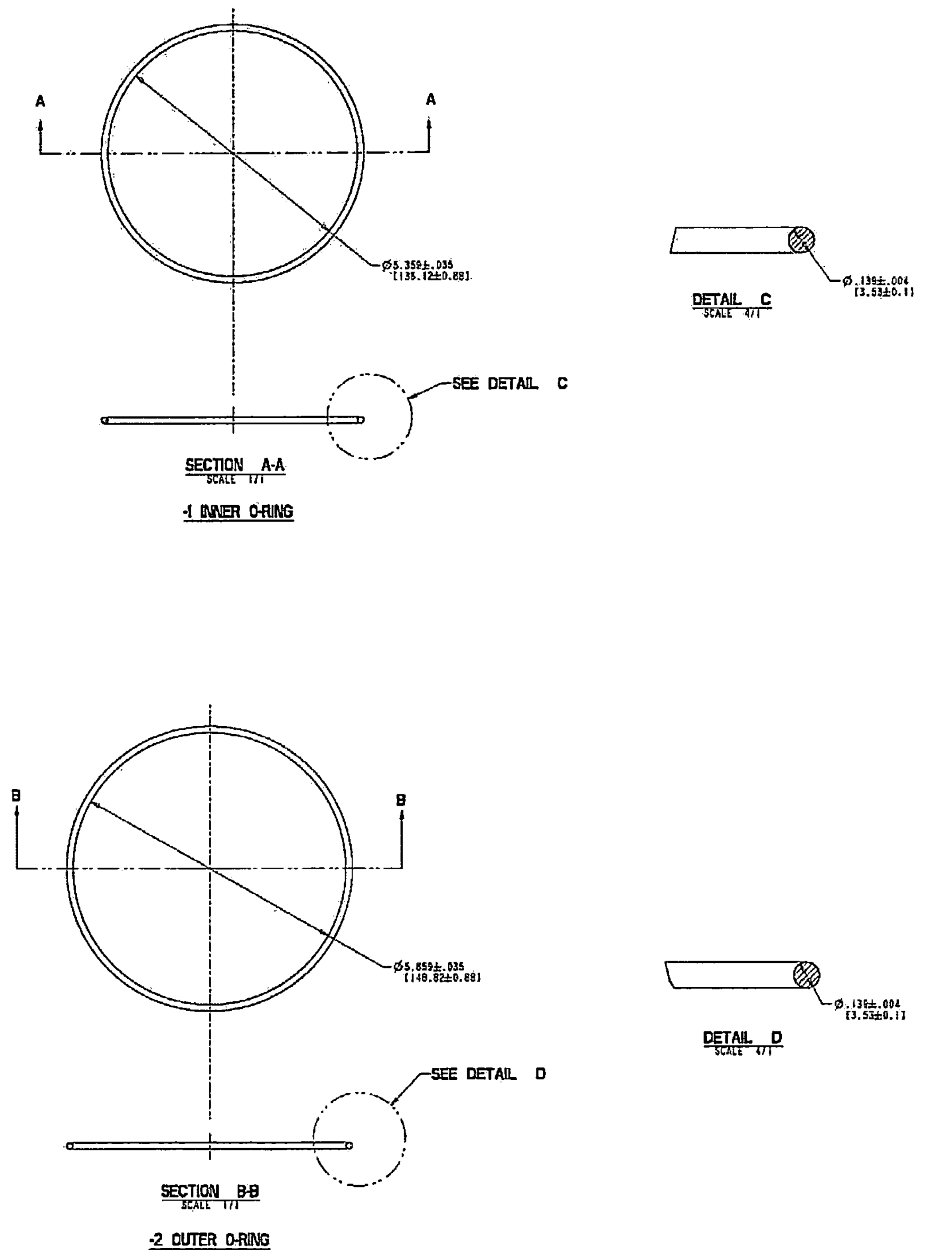
UNCLASSIFIED



NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES.[mm].
4. (D) O-RING SHALL MEET THE REQUIREMENTS SPECIFIED IN EQUIPMENT SPECIFICATION SPC-M801580-0002.

PARTS LIST

M2E801580 A123-2	M2E801580 A013-1	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
	AR	-2	OUTER O-RING	SEE NOTE 4		2
AR	AR	-1	INNER O-RING			1
← QTY REQ'D NEXT ASSEMBLY						

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REVISION	DATE	SAE APPROVAL
D	08/05/2012	J.F. DeCLUE

This document has been reviewed by a Y-12 DC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: DREW WINDER Date: 6/06/2012

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PART	REV	DESCRIPTION (REVISION OR ISSUE PURPOSE)
000	D	RESPECIFIED MATERIAL COMPOSITION AND SPECIFICATION FOR O-RINGS
000	C	ADDED REFERENCE NOTE 5.
000	B	GEN REV: -1 WAS 2-253; -2 WAS 2-257; 302°F WAS 300°F
000	A	ISSUED FOR PROTOTYPE PROCUREMENT

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONS; XX DECIMALS ±.01; XXX DECIMALS ±.005; ANGLES ±0.5°; BREAK SHARP EDGES .03 MAX; FINISH 125 RMS

DRAWING APPROVALS

DRW	JRJ/D.W. SPARKS	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	GAB	10/29/03
SUP	J.L. HICKS	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
SE		
DRTED	D.R. MILLER	10/29/03
WE	N/R	

Y-12 National Security Complex managed by B & W Technical Services Y-12, LLC for the Department of Energy under U.S. Government contract DE-AC05-00OR22800, Oak Ridge, Tennessee

PROJECT NAME: ES-3100 SHIPPING PACKAGE

CONTAINMENT VESSEL O-RING DETAILS

CAE	DIAG	DT	DC	CH	SYSTEM	STATUS	SIZE	BLDG	FL	CLASS
6	N	L	F	CH	PKG	IN	E	NA	NA	U

SH.	OF	TYPE		PART	REV
1	1	DD	M2E801580A013	000	D

UNCLASSIFIED

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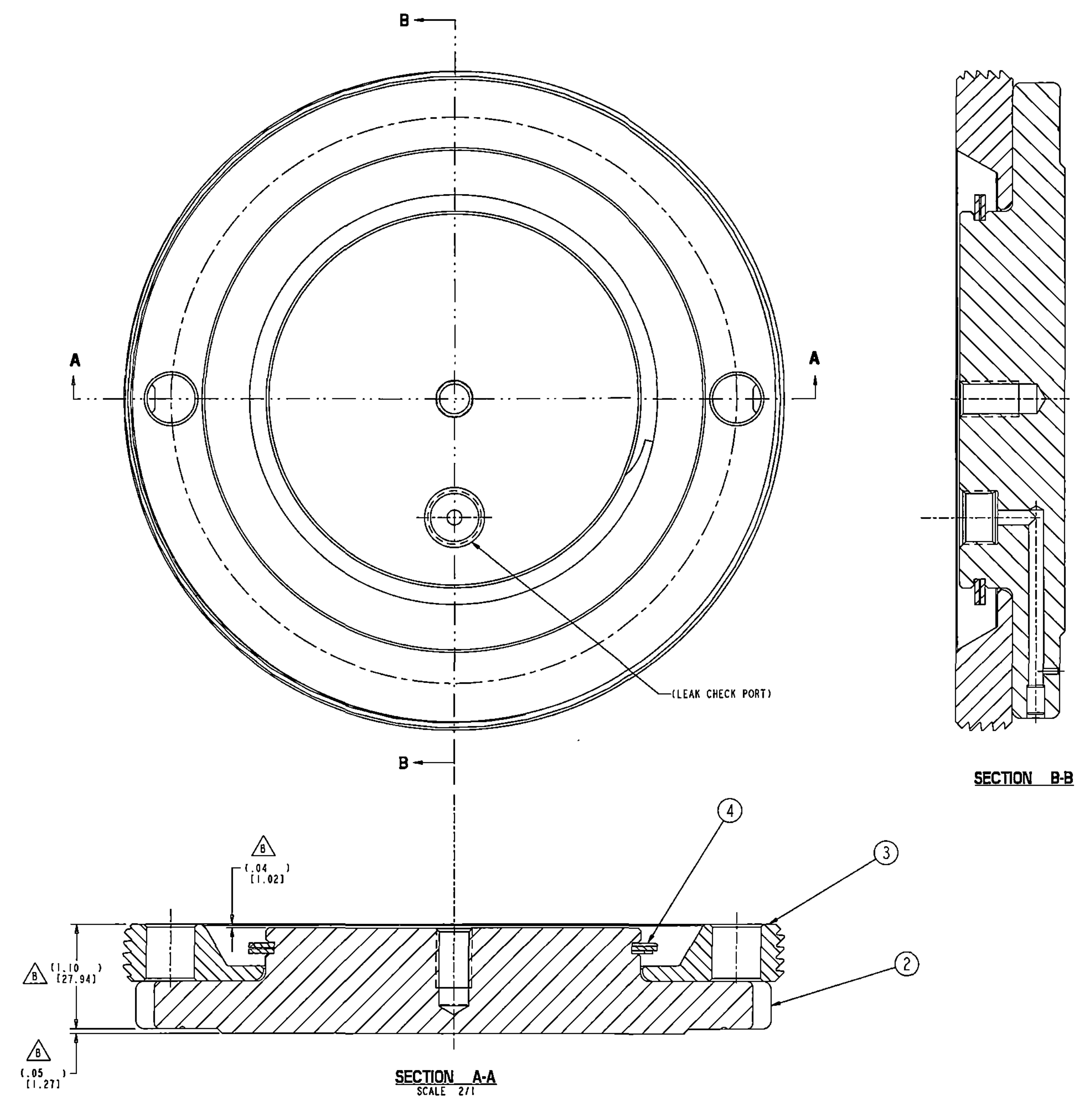
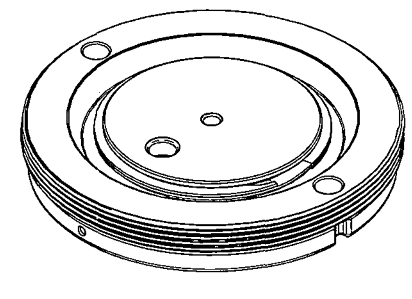


-1 CONTAINMENT VESSEL LID ASSEMBLY



ISOMETRIC VIEW
SCALE 1/1

NOTES

1. INTERPRET DRAWING PER ENGINEERING DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994. PERFECT ORIENTATION AT MMC FOR INTERRELATED FEATURES REQUIRED.
3. DIMENSIONS ARE IN INCHES [mm].
4. APPROXIMATE WEIGHT: 10.54 LBS [4.78 Kg].
5. FOR ADDITIONAL REQUIREMENTS SEE JS-YMN3-801580-A001.

M2E801580 A023-2	M2E801580 A011-1	-	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
		1	WSM-400-S02	EXTERNAL RETAINING RING	SMALLEY STEEL RING CO. 385 GILMAN AVE. WHEELING, IL 60090		4
		1	M2E801580A016-1	CONTAINMENT VESSEL CLOSURE NUT			3
		1	M2E801580A015-1	CONTAINMENT VESSEL SEALING LID			2
AR	AR	X	-1	CONTAINMENT VESSEL LID ASSEMBLY			1
← QTY REQD NEXT ASSY				PARTS LIST			

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
B	2/10/05	JF DECLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: ROGER D. AIGNER Date: 2/10/05

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DM	DATE	PE	DATE	PM	DATE
B	GEN. REV. THREAD RELIEF IN SECTION B-B; DIMS WERE 3 PLACE	JRP	SMM	GAB	RDA	DPS	11/23/05	GAB	2/10/05	JGA	2/10/05
A	ISSUED FOR PROTOTYPE PROCUREMENT	DWS	JSL	GAB	JLH	JCW	10/29/03	MRF	10/29/03	DBM	10/29/03

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK (AR, CV, ST, HV, EM, TP, PD, EE, IE, M, NP)

SCALE: NOTED
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS
XXX DECIMALS
ANGLES
BREAK SHARP EDGES MAX
FINISH

DRAWING APPROVALS		DATE
DRW	JRJ for D.W. SPARKS	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

BWXT Y-12 — Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800 • Oak Ridge, Tennessee •

PROJECT NAME: ES-3100 SHIPPING PACKAGE

CONTAINMENT VESSEL LID ASSEMBLY

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	S	U

51	52	53		REV
CM	PKG	IN	M2E801580A014	B

M2E801580A014

NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, IS MADE AS TO THE ACCURACY, COMPLETENESS OR USEFULNESS OF THE INFORMATION OR STATEMENTS CONTAINED IN THESE DRAWINGS, OR THAT THE USE OR DISCLOSURE OF ANY INFORMATION, APPARATUS, METHOD, OR PROCESS DISCLOSED IN THESE DRAWINGS MAY NOT INFRINGE PRIVATE RIGHTS OF OTHERS. NO LIABILITY IS ASSUMED WITH RESPECT TO THE USE OF, OR FOR DAMAGES RESULTING FROM THE USE OF ANY INFORMATION, APPARATUS, METHOD OR PROCESS DISCLOSED IN THESE DRAWINGS. DRAWINGS MADE AVAILABLE FOR INFORMATION TO BIDDER ARE NOT TO BE USED FOR OTHER PURPOSES AND ARE TO BE RETURNED UPON REQUEST OF THE FORWARDING CONTRACTOR.

P THIS DRAWING PRODUCED ON PRO/ENGINEER

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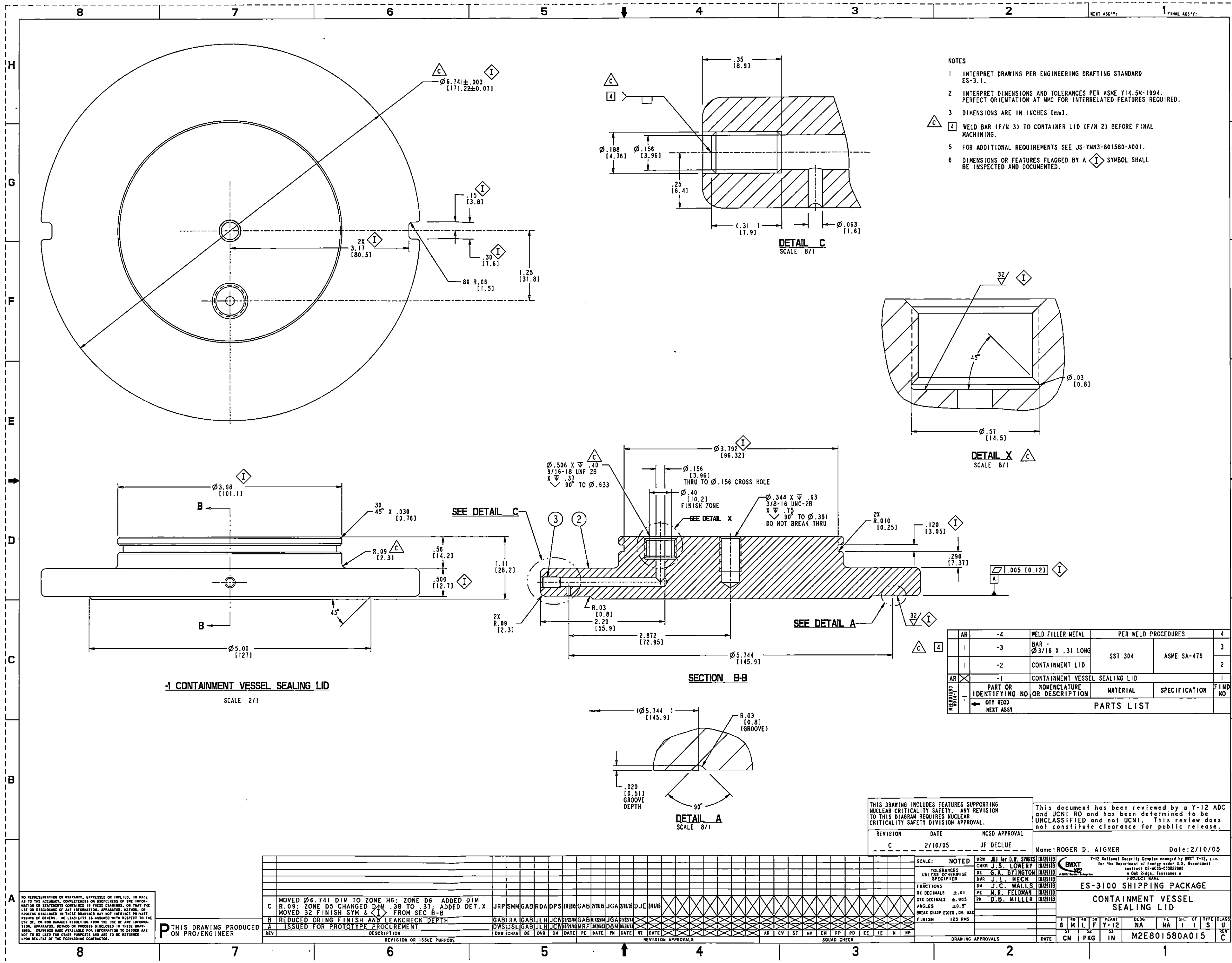
NOTES
1 INTERPRET DRAWING PER ENGINEERING DRAFTING STANDARD ES-3.1.
2 INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994. PERFECT ORIENTATION AT MMC FOR INTERRELATED FEATURES REQUIRED.
3 DIMENSIONS ARE IN INCHES [mm].
4 WELD BAR (F/N 3) TO CONTAINER LID (F/N 2) BEFORE FINAL MACHINING.
5 FOR ADDITIONAL REQUIREMENTS SEE JS-YMN3-801580-A001.
6 DIMENSIONS OR FEATURES FLAGGED BY A I SYMBOL SHALL BE INSPECTED AND DOCUMENTED.
DETAIL C
SCALE 8/1
DETAIL X
SCALE 8/1
-1 CONTAINMENT VESSEL SEALING LID
SCALE 2/1
SECTION B-B
SEE DETAIL C
SEE DETAIL A
SEE DETAIL X
DETAIL A
SCALE 8/1
PARTS LIST
WELD FILLER METAL
PER WELD PROCEDURES
BAR - Ø3/16 X .31 LONG
SST 304
ASME SA-479
CONTAINMENT LID
CONTAINMENT VESSEL SEALING LID
THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.
REVISION C DATE 2/10/05 NCSD APPROVAL JF DECLUE
This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.
Name: ROGER D. AIGNER Date: 2/10/05
MOVED Ø6.741 DIM TO ZONE H6; ZONE D6 ADDED DIM R.09; ZONE D5 CHANGED DIM .38 TO .37; ADDED DET. X MOVED 32 FINISH SYM & I FROM SEC B-B
REDUCED ORING FINISH AND LEAKCHECK DEPTH
ISSUED FOR PROTOTYPE PROCUREMENT
THIS DRAWING PRODUCED ON PRO/ENGINEER
SCALE: NOTED
DRW JRJ for D.W. SPARKS
CHKR J.S. LOWERY
DE G.A. BYINGTON
DVR J.L. HECK
DM J.C. WALLS
PE M.R. FELDMAN
PM D.B. MILLER
Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800
Oak Ridge, Tennessee
ES-3100 SHIPPING PACKAGE
CONTAINMENT VESSEL SEALING LID
M2E801580A015
REV C

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NOTES

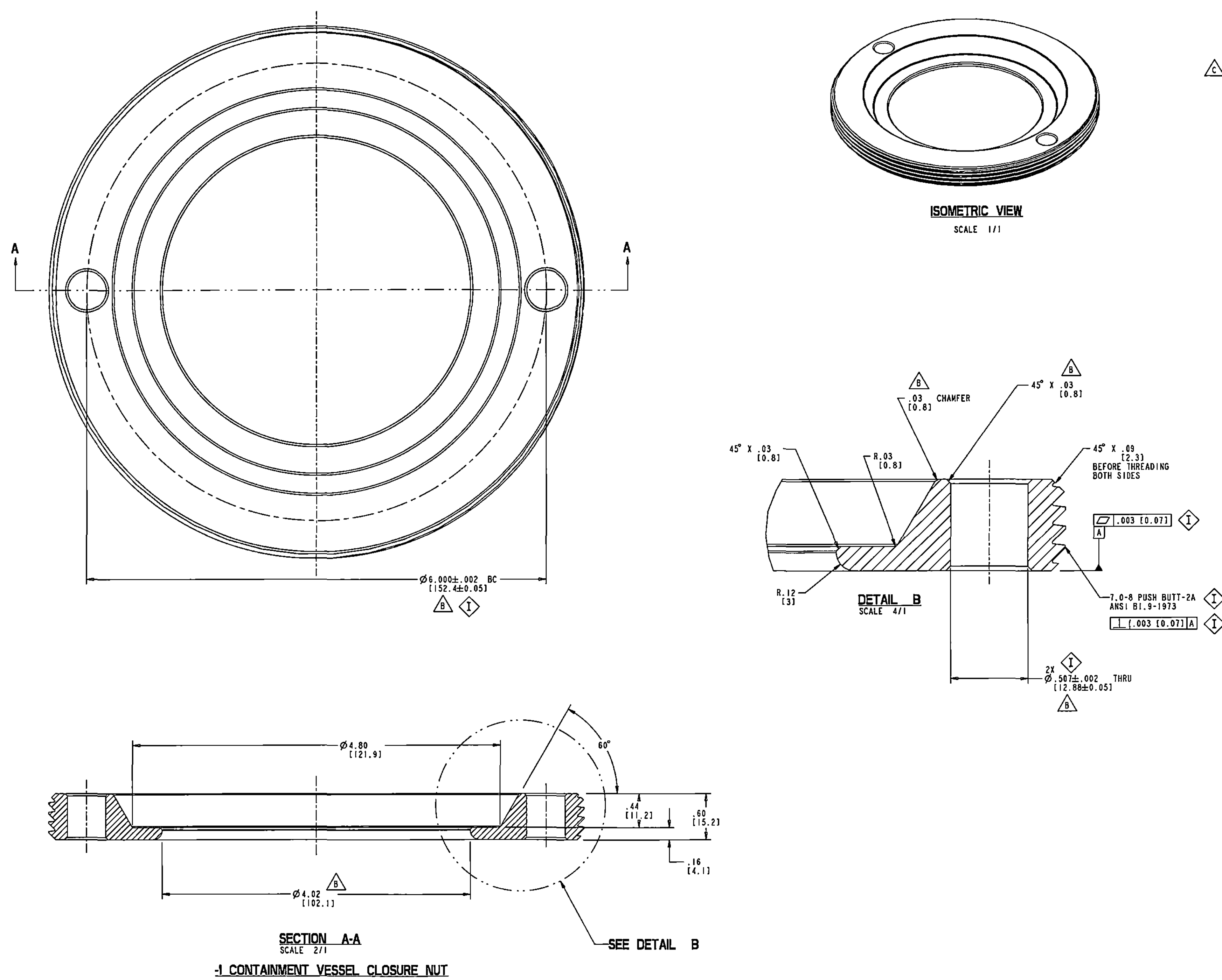
1 INTERPRET DRAWING PER ENGINEERING DRAFTING STANDARD ES-3.1.

2 INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994. PERFECT ORIENTATION AT MMC FOR INTERRELATED FEATURES REQUIRED.

3 DIMENSIONS ARE IN INCHES [mm].

(C) 4 FOR ADDITIONAL REQUIREMENTS SEE JS-YMN3-801580-A001.

5 DIMENSIONS AND FEATURES FLAGGED BY A (I) SYMBOL SHALL BE INSPECTED AND DOCUMENTED.1



AR	AR	-1	CONTAINMENT VESSEL CLOSURE NUT	NITRONIC 60 SST	ASME SA-479 UNS-S21800	1
M2E801580A016	M2E801580A015	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
← QTY REQD NEXT ASSY		PARTS LIST				

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
B	2/10/05	JF DECLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: ROGER D. AIGNER Date: 2/10/05

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DM	DATE	PE	DATE	PM	DATE
B	ADDED CHAMFER IN DETAIL B; MOD. HOLE TOL. REMOVED NOTE 4; RENUMBERED NOTES IN GEN MOTES	JRP	SMM	GAB	RDA	DPS	11/17/05	GAB	2/10/05	JGA	2/10/05
A	ISSUED FOR PROTOTYPE PROCUREMENT	DWS	JSL	GAB	JLH	JCW	10/29/03	MRF	10/29/03	DBM	10/29/03

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK: AR CV ST HV EM FP PD EE IE M NP

P THIS DRAWING PRODUCED ON PRO/ENGINEER

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±.01
XXX DECIMALS ±.005
ANGLES ±0.5°
BREAK SHARP EDGES .06 MAX
FINISH 125 RMS

DRAWING APPROVALS		DATE
DRW	JRJ for D.W. SPARKS	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

BWXT Y-12 — Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800 • Oak Ridge, Tennessee •

PROJECT NAME: ES-3100 SHIPPING PACKAGE

CONTAINMENT VESSEL CLOSURE NUT

1	48	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	S	U

51	52	53		REV
CM	PKG	IN	M2E801580A016	B

M2E801580A016

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UNCLASSIFIED

NOTES

1 INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1

2 INTERPRET DIMENSIONS AND TOLERANCES PER "RMA" RUBBER HANDBOOK (RMA-3E2) CLASS "A2 PRECISION."

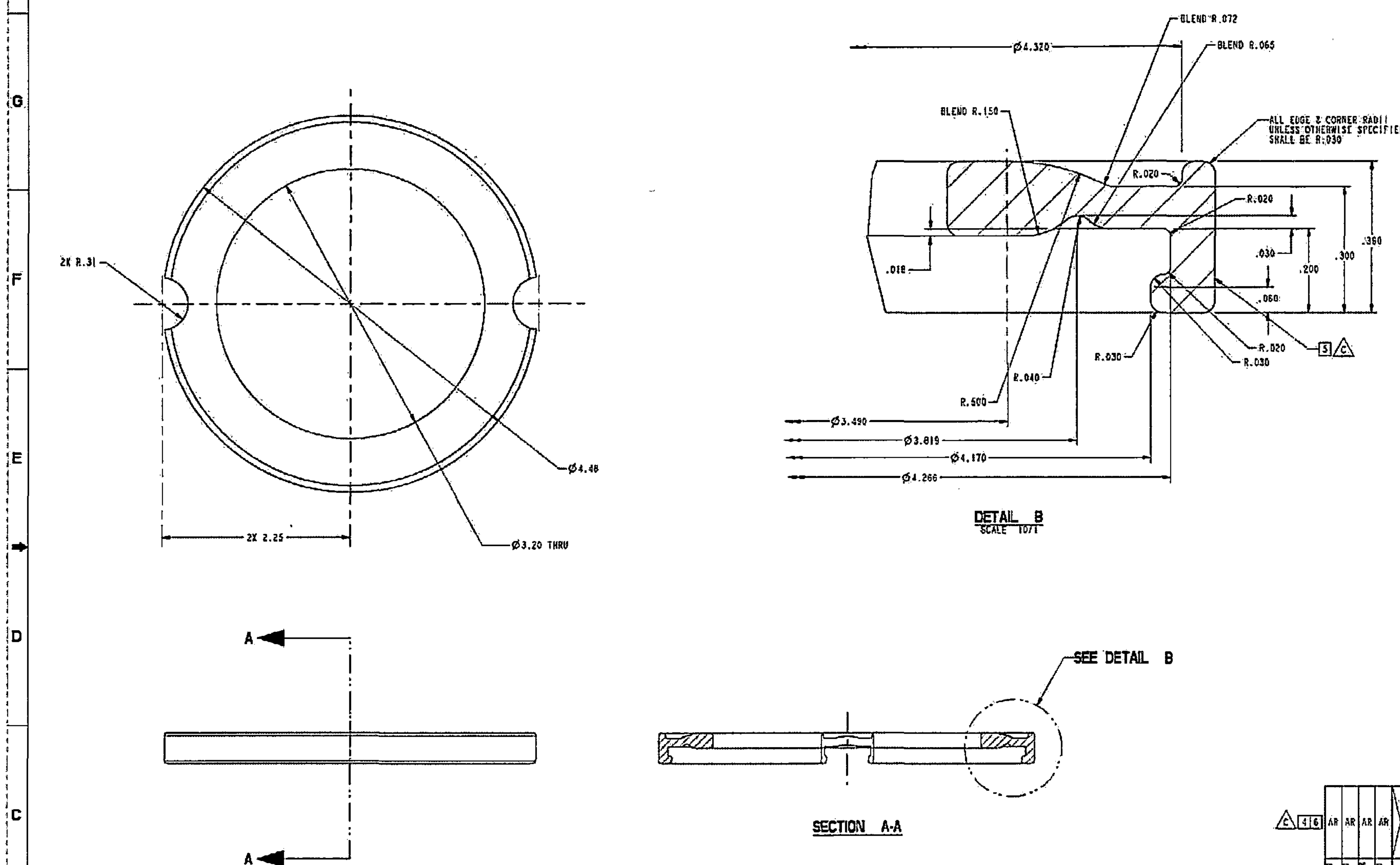
3 DIMENSIONS ARE IN INCHES.

[4] MANUFACTURER/SUPPLIER TO PROVIDE CERTIFICATE OF COMPLIANCE FOR ALL FEATURES OF THESE ITEMS.

(C) [5] IN APPROXIMATE LOCATION SHOWN, ENGRAVE DRAWING NUMBER AND REVISION LETTER IN 1/4" HIGH CHARACTERS IN THE MOLD TO MAKE A LEGIBLE RAISED MARKING IN THE PART.

(C) [6] FOR ADDITIONAL INFORMATION SEE EQUIPMENT DATA SHEET DS-801580-0002.

7 FOR REFERENCE ONLY:
WEIGHT: 0.0588 LBS (26.7 g)



-1 CONTAINMENT VESSEL VIBRATION ABSORBING SILICONE 4.25" CAN PAD
SCALE 2/1

QTY REQ'D					PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
(C) [4][6] AR	AR	AR	AR	AR	CONTAINMENT VESSEL VIBRATION ABSORBING SILICONE 4.25" CAN PAD	CONTAINMENT VESSEL VIBRATION ABSORBING SILICONE 4.25" CAN PAD	SILICONE RUBBER, ASO-838, SILICA FILLED, LOW HYDROGEN AND LOW VOLATILE VAPORS, POST CURED HARDNESS 25+/- 5 SHORE A	SEE NOTE 6	1

PARTS LIST

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY ANALYSIS ENGINEERING APPROVAL.

REVISION	DATE	SAE APPROVAL
C	06/05/2012	J.I. DeCLUE

This document has been reviewed by a Y-12 DC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: DREW WINDER Date: 05/06/12

THIS DRAWING PRODUCED ON PRO/ENGINEER

THIS DRAWING IS LOANED FOR SOLE USE OF THE INTENDED RECIPIENT AND ONLY FOR THE LIMITED PURPOSES FOR WHICH IT WAS PROVIDED. USE BY OTHER ENTITIES OR FOR OTHER PURPOSES IS PROHIBITED AND AT THE USER'S OWN RISK. DRAWINGS ARE TO BE RETURNED UPON REQUEST OF THE FORWARDING RECIPIENT.

PART	REV	DESCRIPTION
000	C	REVISED NOTES 5 & 6
000	B	DELETED NOTE 8: ADDED NEXT ASS'Y TO BOM CHNG LOCATION OF INDEX NOTE 5 TO DET. B
000	A	ISSUED FOR DESIGN REVIEW

SCALE: NOTED

DRW R.D. AIGNER; CHKR J.S. LOWERY; DE G.A. BYINGTON; SUP J.L. HECK; DM J.C. WALLS; PE G.A. BYINGTON; DATED G.H. SINGLETON; ME N/R

Y-12 National Security Complex

PROJECT NAME: ES-3100 SHIPPING PACKAGE

CONTAINMENT VESSEL VIBRATION ABSORBING SILICONE 4.25 CAN PADS

M2E801580A024

UNCLASSIFIED

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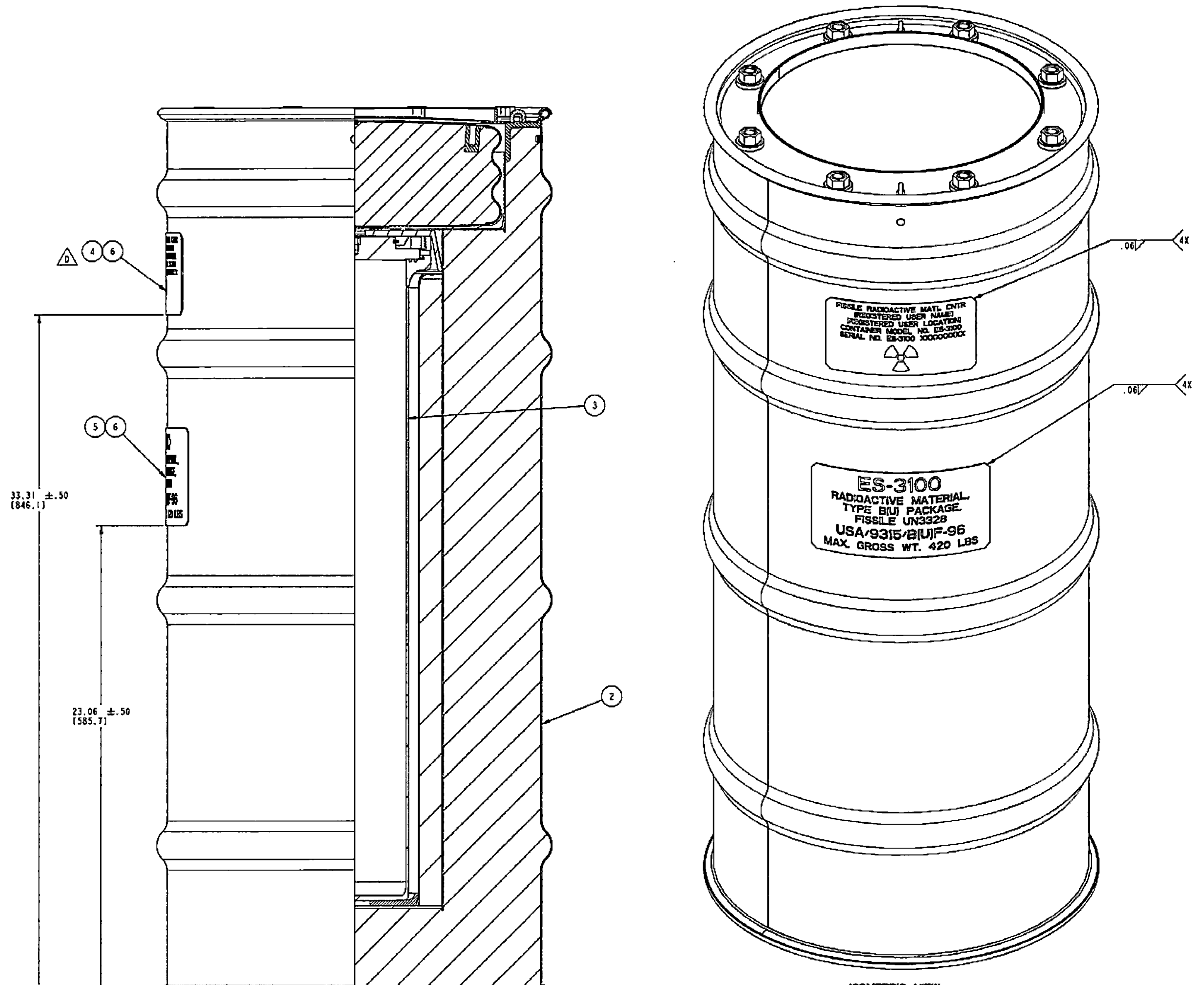
NOTES

1. INTERPRET DRAWING PER MECHANICAL DRAFTING STANDARD ES-3.1.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES [mm].
4. APPROXIMATE WEIGHT: 323.8 LBS [146.9 Kg]
5. FOR ADDITIONAL REQUIREMENTS SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A002.
6. WELDING SYMBOLS SHALL BE INTERPRETED IN ACCORDANCE WITH AWS A2.4.



ISOMETRIC VIEW
SCALE 1/2

-1 MAIN ASSEMBLY
SCALE 1/2

QTY. REQ'D	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
AR	-6	WELD FILLER METAL			6
1	M2E801580A010-2	ES-3100 DATA PLATE			5
1	M2E801580A010-1	ES-3100 TREFOIL DATA PLATE			4
1	M2E801580A011-1	CONTAINMENT VESSEL ASSEMBLY			3
1	M2E801580A001-1	DRUM ASSEMBLY			2
X	-1	MAIN ASSEMBLY			1

PARTS LIST

THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DIAGRAM REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REVISION	DATE	NCSD APPROVAL
D	09/10/08	J.F. DeCLUE

This document has been reviewed by a Y-12 ADC and UCNI RO and has been determined to be UNCLASSIFIED and not UCNI. This review does not constitute clearance for public release.

Name: R.D. AIGNER Date: 09/11/08

REV	DESCRIPTION	DRW	CHKR	DE	DVR	DM	DATE	PE	DATE	PM	DATE	ET	DATE
D	REVISED TREFOIL DATA PLATE	JRJ	RDA	LR	GAB	WIN	[illegible]	LR	[illegible]	JGA	[illegible]	NA	NA
C	REVISED TREFOIL DATA PLATE	JRJ	RDA	JRJ	GAB	WIN	[illegible]	[illegible]	[illegible]	JGA	[illegible]	NA	NA
B	GEN REV;CHG. NOTE 4;ADDED NOTES 5 & 6; CHG. F/N 6 WAS BLIND RIVIT;WEIGHTS & VOLS IN NOTE 10 UPDATED TO REFLECT NEW MAT'L.	JRP	SMM	GAB	RDA	DPS	[illegible]	GAB	[illegible]	JGA	[illegible]	DJE	[illegible]
A	ISSUED FOR PROTOTYPE PROCUREMENT	JRJ	JSL	GAB	JLH	JCW	[illegible]	MRF	[illegible]	DBM	[illegible]		

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SOUND CHECK

P THIS DRAWING PRODUCED ON PRO/ENGINEER

SCALE: NOTED

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±.20
XXX DECIMALS
ANGLES
BREAK SHARP EDGES MAX
FINISH

DRAWING APPROVALS		DATE
DRW	J.R. JACKSON	10/29/03
CHKR	J.S. LOWERY	10/29/03
DE	G.A. BYINGTON	10/29/03
DVR	J.L. HECK	10/29/03
DM	J.C. WALLS	10/29/03
PE	M.R. FELDMAN	10/29/03
PM	D.B. MILLER	10/29/03

BWXT Y-12
Y-12 National Security Complex managed by BWXT Y-12, L.L.C. for the Department of Energy under U.S. Government contract DE-AC05-00OR22800
Oak Ridge, Tennessee

PROJECT NAME
ES-3100 SHIPPING PACKAGE

MAIN ASSEMBLY

1	46	49	50	PLANT	BLDG	FL	SH.	OF	TYPE	CLASS
6	M	L	F	Y-12	NA	NA	1	1	A	U

51	52	53		REV
CM	PKG	IN	M2E801580A031	D

M2E801580A031

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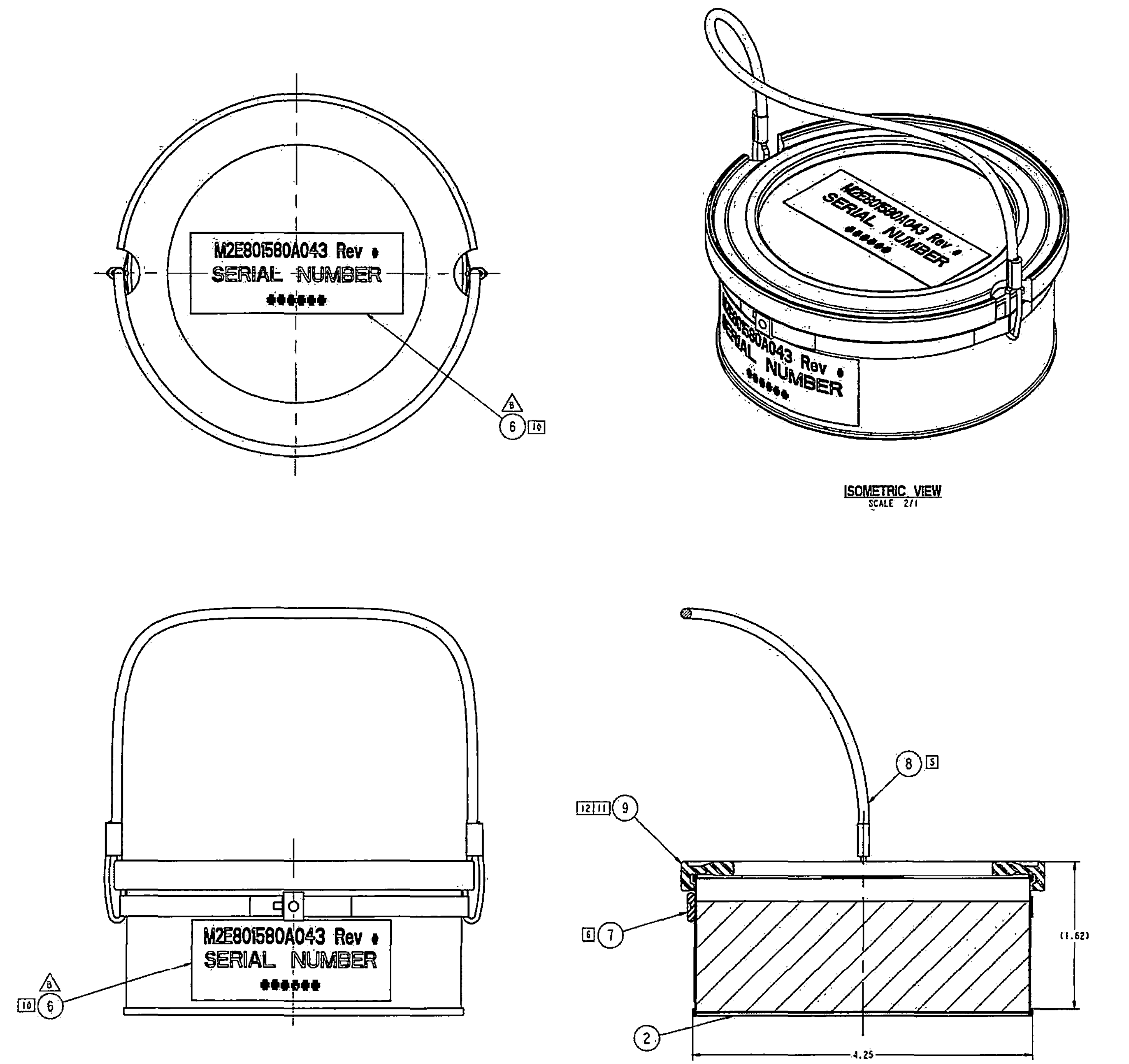
UNCLASSIFIED

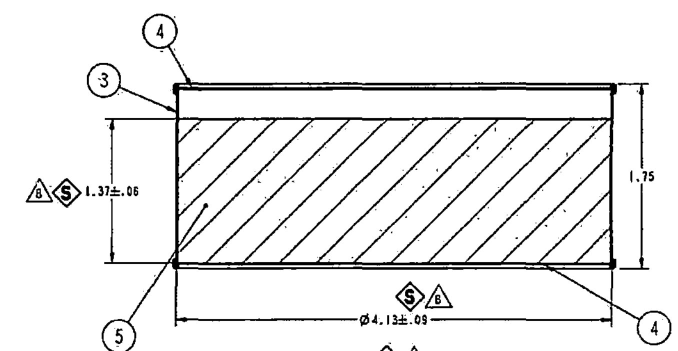
NOTES

1. DELETED
2. DELETED
3. DELETED
4. FOR FURTHER INFORMATION, SEE EQUIPMENT SPECIFICATION JS-YMN3-801580-A005, CASTING CATALOG NO. 277-4 NEUTRON ABSORBER.
5. FOR PURCHASE OF F/N 8, SEE DOCUMENT #DS-YMN3-801580-A001.
6. USE THE BAND-IT TIE-LOCK II HAND TOOL "A920" TO ATTACH THE STAINLESS STEEL BANDS AND CABLE ASSEMBLIES TO THE MATERIAL CANS. THE TOOL'S TENSION SETTING SHALL BE SET BETWEEN 4 AND 8.
7. REFERENCE DOCUMENT #DAC-YMN3-801580-A001.
8. FOR REFERENCE ONLY FIND NO 1; NOMINAL WEIGHT: 1.38 LBS [0.626 KG]
9. DELETED
10. MARK WITH PERMANENT LABELS F/N 6 DRAWING NUMBER, REVISION LETTER AND SIX DIGIT SERIAL NUMBER IN .18±.03 HIGH CHARACTERS.
11. SUPPLIED BY COMPANY.
12. FOR SHIPMENTS, THE USE OF VIBRATION PAD, FIND NO.9 WITH HEAVY CAN SPACER, IS OPTIONAL.



ISOMETRIC VIEW
SCALE 2/1

-1 HEAVY CAN SPACER ASSEMBLY (SST)
SCALE 2/1



MINIMUM WEIGHT: 1.16 LB [526 G]
MAXIMUM WEIGHT: 1.56 LB [707 G]

-2 FILLED CAN
SCALE 2/1

PARTS LIST

Note	-2	-1	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	FIND NO
12 11		AR	M2E801580A024-1	VIBRATION ABSORBING SILICONE 4.25" CAN PAD			9
5		1	-8	CABLE LANYARD	REFERENCE NOTE 5		8
6		1	AS213	BAND CLAMP	304 SST	BAND-IT-IDEX, INC. DENVER, CO 80216	7
B 10		2	WL-OL875WJ OR EQUAL	2.625" BY 1" VINYL COATED WEATHERPROOF WHITE PRINTER LABELS		WORLDLABEL.COM 335 CONVENT AVE, STE 2A NEW YORK NY 10031 SALES (866) 226-8869	6
4	AR		-5	277-4 FILLER		JS-YMN3-801580-A005	5
	2		-4	CAN END COVER	304/304L STAINLESS STEEL 30 GA. (0.012)	ASTM A240	4
	1		-3	CAN BODY	304/304L STAINLESS STEEL 30 GA. (0.012)	ASTM A240	3
	X	1	-2	FILLED CAN			2
		X	-1	HEAVY CAN SPACER ASSEMBLY (SST)			1

QTY REQD NEXT ASSEMBLY

UNCLASSIFIED

THIS DOCUMENT HAS BEEN REVIEWED BY A Y-12 DC/UCNI-RO AND HAS BEEN DETERMINED TO BE UNCLASSIFIED AND CONTAINS NO UCNI. THIS REVIEW DOES NOT CONSTITUTE CLEARANCE FOR PUBLIC RELEASE.

NAME: STAN THOMAS
DATE: 05/01/16
TITLE: PKG ENGR
ORGANIZATION: PACKAGING

CURRENT ISSUE APPROVALS
DES RW JOHNSON — ACS AD WILKINSON
DT LA BYINGTON
CHKR L ROBERSON
DVR ML GOINS
SE N/A
PE L ROBERSON
EM JC ANDERSON

NUCLEAR CRITICALITY SAFETY
THIS DRAWING INCLUDES FEATURES SUPPORTING NUCLEAR CRITICALITY SAFETY. ANY REVISION TO THIS DRAWING REQUIRES NUCLEAR CRITICALITY SAFETY DIVISION APPROVAL.

REV	DATE	REVISION DESCRIPTION
B	3/3/2016	UPDATED FORMAT, MODIFIED REV LETTERS ON F/N 6 & CALL OUT ON PARTS LIST. DELETED NOTES 1-3 & 9. CHANGED DIAMOND 1 TO DIAMOND 5 ON F/N 2.
A	6/11/12	REVISED NOTES AND ADDED NOTE 12 FOR FIND NO.9
0	9/10/09	ORIGINAL ISSUE

NEXT ASSEMBLY/REFERENCE DOCUMENTS: N/A

SCALE: NOTED
SHEET SIZE REPRESENTATION: 1 INCH SQUARE AT FULL SIZE
SCALE PROVIDED FOR REFERENCE ONLY DO NOT SCALE

TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONS; XX DECIMALS ±.01; XXX DECIMALS ±.005; ANGLES ±0.5°; BREAK SHARP EDGES .01-.03; FINISH 125 RMS
THIRD ANGLE PROJECTION

IMPORTANT TO FORM-FIT-FUNCTION INDEPENDENT VERIFICATION REQUIRED
IMPORTANT TO SAFETY SHALL BE 100% INSPECTED AND NOT DEVIATED WITHOUT APPROVAL

APPROXIMATE WEIGHT: N/A
DIMENSIONING AND TOLERANCING: ASME Y14.5M - 1994
ALL DIMENSIONS ARE IN INCHES
SOFTWARE: CREO 2.0

Y-12 NATIONAL SECURITY COMPLEX
CONSOLIDATED NUCLEAR SECURITY, LLC
P.O. BOX 2009 OAK RIDGE, TN 37831
US GOVERNMENT CONTRACT: DE-NA0001942
USERS MUST REFER TO THE TRANSMITTAL DOCUMENTS THAT ACCOMPANIED DELIVERY OF THIS DRAWING FOR ANY APPLICABLE DISCLAIMERS GOVERNING THE DRAWING.

PROJECT: ES-3100 SHIPPING PACKAGE
TITLE: HEAVY CAN SPACER ASSEMBLY (SST)
DRAWING NUMBER: M2E801580A043 — PART 000 — REV B
RECORD NO: N/A — IDIS: N/A — STATE: IF — SHEET 1 OF 1

UNCLASSIFIED

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Appendix 1.4.9

DESIGN ANALYSES AND CALCULATIONS, DAC-PKG-801624-A001, MIXING WEIGHTS AND ELEMENTAL COMPOSITION OF 277-4 NEUTRON POISON USED IN THE ES-3100

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Design Analyses and Calculations

Title Page	
Calculation No.:	DAC-PKG-801624-A001
Calculation Title:	Mixing Weights And Elemental Composition Of 277-4 Neutron Poison used in the ES-3100
Preparer's Organization:	Packaging Engineering
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Comments/Purpose: The purpose of this DAC is to enable a tight quality control on the amount of neutron poison materials used in each shipping package.

Printed Name and Signature

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Revision Log

Rev	Date	Description	Total Pages	Affected Pages
0	January 18, 2006	Initial issue	Front matter, 1-3 Body 4-21 Appendix 1, 22-24 Appendix 2, 24	All
A	January 20, 2006	Removed Report references and Updated Tables 10, 11, 12, and 13.	Front matter, 1-3 Body 4-21 Appendix 1, 22-24 Appendix 2, 24	4, 10, 18, 19, 20
B	October 12, 2006	Updated Table 7, 277-4 Composition @ Extreme Densities and LOD%. Updated DAC format to new log. New DAC format applied.	Front matter, 1-3 Body 4-22 Appendix 1, 23-24 Appendix 2, 25	1, 2, 14

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1. Objective

The purpose of this DAC is to define the amounts of materials to mix and manufacture the borated cement neutron poison used in the ES-3100 Shipping Container as one batch per shipping container. The exact amount of B_4C added to be the mixture shall be calculated in this design analysis to be greater than 7.61×10^{20} atoms/cc of ^{10}B at the minimum density and maximum hydration. This elemental analysis of the minimum value of ^{10}B was used in the ES-3100 SAR Criticality Safety calculations.

2. Purpose

By adding the proper amount of boron carbide in each ES-3100 Shipping Container mass balanced, assuming thorough mixing, macro homogeneity is obtained. This will enable a tight quality control on the amount of neutron poison materials used in each shipping package.

3. References

The ES-3100 Shipping Container is placed in BWXT Y-12 National Security Complex drawing M2E801580A002 following Equipment Specification JS-YMN3-8015580-A005. Two sample cans are taken during each shipping package pouring of the casting into drawing M2E801580A026-2.

4. Materials to Mix

4.1. B_4C

Boron carbide (B_4C) powder shall be procured as Type 1 Nuclear-Grade Boron Carbide Powder per ASTM C 750-03 shipped in sealed steel containers. An approximate partial size of 106 micrometers (0.0041 inches) is generated by having 100% of the grit pass through a No. 140 Sieve per ASTM E 11. A copy of the chemical and elemental analysis purity shall be in accordance with ASTM C 791.

4.2. 277-0

Thermo Electron's proprietary Catalog No. 277 – Heat Resistant Shielding (with no Boron), is a type of high alumina cement and will be referred to as 277-0. The manufactures information can be found in Appendix 1 & 2. This dry powder shall be shipped in sealed open head steel drums and has no shelf life limitations if keep dry and free flowing. Once the container is opened it shall be discarded if clumps or lumps are observed in the material greater than 0.5 inches.

4.3. Water

The water shall be potable, filtered through a 20-micron filter, and have a chlorine content of less than 4 ppm. If the potable water's chlorine content is higher then 4 ppm, use an activated charcoal filter or some other means to reduce the amount of chlorine below 4 ppm.

5. Scope of Calculations

The bounding elemental calculations shall be completed at the minimum ^{10}B level for the compositional purity, isotopic atomic percentage, and scale measurements.

5.1. Amount of B_4C in 277-4 Borated High Alumina Cement

Define the method for mixing 277-4 as a two part method of 277-0 and B_4C and calculate the volumetric atomic concentrations.

5.2. 277-4 Borated High Alumina Cement at Extreme Conditions

Calculate the minimum amount of B_4C to add to the 277-4 mixture to generate a volumetric atomic concentration greater than 7.61×10^{20} atoms/cc of ^{10}B at the minimum density and maximum hydration.

5.3. ^{10}B Areal Density at Minimum ^{10}B Content and Density

Calculate the ^{10}B Areal Density between the fissile mass loads in two adjacent shipping packages.

5.4. Volumetric Atomic Concentrations at Average Density and LOD%

Calculate the average density and hydration volumetric atomic concentrations.

5.5. Extreme Densities and LOD% Volumetric Atomic Concentrations

Calculate the extreme density and hydration volumetric atomic concentrations.

5.6. Define the Masses Needed To Mix a Batch of 277-4 For a ES-3100

Calculate the mass weights used to mix a batch used in one ES-3100.

5.7. Define the Volumetric Atomic Concentrations at NCT and HAC

At higher temperatures especially above 212°F the chemically unbound or free water will leave the cast cement. Using the minimum boron mixer weights calculated in Section 7.2 define the NCT and HAC volumetric atomic concentrations at a minimum manufactured density, hydration for the calculated temperatures.

5.8. Define the Nominal Volumetric Atomic Concentrations

Using nominal mixer weights from Section 7.6 calculate the nominal ^{10}B content.

6. Base Material Elemental Volumetric Concentrations

6.1. Boron Carbide Powder B_4C

The elemental composition weight percents of B_4C must be defined per ASTM C 750-03, using Type 1 Nuclear-Grade Boron Carbide Powder as noted in Table 1 from ASTM C 750-03.

TABLE 1 Chemical Requirements

Constituent	Composition, Weight %[A]		
	Type 1	Type 2	Type 3
Total boron[B]	81.0 max 76.5 min	81.0 max 73.0 min	81.0 max 70.0 min
HNO_3-soluble boron	0.5 max	0.6 max	not determined
Water soluble boron	0.2 max	0.2 max	1.0 max
Fluoride	25 µg/g max	25 µg/g max	not determined
Chloride	75 µg/g max	75 µg/g max	not determined
Calcium	0.3 max	0.3 max	not determined
Iron	1.0 max	1.0 max	2.0 max
Total boron plus total carbon	98.0 min	97.0 min	94.0 min

[A]Unless otherwise indicated (percentages based on a dry weight of boron carbide).
[B]Unless otherwise specified, the ^{10}B isotopic content in the boron shall be 19.90 ± 0.3 atom % for Types 1 and 2 and 19.90 ± 0.5 atom % for Type 3.

Find the minimum ^{10}B weight percents using ASTM C 750-03 Type 1 at ^{10}B equal to 19.9±0.3 atom % of natural boron (NatB).

At the minimum 19.6 atom % of ^{10}B the ^{11}B would be 100-19.6 = 80.4 atom %.

Using the molecular weights of ^{10}B the ^{11}B:
B10 = 10.0129370×19.6% = 1.962535652 (g/mol)
B11 = 11.0093055×80.4% = 8.851481622 (g/mol)
NatB = B10 + B11 = 1.962535652 + 8.851481622 (g/mol)
NatB = 10.81401727% (g/mol) Min per ASTM C 750-03 Type 1

B10 wt% = B10 / NatB = 1.962535652 / 10.81401727
B10 wt% = 18.14807211 wt% Min per ASTM C 750-03 Type 1

Using the minimum total natural boron of 76.5 wt% the following weight percentages are calculated.

B10 wt% = 76.5% × 18.148 wt%
B10 wt% = 13.883 wt%

B11 wt% = 76.5 − 13.883 wt%
B11 wt% = 62.617 wt%

One of the largest B_4C impurities in Table 1 is the nitric acid (HNO_3). As shown in Table 4 the 277-4 neutron poison solid requires hydrogen and contains a large amount of oxygen. Therefore, a conservative approximation shall be to change the balance of the weight percents from 0.5 to 0.7 wt% and make up the difference with nitrous trioxide (NO_3) removing the hydrogen from this impurity.

Determine the weight percents of nitrous trioxide (NO_3)
NO_3 = MW(N) + 3×MW(O) (g/mol)
NO_3 = 14.0067 + 3×15.9949 (g/mol)
NO_3 = 61.9914 (g/mol)

N wt% = 14.0067 / 61.9914
N wt% = 0.225946 wt%

For 0.7 wt% NO_3
N wt% = 0.225946 % ×0.7 wt%
N wt% = 0.158 wt%

O wt% = NO_3 wt% − N wt%
O wt% = 0.7 − 0.158 wt%
O wt% = 0.542 wt%

Table 2, Nuclear-Grade Boron Carbide Powder Elemental Composition Weight Percents

Element	At.wt (g/mol)	B_4C (wt%)
Hydrogen	1.0078	
B Nat	10.8140	
^{10}B	10.0129	13.883%
^{11}B	11.0093	62.617%
Carbon	12.0000	21.500%
Nitrogen	14.0067	0.158%
Oxygen	15.9949	0.542%
Sodium	22.9895	
Magnesium	24.3051	
Aluminum	26.9818	
Silicon	28.0853	
Sulfur	32.0636	
Calcium	40.0803	0.300%
Iron	55.8447	1.000%
Sum		100.000%

6.2. Catalog No. 277 – Heat Resistant Shielding With no Boron (277-0)

Verify the hydrogen elemental composition weight percent of Thermo Electron's proprietary Catalog No. 277 – Heat Resistant Shielding using the density of 1.61 g/cc (100.509 lb/ft^3), also called 277-0. Used the published weight percents for No. 277 – Heat Resistant Shielding with no boron and calculate the hydrogen atoms per cc. According to Appendix 2; Thermo Electron Corp. Heat Resistant Shielding Catalog No. 277 Typical Elemental Analysis Without Boron, EA-277, May 1988.

Table 3, Catalog No. 277 – Heat Resistant Shielding Elemental Composition for one ft^3

Element	At.wt (g/mol)	(wt%)	(lb/ft^3)	N_e (Atoms/cc)
Hydrogen	1.0078	3.730%	3.749	3.588E+22
B Nat	10.8140			
^{10}B	10.0129			
^{11}B	11.0093			
Carbon	12.0000			
Nitrogen	14.0067			
Oxygen	15.9949	59.140%	59.441	3.585E+22
Sodium	22.9895	0.080%	0.080	3.374E+19
Magnesium	24.3051	0.230%	0.231	9.175E+19
Aluminum	26.9818	26.590%	26.725	9.555E+21
Silicon	28.0853	1.680%	1.689	5.800E+20
Sulfur	32.0636	0.210%	0.211	6.350E+19
Calcium	40.0803	8.040%	8.081	1.945E+21
Iron	55.8447	0.300%	0.302	5.209E+19
Sum		100.00%	100.509	

The calculated value of hydrogen atoms per cc matched the recorded value in the typical elemental analysis of Catalog No. 277 – Heat Resistant Shielding. The following calculations use the molecular weights; Hydrogen 1.0078 g/mol, Oxygen 15.9994 g/mol, and water 18.0153 g/mol.

One must now determine how much water is in this solid casting. Water within the cast solid is defined in a water weight "Loss On Drying" (LOD) test in a weight percent of the initial density. The LOD% is calculated based upon the amount of hydrogen.

LOD% = H wt% × (MW H_2O) / (MW H_2)
LOD% = 3.730% × (18.0150 / (2× 1.0078)
LOD% = 33.338% as defined by the manufacture

$$H\ (lb/ft^3) = \frac{277\ \text{cast density}(lb/ft^3) \times \text{LOD wt\%} \times (2 \times \text{H Mw (g/mol)})}{\text{Water Mw (g/mol)}}$$

$$H\ (lb/ft^3) = \frac{277\ \text{cast density}(lb/ft^3) \times \text{LOD wt\%} \times (2 \times 1.0078\ (g/mol))}{18.0153\ (g/mol)}$$

$$H\ (lb/ft^3) = 277\ \text{cast density}(lb/ft^3) \times \text{LOD wt\%} \times 0.1118826775$$

The volumetric atomic concentrations are calculated below.

$$\text{H atoms/cc} = \frac{((\text{H density(lb/ft}^3)) \times (\text{N}_A \text{ atoms/mol}))}{(\text{H Mw (g/mol)} \times (62.42796\ (\text{lb/ft}^3)/(\text{g/cc}))}$$

$$\text{H atoms/cc} = \frac{((\text{H density(lb/ft}^3)) \times (6.0221415\times10^{23} \text{ atoms/mol}))}{(1.0078\ (\text{g/mol}) \times (62.42796\ (\text{lb/ft}^3)/(\text{g/cc}))}$$

$$\text{H atoms/cc} = ((\text{H density(lb/ft}^3)) \times 9.571884693\times10^{21}(\text{H atoms/cc})/(\text{lb/ft}^3)$$

$$\text{H atoms/cc} = (277 \text{ cast den (lb/ft}^3) \times \text{LOD wt\%}\times0.1118826775) \times 9.571884693\times10^{21}(\text{H atoms/cc})/(\text{lb/ft}^3)$$

$$\text{H atoms/cc} = (277 \text{ cast density (lb/ft}^3) \times \text{LOD wt\%})\times 1.070928088\times10^{21}(\text{H atoms/cc})/(\text{lb/ft}^3)$$

$$\text{H atoms/cc} = (100.509\ (\text{lb/ft}^3) \times 33.338 \text{ wt\%})\times 1.070928088\times10^{21}(\text{H atoms/cc})/(\text{lb/ft}^3)$$
$$\text{H atoms/cc} = 3.588432683\times10^{22} \text{ atoms/cc}$$

This calculated hydrogen elemental composition compares well to the documented value found in Appendix 2.

Using the hydrogen density the volume of water in the casting may be calculated as a fraction of Specific Gravity.
@ H = 3.749 (lb/ft^3)

$$\text{SGF} = \text{H (lb/ft}^3) \times \text{Water Mw (g/mol)} / ((2 \times \text{H Mw (g/mol)} \times \text{Water density (lb/ft}^3))$$
$$\text{SGF} = \text{H (lb/ft}^3) \times 18.0153\ (\text{g/mol}) / ((2 \times 1.0078\ (\text{g/mol})) \times 62.42796\ (\text{lb/ft}^3))$$
$$\text{SGF} = \text{H (lb/ft}^3) \times 0.143172$$
$$\text{SGF} = 3.749\ (\text{lb/ft}^3) \times 0.143172\ (1/(\text{lb/ft}^3))$$
$$\text{SGF} = 0.53675$$

Or the casting is 53.67% water by volume

7. Calculations

7.1. Amount of B_4C in 277-4 Borated High Alumina Cement

The boron carbide powder and Catalog No. 277 – Heat Resistant Shielding materials must now be combined to generate our neutron poison called 277-4 borated high alumina cement. An iterative solution was used to calculate the density of the 277-4 using the single component weight percents. First the mass amount of boron carbide powder must be selected and volume calculated. The B_4C volume is subtracted from one cubic foot to determine the volume of 277-0 cement. From the 277-0 cement volume the mass is calculated and all of the components' masses. As more boron carbide powder is added to the mixture it gets heavier and reduces the amount of relative hydrogen available to the neutron poison system in the cement.

Select or guess a mass of 5.88 lbs of B_4C for one cubic foot of casting with a theoretical density of 2.52 g/cc (157.318 lb/ft^3), found in the CRC Handbook of Chemistry and Physics, 55th Ed., page B-74. Verify this amount of B_4C needed in Section 7.2.

Calculate the volume of B_4C;
B4C vol = Mass (lb) / Den (lb/ft^3)
B4C vol = 5.88 lb / 157.318 lb/ft^3
B4C vol = 0.03738 ft^3

Calculate the volume and mass of the 277-0 material using the density of 1.61 g/cc (100.509 lb/ft^3).

277-0 vol = 1 - 0.03738 ft^3
277-0 vol = 0.96262 ft^3

277-0 mass = 0.96262 ft^3×100.509 lb/ft^3
277-0 mass = 96.7523 lb

Table 4, 277-4 Borated High Alumina Cement Elemental Composition for one ft^3

Element	At.wt (g/mol)	277-0 (lb/ft^3)	B_4C (lb/ft^3)	277-4 (lb/ft^3)
Hydrogen	1.0078	3.6089	0.0000	3.6089
B Nat	10.8140			
^{10}B	10.0129	0.0000	0.8163	0.8163
^{11}B	11.0093	0.0000	3.6819	3.6819
Carbon	12.0000	0.0000	1.2642	1.2642
Nitrogen	14.0067	0.0000	0.0093	0.0093
Oxygen	15.9949	57.2193	0.0319	57.2512
Sodium	22.9895	0.0774	0.0000	0.0774
Magnesium	24.3051	0.2225	0.0000	0.2225
Aluminum	26.9818	25.7264	0.0000	25.7264
Silicon	28.0853	1.6254	0.0000	1.6254
Sulfur	32.0636	0.2032	0.0000	0.2032
Calcium	40.0803	7.7789	0.0176	7.7965
Iron	55.8447	0.2903	0.0588	0.3491
Sum		96.7523	5.8800	102.6323

Calculate the as-defined by the manufacture and mixed to this ratio LOD%.
H wt% = H lb/ft^3 / Total Mass lb/ft^3
H wt% = 3.6089 / 102.6323
H wt% = 3.5163 wt%

LOD% = H wt% × (MW H_2O) / (MW H_2)
LOD% = 3.5163 wt% × (18.0150 / (2× 1.0078)
LOD% = 31.4279 wt%

7.2. 277-4 Borated High Alumina Cement at Extreme Conditions

The casting process overloads the mixture with water to allow the wet mix to flow. Dependent upon the amount of surface area and curing conditions of the casting the water content varies. As the water content varies both oxygen and hydrogen elemental masses change while the other solid masses stay fixed from in the matrix shown in Table 4. The left most density column in Table 5 shows the adjusted hydrogen and oxygen masses to a LOD% of 31.8%, while keeping all the other elemental concentrations the same. At this calculated LOD% the weight percent is calculated. Due to the possibility of small air bubbles the density could also vary. Therefore the calculated LOD% weight percents can now be multiplied by a density to generate the elemental volumetric concentrations at any LOD%. From the elemental volumetric concentration the atomic concentrations are calculated at the selected LOD% and density. Testing has shown that 99.7% of the 277-4 companion sample can castings will have an LOD% of 30.2%±1.6% and density of 105±5 lb/ft^3. Although, the ES-3100 drum has a larger casting with small percentage of the surface open to the air. The small open surface to volume ratio keep the 277-4 casting hydrated. Three castings that have been stored in an office environment for over a year had a density of 123 lb/ft^3. The difference being water content measured by the LOD% testing. This extra water make the 277-4 work better. Therefore, we would not want to overly reduce the extra moisture. An acceptable density range for this material shall be 105 −5+15 lb/ft^3 has been selected.

To calculate the elemental weight percents at a different LOD% like 31.8% another iterative calculation is required to adjust the volumetric concentrations of water. Assume a LOD% for Table 4 was 31.9735%

Delta LOD% = 31.9735% − 31.4279%
Delta LOD% = 0.5456%

Therefore for one cubic foot the water loss or gain from the definition in Table 4 is;
Del WW = Delta LOD% × Tab4Den × Volume
Del WW = 0.5456% × 102.6323 (lb/ft^3) × 1 (ft^3)
Del WW = 0.5599 lb

The amount of hydrogen weight change in a cubic foot is;
Del H = Del WW × (MW H_2) / MW H_2O
Del H = 0.5599 × (2×1.0078) / 18.0150
Del H = 0.0626 lb

Del O = Del WW − Del H
Del O = 0.5599 − 0.0626
Del O = 0.4973 lb

All values in the left column of Table 5 are same as the 277-4 masses in Table 4 except that the Hydrogen has gained 0.0626 lb and the Oxygen has gain 0.4973 lb. Using the new Table 5 elemental volumetric concentrations the weight percents are calculated. The elemental weight percents are multiplied by a desired density. The minimum acceptable density based upon testing is 100 lb/ft^3.

Table 5, 277-4 Elemental Composition @ 100 lb/ft³ & 31.8% LOD as manufactured

Element	@LOD% (lb/ft^3)	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	3.6715	3.5579%	3.5579	3.406E+22
B Nat				
^{10}B	0.8163	0.7911%	0.7911	7.621E+20
^{11}B	3.6819	3.5680%	3.5680	3.126E+21
Carbon	1.2642	1.2251%	1.2251	9.848E+20
Nitrogen	0.0093	0.0090%	0.0090	6.207E+18
Oxygen	57.7485	55.9620%	55.9620	3.375E+22
Sodium	0.0774	0.0750%	0.0750	3.147E+19
Magnesium	0.2225	0.2156%	0.2156	8.559E+19
Aluminum	25.7264	24.9306%	24.9306	8.913E+21
Silicon	1.6254	1.5752%	1.5752	5.410E+20
Sulfur	0.2032	0.1969%	0.1969	5.924E+19
Calcium	7.7965	7.5553%	7.5553	1.818E+21
Iron	0.3491	0.3383%	0.3383	5.843E+19
Sum	103.1923	100.0000%	100.0000	8.419E+22
B Nat	4.4982	4.3590%	4.3590	3.888E+21

The minimum amount of B_4C added to be the mixture shall be calculated to be greater than 7.61×10^{20} atoms/cc of ^{10}B at the minimum density and maximum hydration as defined in Section 5.1.

7.3. Calculate the ^{10}B Areal Density at Minimum ^{10}B Content and Density

The ^{10}B Areal Density for one cylinder casting thickness of 1.12 inches (2.8448 cm)
B10 Areal Density = (B10 atoms/cc × Thickness cm) × (B10 Mw g/mol / N_A atoms/mol)

$$\text{B10 Areal Den} = \frac{7.621\times10^{20}\ (\text{B10 atoms/cc}) \times (2.8448\ \text{cm}) \times (10.0129370\ \text{g/mol})}{6.0221415\times10^{23}\ \text{atoms/mol}}$$

B10 Areal Den = 0.0360474235 g/cm² for one thickness

Between two packages next to each other in the most reactive arrangement the fissile mass loads are separated by two cast neutron poison cylinders.
B10 Areal Den = 0.0360474235 × 2
B10 Areal Den = 0.072094847 g/cm²
B10 Areal Den = 72.09 mg/cm²

7.4. Volumetric Atomic Concentrations at Average Density and LOD%

Using the same methodology shown in Section 7.1 the volumetric atomic concentrations shall be calculated at the average density and LOD%. The average LOD% of 30.2% and density should be 105 −5+15 lb/ft^3 shall be used and shown in Table 6.

Table 6, 277-4 Elemental Composition @ 105 lb/ft^3 & 30.2% LOD as manufactured

Element	@LOD% (lb/ft^3)	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	3.4068	3.3789%	3.5479	3.396E+22
B Nat				
^{10}B	0.8163	0.8096%	0.8501	8.190E+20
^{11}B	3.6819	3.6517%	3.8343	3.360E+21
Carbon	1.2642	1.2538%	1.3165	1.058E+21
Nitrogen	0.0093	0.0092%	0.0097	6.670E+18
Oxygen	55.6477	55.1913%	57.9509	3.495E+22
Sodium	0.0774	0.0768%	0.0806	3.382E+19
Magnesium	0.2225	0.2207%	0.2317	9.198E+19
Aluminum	25.7264	25.5155%	26.7913	9.578E+21
Silicon	1.6254	1.6121%	1.6927	5.814E+20
Sulfur	0.2032	0.2015%	0.2116	6.366E+19
Calcium	7.7965	7.7326%	8.1192	1.954E+21
Iron	0.3491	0.3462%	0.3635	6.279E+19
Sum	100.8268	100.0000%	105.0000	8.652E+22
B Nat	4.4982	4.4613%	4.6844	4.179E+21

7.5. Extreme Densities and LOD% Volumetric Atomic Concentrations

The high density is base upon both the hydration and compaction or the amount of entrapped air, if any. The ES-3100 shipping package 277-4 neutron poison cylinder castings hold the moisture well. This moisture is a key part of how the 277-4 neutron poison works. Therefore, it has been decided to accept the 277-4 neutron poison casting up to 120 lb/ft^3 making the density range 100 to 120 lb/ft^3. Most of the companion sample cans will have a density close to 105 lb/ft^3 while the cylinders are expected to be dried to just below the 120 lb/ft^3 limit, therefore density should be 105 −5+15 lb/ft^3. Using the calculation method in Section 7.1 the extreme densities and hydration levels atomic concentrations were calculated (Table 7).

Table 7, 277-4 Composition @ Extreme Densities and LOD% and compared to the average values as manufactured

Den (lb/ft^3)	^{10}B (wt%)	^{10}B (atoms/cc)	B Nat (wt%)	B Nat (atoms/cc)	LOD (wt%)	H (wt%)	H (atoms/cc)
100.0	0.7911%	7.621E+20	4.359%	3.888E+21	31.80%	3.5579%	3.406E+22
105.0	0.7534%	7.621E+20	4.152%	3.888E+21	35.05%	3.9212%	3.941E+22
110.0	0.7192%	7.621E+20	3.963%	3.888E+21	38.00%	4.2516%	4.477E+22
115.0	0.6879%	7.621E+20	3.791%	3.888E+21	40.69%	4.5531%	5.012E+22
120.0	0.6592%	7.621E+20	3.633%	3.888E+21	43.17%	4.8296%	5.547E+22
105.0	0.8096%	8.190E+20	4.461%	4.179E+21	30.20%	3.3789%	3.396E+22
100.0	0.8282%	7.979E+20	4.564%	4.071E+21	28.60%	3.1999%	3.063E+22
105.0	0.8440%	8.538E+20	4.651%	4.356E+21	27.24%	3.0475%	3.063E+22
110.0	0.8584%	9.096E+20	4.730%	4.641E+21	26.00%	2.9090%	3.063E+22
115.0	0.8715%	9.655E+20	4.802%	4.926E+21	24.87%	2.7825%	3.063E+22
120.0	0.8835%	1.021E+21	4.868%	5.211E+21	23.83%	2.6666%	3.063E+22

7.6. Mass of Materials Needed To Mix a Batch of 277-4 For One ES-3100

The as define 277-4 mixture shown in Table 4 shall be the bases for the two part dry mixing recipe. The amount of B_4C added to be the mixture shall be calculated to be greater than 7.61×10^{20} atoms/cc of ^{10}B at the minimum density and maximum hydration as shown in Section 7.2. Now the amount of water, B_4C and Thermo Electron's proprietary Catalog No. 277 – Heat Resistant Shielding (277-0) dry powder must be calculated per shipping container.

According to Appendix 1; Thermo Electron Corp. Heat Resistant Shielding Catalog No. 277 product information sheet 277-103:

96 lbs of dry mix is required to obtain one cubic foot.
Required water is 27±1% of the total dry powder weight.

From Section 7.1 for one cubic foot the volume and mass of B_4C is 0.03738 ft^3, 5.88 lb at a density of 157.318 lb/ft^3. The 277-0 materials volume and mass is 0.96262 ft^3, 96.7523 lb a density of 100.509 lb/ft^3. Together this mixture generated a total density of 102.6323 lb/ft^3.

For one cubic foot Cast Volume
277-4 Vol = Vol B_4C + Vol 277-0
277-4 Vol = 0.03738 + 0.96262 ft^3
277-4 Vol = 1.00000 ft^3

For one cubic foot Cast Mass for one cubic foot
277-4 Mass = Mass B_4C + Mass 277-0
277-4 Mass = 5.88 + 96.7523 lb
277-4 Mass = 102.6323 lb for one cubic foot

Using the 96 lbs of dry mix required to obtain 1 ft^3 calculate the mass of 277-0 dry mix required for this casting.
277-0 Dry Mix Mass = Vol 277-0 × Dry Mix Density
277-0 Dry Mix Mass = 0.96262 ft^3 × (96 lb/ft^3)
277-0 Dry Mix Mass = 0.96262 ft^3 × (96 lb/ft^3)
277-0 Dry Mix Mass = 92.4115 lb

The 277-0 dry mix plus the B_4C mass required for one cubic foot casting is;
277-4 Dry Mix Mass = 277-0 Dry Mix Mass × Mass B_4C
277-4 Dry Mix Mass = 92.4115 + 5.88 lb
277-4 Dry Mix Mass = 98.2915 lb

Defining the calculated mass as percent weight one gets;
Dry Mix B_4C wt% = Mass B_4C / 277-4 Dry Mix Mass
Dry Mix B_4C wt% = 5.88 / 98.2915 × 100%
Dry Mix B_4C wt% = 5.9822%

277-0 Dry Mix wt% = 100% − Dry Mix B_4C wt%
277-0 Dry Mix wt% = 100% − 5.9822%
277-0 Dry Mix wt% = 94.0178%

For a 50 lb 277-4 Dry Mix Mass calculate the weights of 277-0 Dry Mix, B_4C, and water;
Dry Mix B_4C = 5.9822% × 50 lb
Dry Mix B_4C = 2.9911 lb

277-0 Dry Mix = 94.0178%× 50 lb
277-0 Dry Mix = 47.0089 lb

The divisions on the scale used to weigh the 277-0 Dry Mix are every 0.2 lbs. I will assume that the tolerance on the measurement is 0.1%.
Therefore, the maximum scale error could be;
Max Scale Error = Mass × 0.001 + 0.1
Max Scale Error = 47.0089× 0.001 + 0.1
Max Scale Error = 0.147 lb

To assure the minimum amount of ^{10}B the maximum amount of cement must be controlled. Therefore the Maximum 277-0 Dry Mix mass should be;
Max 277-0 Dry Mix = 277-0 Dry Mix − Max Scale Error
Max 277-0 Dry Mix = 47.0089 − 0.147 lb
Max 277-0 Dry Mix = 46.8619 lb

Since the scales divisions are every 0.2 lbs the maximum 277-0 mass is;
Max 277-0 Dry Mix = 46.80 lb (for the scales)
Should be weigh on a small scale with divisions of at least 0.20 lb

The Dry Mix B_4C for a 50 lb 277-4 Dry Mix Mass would be;
Dry Mix B_4C = 50.00 − 46.80 lb
Dry Mix B_4C = 3.20 lb
Should be weigh on a small scale with divisions of at least 0.01 lb

Defining the scale mass as percent weight one gets;
Dry Mix B_4C wt% = Mass B_4C / 277-4 (Dry Mix Mass)
Dry Mix B_4C wt% = 3.20 / 50 × 100%
Dry Mix B_4C wt% = 6.40%

277-0 Dry Mix wt% = 100% – 6.40%
277-0 Dry Mix wt% = 93.60%

Mixing water required for the 50 lb dry mix bag at 27±1% dry mix weight.
Water Mix Weight = 277-4 Dry Mix Mass × 27%
Water Mix Weight = 50.0 × 27%
Water Mix Weight = 13.50 lb

Table 8, 277-4 Dry Mixing weights for one ES-3100

277-0 Dry Mix wt		Dry Mix B_4C		277-4 Dry Mix Mass		Water Mix Weight	
Mass	Scale Div	Mass	Scale Div	Mass	Scale Div	Mass	Scale Div
46.80	0.20	3.20	0.01	50.00	NA	13.50	0.2

Using the maximum total natural boron of 76.5 wt% calculate the weight percentage of natural boron in the dry powder mix.

NatB = B_4C wt% × 76.5 wt%
NatB = 6.4% × 76.5 wt%
NatB = 4.896 wt%

7.7. Define the Volumetric Atomic Concentrations at NCT and HAC

Testing of cast 277-4 shows that our sample cans will be dehydrated at elevated temperatures. Twenty five sample cans were tested at 250°F for 168 hours for the Normal Conditions of Transport (NCT). Then after weighing them they were heated to 320°F for 4 hours for the Hypothetical Accidental Conditions (HAC). Then after weighing them they were heated to 1475°F for 4 hours to totally dehydrate them. This test information has defined the change in hydration from the "as manufactured" to a worst case NCT and the worst case HAC. As the water was removed the cast solids density was also reduced.

Specific Gravity Fraction of water
SGF = H (lb/ft^3) × 0.143172 (1/(lb/ft^3))
SGF = 3.531 (lb/ft^3) × 0.143172 (1/(lb/ft^3))
SGF = 0.5055
On the average the castings are 50.55% water by volume.

Inversely the hydrogen weight concentration is calculated by;
H (lb/ft^3) = SGF / 0.143172

The as manufactured 277-4 casting has an amount of water that was measured with "Lost On Drying" (LOD) tests. Sample cans were placed in an oven at 250°F for 168 hours the weights were measured and after an additional heating to 320°F for 4 hours the weights were measured again. From those weights the amount of water was calculated and presented in Table 9 as a fractional specific gravity of hydration levels generated at different conditions were calculated to be;

Table 9, 277-4 Average Affects Of Temperature Conditions on 25 Tested Cans

	As Manufactured	NCT (250°F @ 168 hours)	HAC (NCT+320°F @ 4 hours)
SG	0.5055	0.4445	0.4435
H (lb/ft^3)	3.531	3.105	3.098
H (wt%)	3.378%	3.083%	3.078%
Percent H (%)	100%	87.93%	87.73%
Ave Density (lb/ft^3)	104.51	100.70	100.64

Therefore, the 277-4 cast solid material at NCT values has 87.93% the hydrogen of the as manufactured material and at HAC values has 87.73% the hydrogen of the as manufactured material. The reduction in hydrogen of water weight affect both the hydrogen and oxygen content in the 277-4 cast solid material. The as manufactured data in Table 6 277-4 Elemental Composition @ 105 lb/ft^3 & 30.2% LOD matches the average hydrogen weight percent in Table 9. In order to generate the minimum density and minimum hydrogen calculation the calculation method in section 7.4 must be modified.

The minimum as manufactured density is 100 lb/ft^3. Only the water weight in the form of hydrogen and oxygen is reduced by leaving the casting matrix. The hydrogen weight percent should also be reduced from the minimum manufactured value of 100% to 87.93% for NCT and 87.73% for HAC. This water mass reduction must be applied at the minimum density and hydrogen content. Table 7 has two different extreme values for ^{10}B and hydrogen. The affects of extended temperature extremes must be evaluated for both conditions. The conservation of mass shall be used for these calculations keeping the lb/ft^3 of the minerals the same while the weight percents change as the hydration level does.

The minimum hydrogen of 3.1999% occurs at a 28.60% LOD and 100 lb/ft^3 density shown in Tables 7 and 10. Therefore, using the data from Table 9 the hydrogen concentration would be reduced by the percentage;

Minimum Manufactured H wt%= 3.1999% Table 10

NCT Hydrogen wt% = 3.1999% × 87.93%
NCT Hydrogen wt% = 2.8137% Table 11

HAC Hydrogen wt% = 3.1999% × 87.73%
HAC Hydrogen wt% = 2.8073% Table 12

The minimum ^{10}B mixture has hydrogen at 3.5579%, and it occurs at a 31.80% LOD and 100 lb/ft^3 density. Therefore, using the data from Table 9 the hydrogen concentration would be reduced by the percentage;
Minimum Manufactured H wt%= 3.5579% Table 5

NCT Hydrogen wt% = 3.5579% × 87.93%
NCT Hydrogen wt% = 3.1284% Table 13

HAC Hydrogen wt% = 3.5579% × 87.73%
HAC Hydrogen wt% = 3.1213% Table 14

Table 10, 277-4 Manufactured Minimum Density @ Minimum Hydrogen
277-4 Elemental Composition @ 100 lb/ft^3 & 28.6% LOD

Element	@LOD% (lb/ft^3)	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	3.1541	3.1999%	3.1999	3.063E+22
B Nat				
^{10}B	0.8163	0.8282%	0.8282	7.979E+20
^{11}B	3.6819	3.7354%	3.7354	3.273E+21
Carbon	1.2642	1.2826%	1.2826	1.031E+21
Nitrogen	0.0093	0.0094%	0.0094	6.498E+18
Oxygen	53.6410	54.4207%	54.4207	3.282E+22
Sodium	0.0774	0.0785%	0.0785	3.295E+19
Magnesium	0.2225	0.2258%	0.2258	8.960E+19
Aluminum	25.7264	26.1004%	26.1004	9.331E+21
Silicon	1.6254	1.6491%	1.6491	5.664E+20
Sulfur	0.2032	0.2061%	0.2061	6.202E+19
Calcium	7.7965	7.9098%	7.9098	1.904E+21
Iron	0.3491	0.3541%	0.3541	6.117E+19
Sum	98.5673	100.0000%	100.0000	8.061E+22
B Nat	4.4982	4.5636%	4.5636	4.071E+21

Table 11, 277-4 Reduce for **NCT** Minimum Density @ Minimum Hydrogen 277-4 Elemental Composition @ 95.39 lb/ft^3 & 25.15% LOD after 250°F for 168 hours

Element	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	2.8137%	2.6840	2.569E+22
B Nat			
^{10}B	0.8682%	0.8282	7.979E+20
^{11}B	3.9160%	3.7354	3.273E+21
Carbon	1.3446%	1.2826	1.031E+21
Nitrogen	0.0099%	0.0094	6.498E+18
Oxygen	52.7581%	50.3252	3.035E+22
Sodium	0.0823%	0.0785	3.295E+19
Magnesium	0.2367%	0.2258	8.960E+19
Aluminum	27.3622%	26.1004	9.331E+21
Silicon	1.7288%	1.6491	5.664E+20
Sulfur	0.2161%	0.2061	6.202E+19
Calcium	8.2922%	7.9098	1.904E+21
Iron	0.3713%	0.3541	6.117E+19
Sum	100.0000%	95.3886	7.320E+22

B Nat	4.7842%	4.5636	4.071E+21

Table 12, 277-4 Reduce for **HAC** Minimum Density @ Minimum Hydrogen 277-4 Elemental Composition @ 95.32 lb/ft^3 & 25.09% LOD after NCT & 320°F for 4 hours

Element	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	2.8073%	2.6758	2.561E+22
B Nat			
^{10}B	0.8689%	0.8282	7.979E+20
^{11}B	3.9190%	3.7354	3.273E+21
Carbon	1.3456%	1.2826	1.031E+21
Nitrogen	0.0099%	0.0094	6.498E+18
Oxygen	52.7305%	50.2605	3.031E+22
Sodium	0.0824%	0.0785	3.295E+19
Magnesium	0.2369%	0.2258	8.960E+19
Aluminum	27.3831%	26.1004	9.331E+21
Silicon	1.7301%	1.6491	5.664E+20
Sulfur	0.2163%	0.2061	6.202E+19
Calcium	8.2986%	7.9098	1.904E+21
Iron	0.3715%	0.3541	6.117E+19
Sum	100.0000%	95.3158	7.308E+22

B Nat	4.7879%	4.5636	4.071E+21

Table 13, 277-4 Reduce for **NCT** Minimum Density @ Minimum Boron 277-4 Elemental Composition @ 94.67 lb/ft^3 & 27.96% LOD after 250°F for 168 hours

Element	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	3.1284%	2.9617	2.835E+22
B Nat			
^{10}B	0.8356%	0.7911	7.621E+20
^{11}B	3.7688%	3.5680	3.126E+21
Carbon	1.2941%	1.2251	9.848E+20
Nitrogen	0.0095%	0.0090	6.207E+18
Oxygen	54.1129%	51.2291	3.090E+22
Sodium	0.0792%	0.0750	3.147E+19
Magnesium	0.2278%	0.2156	8.559E+19
Aluminum	26.3340%	24.9306	8.913E+21
Silicon	1.6638%	1.5752	5.410E+20
Sulfur	0.2080%	0.1969	5.924E+19
Calcium	7.9806%	7.5553	1.818E+21
Iron	0.3573%	0.3383	5.843E+19
Sum	100.0000%	94.6709	7.563E+22

B Nat	4.6044%	4.3590	3.888E+21

Table 14, 277-4 Reduce for **HAC** Minimum Density @ Minimum Boron 277-4 Elemental Composition @ 94.59 lb/ft^3 & 27.90% LOD after NCT & 320°F for 4 hours

Element	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	3.1213%	2.9524	2.826E+22
B Nat			
^{10}B	0.8363%	0.7911	7.621E+20
^{11}B	3.7721%	3.5680	3.126E+21
Carbon	1.2952%	1.2251	9.848E+20
Nitrogen	0.0095%	0.0090	6.207E+18
Oxygen	54.0823%	51.1551	3.085E+22
Sodium	0.0793%	0.0750	3.147E+19
Magnesium	0.2280%	0.2156	8.559E+19
Aluminum	26.3572%	24.9306	8.913E+21
Silicon	1.6653%	1.5752	5.410E+20
Sulfur	0.2082%	0.1969	5.924E+19
Calcium	7.9877%	7.5553	1.818E+21
Iron	0.3576%	0.3383	5.843E+19
Sum	100.0000%	94.5876	7.550E+22

B Nat	4.6085%	4.3590	3.888E+21

7.8. Define the Nominal Volumetric Atomic Concentrations

Using nominal mixer weights from Table 8 in Section 7.6 calculate the nominal ^{10}B content at the nominal density and hydration. The following tolerances were taken at the minimum ^{10}B values in ASTM C 750-03 Type 1 at ^{10}B is 19.9±.3 atom% of NatB, Total Boron 81.0 to 76.5, and the mixing weights of 5.88 lb of B_4C to a 102.6323 lb/ft^3 total as shown in Table 4. When these minimum tolerances values are brought to the nominal values one the following differences are found.

NomF ≈Change Atom% × Boron Percentage × Mixer weight changes
NomF ≈ (19.9/19.6) × (78.75/76.5) × (6.4/5.88)
NomF ≈ 1.138

Approximately 13.8% more ^{10}B on the average comparing the values to an exact calculated value is confirmed by comparing the nominal ^{10}B data shown in Table 15 to the data in Table 6.

NomF = Table 15 ^{10}B / Table 6 ^{10}B
NomF = 9.388E+20 / 8.190E+20
NomF = 1.146

On the average 14.6% more ^{10}B is found in the nominal elemental composition.

Table 15, 277-4 At Nominal Density, Boron%, and Mixer Weights
Elemental Composition @ 105 lb/ft^3 & 30.2% LOD

Element	@LOD% (lb/ft^3)	@LOD% (wt%)	@Den & LOD% (lb/ft^3)	N_e (Atoms/cc)
Hydrogen	3.4264	3.3789%	3.5479	3.396E+22
B Nat				
^{10}B	0.9411	0.9280%	0.9744	9.388E+20
^{11}B	4.2445	4.1856%	4.3949	3.851E+21
Carbon	1.2802	1.2624%	1.3255	1.066E+21
Nitrogen	0.0094	0.0093%	0.0098	6.716E+18
Oxygen	55.6706	54.8984%	57.6434	3.476E+22
Sodium	0.0770	0.0760%	0.0798	3.347E+19
Magnesium	0.2215	0.2184%	0.2293	9.103E+19
Aluminum	25.6067	25.2515%	26.5141	9.479E+21
Silicon	1.6179	1.5954%	1.6752	5.754E+20
Sulfur	0.2022	0.1994%	0.2094	6.300E+19
Calcium	7.7605	7.6529%	8.0356	1.934E+21
Iron	0.3484	0.3436%	0.3608	6.232E+19
Sum	101.4065	100.0000%	105.0000	8.682E+22

B Nat	5.1855	5.1136%	5.3693	4.790E+21

8. Conclusion

The dry mix ratios are shown in Table 8 and for 100% dry mix weight and are the following 93.6±0.43% 277-0 Heat Resistant Shielding and 6.4±0.32% Boron Carbide Powder. Once thoroughly dry blended, 27±1% water shall be added to the dry mix weight. Follow the casting specification for final instructions.

The elemental compositional calculations are performed at the minimum ^{10}B level for the compositional purity, isotopic atomic percentage, and scale measurements. The probability of each of these ^{10}B levels being at the minimum limits at the same time is quite remote. As shown in Section 7.8 the minimum limits are over 13 to 14% conservative from the nominal values.

The minimum acceptable casting density at the minimum hydration and ^{10}B levels were subsequently taken at and dehydrated to a worst Normal Conditions of Transport (NCT) and the Hypothetical Accidental Conditions (HAC) temperatures. The thermal stability of the cast 277-4 neutron poison shows little differences between the NCT and the HAC elemental compositions. Therefore, I recommend using the worst case HAC elemental composition for the final Nuclear Criticality Safety Calculations. The largest difference seen is dependent upon the input data. In order to determine the most criticality reactive HAC elemental composition Tables 12 and 14 should both be used to run an infinite array nuclear criticality safety calculation. Upon completion of these calculations the most reactive HAC elemental compositions shall be used for both NCT and HAC calculations.

Appendix 1; Thermo Electron Corp. Heat Resistant Shielding Catalog No. 277 product information sheet 277-103, page 1 of 2

Heat Resistant Shielding
Catalog No. 277

Radiation Measurement & Protection

Thermo
ELECTRON CORPORATION

Well suited to attenuate the neutron flux from power reactors by the inclusion of hydrogen and boron in the form of temperature-resistant additives. It incorporates approximately three times as much hydrogen as ordinary concrete, making the material far superior for neutron shielding applications.

- **Low cost material is completely non-combustible**
- **Rugged and easily cast in the field**

General

High temperature resistance is a frequent requirement for power reactor shielding. Type 277 Heat Resistant Shielding is a refractory material designed to retain a significant portion of its shielding properties at temperatures up to 450° F (230° C) . This material will maintain its physical integrity at temperatures up to 1900° F (1038° C). In addition, this low-cost rugged material is completely non-combustible and can be easily cast in the field. Its compressive strength is 1000 psi (90 BAR).

Type 277 is well suited to attenuate the neutron flux from power reactors by the inclusion of hydrogen and boron in the form of temperature-resistant additives. It incorporates approximately three times as much hydrogen as ordinary concrete, making the material far superior for neutron shielding applications. The refractory matrix also provides good resistance to heat.

Type 277 Heat Resistant material has a boron content of 1.56 %. The hydrogen concentration (which moderates fast neutrons) is approximately one-half that of water. For additional technical information on Type 277, including temperature resistance, refer to TD-277-1002.

Type 277 is offered in the form of a dry mix for casting in place, but can also be supplied in pre-cast shapes.It is readily shaped with ordinary tools (e.g., band-saws or drills). Type 277 Dry Mix is available in 100-lb (45.5kg) or larger containers. Approximately 96-lbs. of dry mix are required to obtain one-cubic ft. of cast material. (1.54 kg of dry mix will give one liter). Detailed mixing instructions are provided with each order. Recommended shelf-life under dry storage conditions is six months.

Catalog No. 277 Heat Resistant Shielding is a refractory material designed to retain a significant portion of its shielding properties at temperatures up to 450° F (230° C). This material will maintain its physical integrity at temperatures of up to 1900° F (1038° C).

In addition Catalog No. 277 is a low cost rugged material which is completely non-combustible and can easily be cast in the field. Its compressive strength is 1000 psi (90 BAR).

Catalog No. 277 is well suited to attenuate neutron flux from power reactors by the inclusion of hydrogen and boron (natural isotope distribution) in the form of temperature resistant additives. It incorporates approximately three times as much hydrogen as ordinary concrete, making the material far superior for neutron shielding applications. The refractory matrix also provides good resistance to heat.

For Contact Information visit www.thermo.com/rmp

Appendix 1; Thermo Electron Corp. Heat Resistant Shielding Catalog No. 277 product information sheet 277-103, page 2 of 2

SPECIFICATIONS

Products Available

Catalog No. 277 is offered in the form of dry mix for casting in place, but can also be supplied in pre-cast shapes and blocks.It is readily shaped with ordinary power tools (e.g. band-saws or drills).

Catalog No. 277 Dry Mix is available in 300-lb (136 kg) containers. Approximately 96-lbs of dry mix are required to obtain one-cubic foot of cast material (1.54 kg of dry mix will give one liter). Water 27 PPH, parts of dry mix (by weight).

Recommended shelf life for Catalog No. 277 under dry-storage conditions is 6 months.

Composition Data

Active Components:

Hydrogen atom density / cm3:	3.4×10^{22}/cc
Natural isotope distribution:	99.98% $_1$H
Boron atom density / cm3:	1.43×10^{21}
Natural isotope distribution:	19.6% $_{10}$B and 80.4% $_{11}$B
Weight percent of all isotopes of boron:	1.56%
Total Density:	1.68 g / cc

Radiation Properties

Macroscopic thermal neutron cross section:	1.1 cm^{-1}
Gamma resistance:	1×10^{11} rads
Neutron resistance:	5×10^{19} n / cm^2

Physical Properties

Appearance and Odor:

State	Powder
Color	Light Gray
Odor	no odor

Mechanical Properties

Machining of 277:	Fair, can be saw cut and drilled
Hardness:	N/A
Tensile Strength (ASTM D368):	100 psi (kg/m²)
Compressive Strength:	1000 psi (kg/m²)

Thermal Properties

Recommended Temperature Limit:	350°F
Melting Point:	N/A
Boiling Point:	N/A
Coefficient of Thermal Conductivity:	1.24×10^{-3} cal-cm/sec cm² °C = 0.3 BTU - ft/hr ft² °F
Heat Capacity:	0.22 cal/g °C
Cubical Coefficient of Expansion:	8×10^{-6} cm3/cm3 °C = 1.4×10^{-5} in³/in³ °F
Linear Coefficient of Expansion	N/A
Vapor Pressure (mm Hg):	N/A
Vapor Density (Air = 1):	N/A
Evaporation Rate (ether=1):	N/A
Percent Volatile by Volume:	N/A
Specific Gravity (H_2O = 1):	1.68 g/cm3

Chemical Properties

Chemical Name & Synonyms:	Borated Hydrogenated Casting Mix
Trade Name & Synonyms:	Catalog No. 277
Chemical Family:	Calcium salts, boron, and hydrogen containing compounds
Formula:	Proprietary
Solubility in Water:	Negligible

Reactivity Data

Reactive Materials	
Reactive Acids:	N/A
Reactive Bases:	N/A
Reactive Metals and Metal Compounds:	N/A
Reactive Oxidizing Agents:	N/A
Reactive Reducing Agents:	N/A

Material Incompatibility

Materials to Avoid: :	N/A
Hazardous Decomposition Products:	
Solid	None
Liquid	None
Gas	None
Hazardous Polymerization:	Will Not Occur

For more information see: TD-277-001

277-103

Radiation Measurement & Protection

Thermo ELECTRON CORPORATION

Appendix 2; Thermo Electron Corp. Heat Resistant Shielding Catalog No. 277 Typical Elemental Analysis Without Boron, EA-277, May 1988.

EA-277
Without Boron
May, 1988

TYPICAL ELEMENTAL ANALYSIS

CATALOG NO. 277 - HEAT RESISTANT SHIELDING

Element	Weight Percent
O	59.14%
Al	26.59
Ca	8.04
H	3.73
Si	1.68
Fe	0.30
Mg	0.23
S	0.21
Na	0.08
Total	100.00%

PROPERTIES

Density = 1.61 g/cc [101 lbs/cu ft]

Hydrogen Atoms per cc = 3.59×10^{22}

Macroscopic Thermal Neutron Cross Section: $\Sigma = 0.01 cm^{-1}$

Recommended Temperature Limit = 350°F [177°C]

Machinability: Fair; can be saw-cut and drilled

Thermal Conductivity, K = 1.24×10^{-3} cal-cm/(sec)(cm)²(°C)

Specific Heat = 0.22 cal/gpC

Coefficient of Theraml Expansion = 1.4×10^{-5}cm per cm per °C

Compressive Strength = 1400 psi

Tensile Strength = 95 psi

Radiation Resistance, gammes: 1×10^{11} Rads

Radiation Resistance, neutrons: 1×10^{21} n/cm²

THERMAL TESTS AND CHARACTERISTICS

These tests have not been performed on this Type 277 without boron. We have examined each test separately, and we feel confident that the results of all these tests and that the characteristics of the material would be essentially the same as for Type 277 with boron.

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Appendix 1.4.10

PYROPHORICITY OF URANIUM METAL

Prepared by: Russell W. Schmidt
BWXT Y-12, L.L.C.
November 2006
Revised June 2007

Reviewed by: Sanford G. Bloom
BWXT Y-12, L.L.C.
November 2006
Re-reviewed June 2007

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Appendix 1.4.10

PYROPHORICITY OF URANIUM METAL

I. Introduction

The ES-3100 is a new shipping container designed for safe and efficient transportation of highly enriched uranium in a wide range of material forms. The ES-3100 has been certified for use with a variety of contents, including enriched uranium metal and alloy. However, the current size limitations on uranium contents in the form of broken metal are unnecessarily restrictive. The size limits exist because under certain conditions uranium metal and some uranium alloys are pyrophoric – they have the potential to spontaneously ignite. The size restrictions are intended to eliminate the possibility of spontaneous ignition during transport.

The purpose of this analysis is to evaluate the potential for uranium metal pieces to spontaneously ignite under the conditions expected for shipment in the ES-3100 shipping container, and to identify limits on the uranium metal content that will prevent spontaneous ignition during transport, while still allowing a high degree of flexibility and utility.

It is important to remember that the content limits developed for the ES-3100 must be implemented in the field. Therefore the criteria derived from this evaluation must be simple, robust, and readily applied in all of the facilities using this package.

This evaluation does not include new laboratory tests of uranium metal ignition parameters. Such tests have been performed and well documented in the past. This evaluation draws on the extensive body of existing data and proven storage and transport practice to identify the bounds within which uranium metal and alloys can be safely transported in the ES-3100 shipping container.

II. Proposed Definition of Pyrophoricity

The Certificate of Compliance (CoC), gives the definition of broken metal in paragraph 5.(b)(1)(ii), as follows:

> *For metal or alloy defined as broken metal, mass limits are specified in Table 2. Uranium metal and alloy pieces must have a surface-area-to-mass ratio of not greater than 1 cm^2/g or must have a mass not less than 50 g, whichever is most restrictive. Powders, foils, turnings, wires, and incidental small particles are not permitted, unless they are restricted to not more than 1 percent by weight of the content per convenience can, and they are either in a sealed, inerted container or are stabilized to an oxide prior to shipment.*

It is suggested that the definition of broken metal in paragraph 5.(b)(1)(ii) be revised to the following:

> *For metal and alloy defined as broken metal, mass limits are specified in Table 2. Uranium metal and alloy pieces must have a surface-area-to-mass ratio of not greater than 1 cm^2/g or must not pass freely through a 3/8-inch (0.0095m) mesh sieve. Particles and small shapes that do not pass this size restriction, as well as powders, foils, turnings, and wires, are not permitted, unless they are either in a sealed container under an inert cover gas.*

III. Rational for Proposed Changes

The proposed text makes the following changes:

- The 50 g minimum piece size is eliminated;
- A 3/8-in. mesh limit is added;
- The phrase "whichever is most restrictive" is deleted;
- Remove oxidation as a treatment for pyrophoric uranium, in this context
- The 1% limit on inerted material is eliminated.

The 1 cm^2/g maximum specific surface area limit is the most significant limit in the original text, and that limit is retained unchanged. Specific surface area is the most significant parameter in determining if a given piece of uranium is at risk of spontaneous ignition under a given set of conditions, and therefore it is appropriate that this restriction should control any other restrictions to the package contents. The discussion section below will demonstrate that the 1 cm^2/g maximum allowable specific surface area is adequate to prevent spontaneous ignition in the ES-3100.

The 50 g minimum piece size is overly restrictive and is inconsistent with the 1 cm^2/g upper limit on specific surface area. Smooth uranium metal pieces can have a mass of less than 0.5 g and still have a specific surface area less than 1 cm^2/g (see example 1). This makes the 50 g limit two orders of magnitude too large. The 50 g limit is nearly an order of magnitude too large even considering metal pieces with the rough surface of broken metal instead of a smooth cast or polished surface.

Example 1.
Consider a smooth uranium metal sphere with a diameter of 0.32 cm (0.126 in.).
The radius of the sphere is 0.16 cm. The density of uranium metal is 19 g/cm^3.
The volume is $V = (4/3) \cdot Pi \cdot r^3 = (4/3) \cdot Pi \cdot (0.16)^3 = 0.01716\ cm^3$
The mass is $M = Density \cdot V = 19\ g/cm^3 \cdot 0.01716\ cm^3 = 0.3260\ g$
The surface area is $A = 4 \cdot Pi \cdot r^2 = 4 \cdot Pi \cdot (0.16)^2 = 0.3217\ cm^2$
The specific surface area is $SA = A/M = 0.3217\ cm^2 / 0.3260\ g = 0.9868\ cm^2/g$
This specific surface area is just within the 1 cm^2/g upper limit.

If instead of a smooth surface the sphere has a rough surface characteristic of broken uranium metal, a larger size is needed to ensure that the 1 cm^2/g limit is maintained. For a roughness factor of three (meaning that the rough surface has an actual surface area that is three times the surface area calculated from the radius), the radius would need to be three times the above example to give the same specific area. In this case:
$r = 3*0.16\ cm = 0.48\ cm$; $V = (4/3) \cdot Pi \cdot (0.48)^3 = 0.463\ cm^3$;
$M = 19\ g/cm^3 \cdot 0.463\ cm^3 = 8.802\ g$; $A = 4 \cdot Pi \cdot (0.48)^2 \cdot 3$ (roughness factor) $= 8.686\ cm^2$
And so the specific surface area is $8.686\ cm^2/8.802g = 0.9868\ cm^2/g$ as above.

Depending on the surface roughness, a sphere with a mass between 0.33 and 8.8 grams will meet the 1 cm^2/g specific surface area limit

The 1 cm^2/g specific surface area limit controls the parameter that is most important in terms of preventing spontaneous ignition, but it is not easy to measure or to use in the field. A mass limit (similar to the 50 g limit in the existing certificate, but more consistent with the 1 cm^2/g specific area limit) could be used, but it is very time-consuming to weigh every piece of metal in a package. An approach that is both effective at enforcing the 1 cm^2/g specific surface area limit and quick and easy to use in the field is

to separate large pieces from small ones in a sieve. The recommended text stipulates a 3/8-in. mesh sieve to quickly remove small particles (with a large specific surface area) from large particles which have a small specific surface area.

As demonstrated in example 1, rough-surfaced spheres 3/8 in. (0.95 cm) in diameter meet the 1 cm^2/g specific surface area limit (a smooth-surfaced sphere of this size has a specific surface area of 0.33 cm^2/g). Therefore, a sphere which does not pass freely through the 3/8-in. mesh sieve will meet the 1 cm^2/g specific surface area limit. Other simple shapes such as cubes and rods are also effectively controlled by the 3/8-in. sieve. Foils, turnings, and wires are explicitly forbidden in both the current and proposed text, unless they are packed in an inert atmosphere.

The phrase "whichever is most restrictive" has been deleted from the proposed text since the sieve test has been sized to effectively enforce the 1 cm^2/g specific surface area limit.

The option of converting pyrophoric uranium to an oxide is removed, since metals need to be shipped as metals for maximum usefulness at the receiver site. In addition, if oxides are produced, packing limits for oxides have been explicitly given in the certificate of compliance.

The final change in the proposed text is to eliminate the 1% of content weight limit on inerted material. This limit is unnecessary for uranium metal sealed in a container containing an inert atmosphere. If the metal has been sealed in a container containing an inert atmosphere, there is no oxygen available to the metal and therefore no chance of combustion.

Uranium metal packaged for transport in the ES-3100 is first placed inside a convenience can or other container. These cans are then placed into the ES-3100 containment vessel (CV). The convenience cans will displace most of the oxygen from the containment vessel, leaving only enough to react with a few grams of metal. If a sealed container containing an inert atmosphere somehow came open in transport (an unlikely scenario given the very limited amount of movement possible inside a properly loaded containment vessel), this small amount of oxygen is not enough to support spontaneous ignition. The containment vessel has been shown to retain its structural integrity and remain leak tight under hypothetical accident conditions, so no additional oxygen can enter.

IV. Discussion

In his 1995 review,[1] Terry Totemeier explains pyrophoricity this way: "Pyrophoricity refers to the tendency of certain metals to ignite and burn in a self-sustaining oxidation reaction. The pyrophoric nature of metals is usually defined in terms of an ignition temperature, which is the temperature at which a metal will ignite and burn in a self-sustained fashion for a given set of conditions." ASTM C-1454[2] defines pyrophoric as "capable of igniting spontaneously under temperature, chemical, or physical/mechanical conditions specific to the storage, handling, or transportation environment".

This evaluation will demonstrate that uranium metal with a specific surface area of 1 cm^2/g will not spontaneously ignite under the conditions existing in the ES-3100 during packaging and transport.

The primary factors determining if the conditions for spontaneous ignition exist are specific surface area and temperature. Totemeier explains, "Because oxidation is a surface reaction, the amount of area available for reaction is a critical factor in the determination of the heat generated in oxidation. Specific area is the best parameter to describe the effect of area, as it also accounts for the amount of material not reacting which can serve as a heat sink." Temperature is critical because the amount of heat generated by the reaction is a function of the reaction rate, which is in turn a function of the temperature. Higher temperatures give higher reaction rates.

An additional safety factor in the case of the ES-3100 is the small amount of oxygen available in the sealed inner containment vessel. This serves to limit the total amount of uranium that can oxidize, and therefore prevents any potential heat build-up from reaching the ignition point of uranium metal.

Ignition Temperature and Transport Conditions

In figures 4 and 5 of his review, Totemeier plots two separate tests of uranium ignition temperatures as a function of specific surface area. For a specific surface area of 1 cm^2/g these two plots give values of 390°C (663 K)[a] and 340°C (613 K), respectively. Using the lower value and rounding down gives a conservative value of 600 K for the ignition temperature of uranium metal in the ES-3100.

The ES-3100 thermal analysis determined that the temperature at the containment vessel wall would not exceed 190°F (361 K) for normal conditions of transport (NCT) and 255°F (397 K) for hypothetical accident conditions (HAC). These values, particularly the HAC temperature, are very conservative. The actual results from six separate package tests showed that the CV wall temperature was typically around 210 °F (372 K), with the highest recorded value of 241 °F (389 K). Note that all of these temperatures are well below the 600 K ignition temperature of the uranium metal contents.

Maximum Temperature from Oxidation – Basic Equations

Uranium metal readily reacts with oxygen to form uranium dioxide (UO_2). This reaction is exothermic. The heat released by the reaction warms the uranium metal, increasing the reaction rate. Under normal conditions for storage and transport, the reaction rate is slow enough that the small amount of heat generated by the reaction is lost to the environment, and a stable steady-state is achieved. If the reaction rate is fast enough, and the metal is relatively well insulated, the temperature of the uranium metal can build, slowly at first but at an increasing rate, until the ignition temperature is reached and the metal ignites and burns.

The task at hand is to evaluate the balance between heat generation and heat loss in the ES-3100 under hypothetical accident conditions to verify that a stable steady state is reached, and that the steady-state condition is safely below the ignition point of uranium metal. A recent paper by Epstein, Malinovic, and Plys[3] lays out a useful approach, which will be followed here without the approximations used in their paper.

[a] The curve in Totemeier figure 4 is discontinuous, with a transition from a lower curve to an upper curve shown at a specific surface area of 6 cm^2/g. At a specific surface area of 1 cm^2/g the upper curve would give an ignition temperature of 550°C, while extrapolation of the lower curve gives 390°C. The original reference from which Totemeier drew figure 4 explains that the transition from the lower curve to the upper curve is influenced by many factors, including the metallurgy of the uranium, any alloying metals or impurities, and the oxygen content of the gas involved. Therefore this analysis uses the lower curve value of 390°C.

For uranium metal packed in cylindrical cans, the generation of heat throughout the can and the associated transfer of heat to the can wall is mathematically identical to the generation of heat within a wire due to electrical resistance. In their text "Transport Phenomena"[4] Bird, Stewart & Lightfoot develop the desired relation (equation 9.2-14):

$$Tcenter - Twall = (S \cdot R^2) / (4 \cdot Kth) \qquad \text{(Equation 1)}$$

where

Tcenter is the temperature at the center of the can (K)
Twall is the temperature at the can wall (K)
S is the heat production per unit volume (W/cm^3)
R is the radius of the can (cm)
Kth is the thermal conductivity of the uranium contents (W/cm K)

The heat production per unit volume is a function of the reaction rate and the heat of reaction. Since the oxidation reaction occurs at the surface of the uranium, the reaction rate is typically stated as a mass reacted per second per unit area. The specific surface area, the uranium metal density, and the packing density are applied to convert the rate per unit uranium surface area to a rate per unit can volume. The result is:

$$S = Rho \cdot Phi \cdot SArea \cdot dHrxn \cdot RxnRate \qquad \text{(Equation 2)}$$

where

Rho is the density of the uranium metal (g/cm^3)
Phi is the packing density of the uranium in the can (cm^3 U/cm^3 can volume)
SArea is the specific surface area of the uranium (cm^2/g)
dHrxn is the heat of reaction (J/g uranium)
RxnRate is the reaction rate (g uranium / ($s \cdot cm^2$))

The reaction rate of uranium metal with oxygen has been evaluated by many researchers over the years. The general form of the rate equation used is:

$$RxnRate = K0 \cdot P^n \cdot e^{(-Te/T)} \qquad \text{(Equation 3)}$$

where

K0 is the reaction rate coefficient (g uranium / ($s \cdot cm^2$))
P is the partial pressure of water vapor (kPa)
n is the exponential coefficient on the partial pressure of water vapor
Te is the activation energy (K)
T is the temperature of the reactants (K)

For the case at hand, the temperature of the reactants is the highest at the can center (Tcenter) and the lowest at the can wall (Twall). The average temperature of the reactants is midway between these two values. For conservatism the reaction rate of the entire contents is evaluated at the maximum temperature, which occurs at the center of the can (Tcenter). This analysis considers heat transfer only through the can walls, and ignores heat transfer through the top and bottom of the can. This is also a conservative assumption.

Equations 1, 2, and 3 are combined to yield:

$$Tcenter - Twall = (R^2 \cdot Rho \cdot Phi \cdot SArea \cdot dHrxn \cdot K0 \cdot P^n \cdot e^{(-Te/Tcenter)}) / (4 \cdot Kth) \quad \text{(Equation 4)}$$

Note that Kth is a property of the can contents (that is, for the bed of uranium metal particles with air in between), and not a property of solid uranium metal. The thermal conductivity of uranium metal is much higher than the thermal conductivity of a bed of uranium metal pieces.

P is the partial pressure of H_2O present in the containment vessel at the center-line temperature. This value is calculated by assuming that the ES-3100 was loaded at ambient conditions of T0 and 100% relative humidity, which yields a water vapor pressure of P0. When the temperature in the containment vessel increases the partial pressure of water vapor increases according to the ideal gas law, which in this case reduces to:

$$P = P0 \cdot (Tcenter/T0) \quad \text{(Equation 5)}$$

In this evaluation, the maximum possible rate of heat generation due to the oxidation of the uranium metal is also of interest since this heat must be carried away by the package, even at HAC. The maximum rate of heat generation is the heat generated by the oxidation of uranium metal at the highest temperature reached during HAC, assuming the maximum allowable load of uranium metal. This is:

$$Qmax = Mmax \cdot SArea \cdot dHrxn \cdot K0 \cdot P^n \cdot e^{(-Te/Tcenter)} \quad \text{(Equation 6)}$$

where

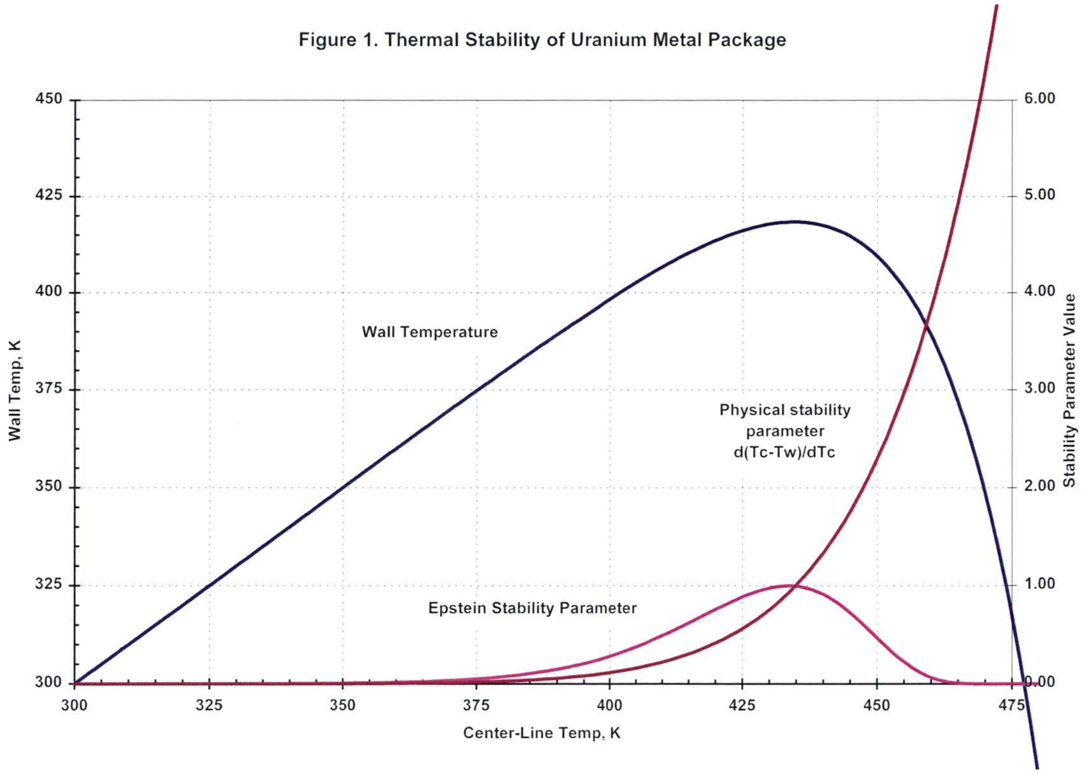
Qmax = the maximum rate of heat generation (W)
Mmax = the maximum uranium metal loading (g)

Evaluation of Thermal Stability

Equation 4 provides the means to evaluate the maximum temperature reached in the uranium metal. It does not by itself validate the stability of the system. This system does present a simple means to evaluate stability – both numerical stability and more importantly physical stability (meaning that the temperature cannot build to spontaneous ignition).

Solving equation 4 for Twall over a range of Tcenter values and plotting the results produces figure 1:

Figure 1. Thermal Stability of Uranium Metal Package



The wall temperature calculated from equation 4 and plotted here is the temperature needed in order to provide enough heat transfer to maintain the given center-line temperature. The wall temperature initially tracks the center-line temperature – the rate of heat generation is low, so a very small temperature difference is sufficient to remove that heat. As the center-line temperature (and therefore the amount of heat generated) increases, the temperature difference needed to keep the center-line temperature steady at the given value increases exponentially. At some point (about 435 K in figure 1) the required temperature difference gets so large that the wall temperature would have to decrease in order to maintain a stable center-line temperature. In an actual package there is no cooling mechanism to do this, and once the center-line temperature exceeds this point the amount of heat generated will exceed the ability to carry off that heat, and the center-line temperature will increase until either the reaction runs out of oxygen or the ignition point is reached. The point at which the required wall temperature stops increasing, marks the maximum stable center-line temperature for the package. The required wall temperature stops increasing at the point where the rate of increase in the needed temperature difference (d(Tcenter-Twall)) equals the rate of increase of the center-line temperature (dTcenter). Stated mathematically, when d(Tcenter-Twall)/dTcenter is less than 1 the required Twall increases along with Tcenter, and stability is maintained. When d(Tcenter-Twall)/dTcenter is greater than 1 Twall would have to drop to maintain stability as Tcenter increases. Since this is not possible in a real package, the temperature in the package would steadily increase to either ignition or consumption of all available oxygen. The value of d(Tcenter-Twall)/dTcenter = 1 marks the maximum stable point for a given package.

Equation 4 is

$$Tcenter - Twall = (R^2 \cdot Rho \cdot Phi \cdot SArea \cdot dHrxn \cdot K0 \cdot P^n \cdot e^{(-Te/Tcenter)}) / (4 \cdot Kth)$$

Taking the first derivative of this equation with respect to Tcenter yields an equation for the stability parameter derived above:

$$d(Tcenter-Twall)/dTcenter = (Tcenter-Twall) \cdot Te/Tcenter^2 \qquad \text{(Equation 7)}$$

The thermal stability of the system is maintained as long as (Tcenter-Twall) • $Te/Tcenter^2 \leq 1$. This parameter is equivalent to the stability parameter "B" developed in Epstein et al, without the simplifying assumptions made in that paper. The value of d(Tcenter-Twall)/dTcenter is plotted in Figure 1, along with the Epstein "B" parameter.

Input Parameters

The key values used to evaluate equations 4, 5, 6, and 7 are shown in Table 1.

Table 1. Key input parameters

Parameter	Value	Units
R	5.27	cm
Rho	19	g/cm^3
Phi	0.26	cm^3/cm^3
SArea	1	cm^2/g
dHrxn	4559	J/g Uranium
K0	76086	$gU/(s \cdot cm^2)$
P0	3.53	kPa
T0	300	K
n	0.3	
Te	11490	K
Kth	0	W/(cm • K)

The sources of these parameters are:

R is the inside radius of a convenience can. The typical can used has an outside diameter of 4.25 in., and an inside diameter of 4.15 in. (10.54 cm).

Rho is the density of uranium metal.

Phi is the packing density of uranium metal when packed into the convenience cans. Operator experience at Y-12 is that a maximum of 5 kg U of broken metal will fit into a 4.25-in. OD by 4.875-in. high can, which has an internal volume of 1000 cm^3. This yields a packing density of 0.26 cm^3/cm^3. The effects of variations on this value are discussed below.

SArea is the specific surface area, which is limited by the package certification to 1 cm^2/g.

dHrxn is the heat of reaction, on a uranium basis. This value came from Totemeier, page 17 (1089 cal/gU = 4559 J/gU).

K0, n, and Te are parameters for the reaction rate equation. As noted above, a number of researchers have analyzed the reaction rate of uranium metal with various combinations of oxygen and water vapor. Numerous models have been developed from this data. This analysis used the published model that best fit the conditions present. Many of the published rate models are only valid up to 100 to 130°C. This evaluation requires evaluation beyond 140°C. Many of the models are for either pure oxygen or pure water vapor. McGillivray[5] notes that the reaction rate at a given temperature varies with both the oxygen concentration and the partial pressure of water vapor. The published model that best matches the conditions of this evaluation (reaction in air at temperatures exceeding 140°C, with a small water vapor partial pressure) is the Pearce model (Pearce, < 100% RH, in Air, T < 192°C) as reported in the Epstein paper.

P0 and T0 are used to calculate P, the partial pressure of H_2O vapor present in the containment vessel at the center-line temperature. This value is calculated by assuming that the ES-3100 was loaded at ambient conditions of T0 = 300 K (80°F) and 100% relative humidity. P0 is therefore the vapor pressure of water at 300K, which is P0 = 3.53 kPa. When the temperature in the containment vessel increases, the partial pressure of water vapor increases according to equation 5.

Kth is the thermal conductivity of the uranium particle bed. The value here was taken from Epstein et al, page 6. Because of the air-filled void spaces, the bed thermal conductivity is much lower than the uranium metal value of 0.3 W/(cm • K).

Results

The set of equations (4, 5, 6, and 7) was evaluated using a commercial software package named Tk!Solver, which has the advantage of being able to automatically iterate to solutions as needed. This is necessary when solving equation 4 for a fixed wall temperature to determine Tcenter. Attachment 1 shows the rules, input and output for the TK!Solver model for the HAC and NCT cases.

The hypothetical accident condition evaluation gave a maximum containment vessel (CV) temperature (Twall) of 255°F (397 K). Evaluating equations 4 through 7 for these conditions yields a Tcenter of 398.4 K (257.5°F), with a maximum heat output (assuming a full load of 36 kgU) of 5.9 Watts, and a stability parameter d(Tcenter-Twall)/dTcenter of 0.102, well below the critical value of 1.0.

The 255°F HAC temperature was based on a uranium heat generation of 0.4 W. The 5.9 W maximum heat generated from the oxidation reaction under those conditions would heat the CV wall above that temperature. The thermal analysis evaluated the HAC for heat generation rates of 20 W and 30 W as well as the 0.4 W standard value. Table 3.7 in the thermal analysis shows that for an assumed 20 W heat generation in the uranium metal contents, the peak CV wall temperature is 277 °F (409.3 K). Using this value ensures that the heat transfer from the uranium contents to the CV wall and to the rest of the package is conservatively addressed.

For the revised HAC wall temperature of 277 °F (409.3 K), equations 4 through 7 yield the following results:

Tcenter = 413.3 K (284.4 °F) (well below the ignition temperature of 600 K)
MaxQ = 17.0 Watts (below the 20W assumption)
d(Tcenter-Twall)/dTcenter = 0.272 (well below the critical value of 1.0)

At the NCT wall temperature of 190°F (360.9 K) the results are:

Tcenter = 361.0 K (190.1 °F) (well below the ignition temperature of 600 K)
MaxQ = 0.289 Watts (below the 0.4W assumption)
d(Tcenter-Twall)/dTcenter = 0.006 (well below the critical value of 1.0)

These values clearly show that uranium metal with a specific surface area of no more than 1 cm^2/g will not spontaneously ignite under any anticipated transport conditions.

Variation in Input Packing Density

The density with which uranium metal is packed into the convenience cans limits the surface area available to oxidize. Operator experience at Y-12 is that a maximum of 5 kg U of broken metal will fit into a 4.25-in. OD by 4.875-in. high can, which has an internal volume of 1000 cm^3. This yields a packing density of 0.26 cm^3/cm^3.

A search of the literature on packing densities reveals a lot of work on smooth spheres, and very little on anything else. Scott and Kilgour[6] experimented with packing smooth steel spheres in cylinders, and reported a maximum packing density of 0.6366 after extensive vibration to compact the steel spheres as much as possible. The steel balls used in this experiment had a coefficient of friction of 0.2, well below the value for smooth uranium metal of 1.0. Subsequent analysis by Kong and Lannutti[7] considering the effects of friction between particles gives packing fractions in the range of 0.41 to 0.46, with higher friction coefficients producing lower packing fractions.

The broken metal routinely packed at Y-12 consists of large, rough, irregular pieces. The reported packing density of 0.26 for this material is consistent with the literature reviewed, particularly Kong and Lannutti. Therefore the value of 0.26 was used as the base value in the analyses reported above.

To bound the metal contents of the ES-3100 two additional cases have been analyzed under hypothetical accident conditions: rough broken metal at a packing density of 0.46 (the upper end of the range reported by Kong & Lannutti); and smooth cast spheres at a packing density of 0.64 (consistent with Scott & Kilgour).

For rough broken metal at a packing density of 0.46 the maximum center temperature at HAC was 422 K, well below the ignition temperature of 600 K. For smooth cast 3/8" spheres at a packing density of 0.64 the maximum center temperature at HAC was 412 K, well below the ignition temperature of 600 K.

Oxygen Limitation in the Containment Vessel

The analysis above placed no restriction on the amount of oxygen available to react with the uranium metal contents. In reality, the ES-3100 containment vessel has a finite volume, which restricts the amount of oxygen available for reaction.

The CV is a cylinder with inside dimensions of 31.00 in. (78.74 cm) tall and 5.06 in. (12.85 cm) in diameter. This produces a volume of 10,215 cm^3, or 10.215 liters. At ambient conditions of 300 K (80.3°F) and 100% relative humidity, 10.215 liters of humid air contains 2.78 g of oxygen from the air, and another 0.23 grams of oxygen in the H_2O. These 3.01 grams of oxygen can react with 22.40 g of uranium metal. This is 0.06% of the ES-3100's capacity.

A mass of 22.4 g of U metal when reacted with 3.01 g of oxygen will produce a maximum total heat output of 102 kJ (96.8 BTU), spread out over the time required for the reaction to take place. This total amount of oxygen could sustain the NCT maximum heat output of 0.289 W for 4.1 days, or the HAC peak heat output for 1.7 hours. If somehow released all at once, the 102 kJ would only raise the temperature of 36 kg of uranium by 24.5 K. More realistically, as shown by the calculations above, any reaction will be slow, with enough time for the heat generated to flow to the CV and the rest of the package.

The ES-3100 CV is 15.1 kg of stainless steel, with a heat capacity of 0.515 J/(g •K). The 102 kJ maximum produced by the oxidation reaction could only raise the temperature of the CV (ignoring contents) by 13.1 K. This heat sink, plus the heat sinks offered by the CV contents, ensures that the oxidation reaction will not be able to build to the 600 K ignition temperature required for spontaneous ignition.

In practice there will less than 3 g of oxygen available to react with the uranium metal inside the closed CV. A full load of uranium will, by itself, displace nearly 20% of the air in the CV. The convenience cans, spacer cans, and other packing materials will displace even more air, further reducing the amount of uranium that could possibly react. Also, the uranium metal is packed inside closed convenience cans. These cans limit the oxygen available to react with the contents to the oxygen in the convenience can itself. Finally, part of the available oxygen will react with the uranium before the peak HAC conditions are reached. Figure 22b in section 3 shows that it will take about 4 hours for the CV wall to reach the maximum temperature in the HAC fire. During this four-hour temperature ramp-up 0.9 grams of oxygen would be consumed by reaction with the uranium, leaving only 2.1 grams available to react once the HAC temperature was reached. Even if the uranium surface area was uncontrolled, lack of oxygen would snuff out any increase in the uranium reaction rate before it could reach the ignition point.

Specific Surface Area Implementation via Sieve

As noted above, the 1 cm^2/g specific surface area limit is not easy to measure or to use in the field. A screening method that is simple and easy to use in the field will reduce the potential for packaging mistakes. The recommended approach is to separate large pieces from small ones in a sieve. The recommended text stipulates a 3/8-in. mesh sieve to quickly remove small particles (with a large specific surface area) from large particles which have a small specific surface area.

Example 1 above showed that the minimum size of a metal sphere meeting the 1 cm^2/g specific surface area limit varies with the degree of surface roughness. In example 1 a smooth sphere 1/8 inch in diameter and a rough sphere 3/8 inch in diameter both had specific surface areas just below the 1 cm^2/g limit. The 3/8-in. mesh is stipulated in the recommended text in order to accommodate both smooth and rough metal.

The actual metal contents of the ES-3100 will include both smooth-surfaced and rough-surfaced metal. The smooth-surfaced items include a variety of cast and machined shapes. The rough-surfaced items are "broken metal" – large castings that have been fractured into smaller pieces. These broken metal pieces will typically have two or three cast surfaces with the remaining 3 or 4 surfaces of fractured metal.

The 3/8-inch mesh recommendation is based on a surface roughness factor of three, meaning that the rough surface has an actual surface area available to react with oxygen that is three times that of a smooth-surface of the same gross dimensions. This roughness factor of three was derived from an evaluation of fracture surfaces for cast uranium metal. Roughness factors ranged from 1.1 to 2.7, with a mean value of 2.0. A roughness factor of three was selected to bound the highest value observed. The 3/8 inch mesh screening is therefore suitable for metal that is fractured on all surfaces. Since as noted

above even broken metal will have several smooth faces the 3/8-inch mesh screening should be quite conservative.

As demonstrated above, a rough-surfaced sphere which does not pass freely through the 3/8-in. mesh sieve will meet the 1 cm²/g specific surface area limit. Other simple shapes such as cubes and rods are also effectively controlled by the 3/8-in. sieve. Foils, turnings, and wires are explicitly forbidden in both the current and proposed text, unless they are packaged in an inert atmosphere. Attachment 2 shows the dimensions of a variety of shapes that have a specific surface area of 1 cm²/g. All of these items will fall through a 3/8-in. sieve, demonstrating that the sieve will effectively enforce the 1 cm²/g specific surface area limit.

Most foils and wires will not fall through a sieve of any reasonable size. The current 50 g test would likewise not reliably exclude these materials, which is why foils, turnings, and wires are explicitly forbidden in both the current and proposed text, unless they are packed in an inert atmosphere. Operator training will be required under either the current or the proposed text to ensure that these items are properly packaged.

Operator Training

As part of the transition to using the new shipping container, training materials are being prepared to instruct the field operations personnel on the proper way to use the ES-3100. As noted above, the training for the operators packing uranium metal into the convenience cans for shipment in the ES-3100 will be important in ensuring that potentially pyrophoric materials are properly categorized and inerted as necessary. This training will cover the following points:

- All metal pieces must be evaluated to ensure that their smallest dimension is larger than the 3/8 inch mesh size.
    - Single solid-metal pieces that are clearly larger than the 3/8-inch mesh in every dimension do not require sieving.
    - Items which are obviously unacceptable, such as foils, wires, and turnings, may be removed before the sieving
    - Any item that is not obviously larger than the 3/8-inch mesh in every dimension and which has not been rejected must be sieved.
    - Any item that falls through the sieve must be rejected.

- Operators need to be alert to items which may not fall through the sieve but which are too small:
    - Long, thin shapes such as wires and turnings may not fall through the sieve when shaken. If the wire or turning could be picked up and poked through the mesh it must be rejected, even if it did not fall through unassisted.
    - Wires or turnings may form a tangled ball which will not fall through. The above criterion applies: if the wire or turning could be separated and poked through the mesh it must be rejected.
    - No distinction is made between wires and rods – if the item could be picked up and poked through the mesh it must be rejected.
    - Foils, thin chips or shards - any item less than 1/8 inch thick – must be rejected.
    - Metal showing visible moisture or signs of having been stored in water must be rejected.

- Rejected items must be separated for proper handling:
  - Rejected items can be shipped if packed under an inert cover gas.
  - An acceptable cover gas must be high-purity (≥ 99%) and dry (≤ 5 ppm moisture).

V. Conclusion

The evaluations performed show that uranium metal conforming to the 1 cm^2/g limit on specific surface area will not spontaneously ignite under any anticipated transport conditions. Spontaneous ignition is independently prevented by both the 1 cm^2/g limit on the uranium metal and by the limited amount of oxygen available in the sealed ES-3100 containment vessel.

The 3/8-in. sieve specified in the revised text effectively applies the 1 cm^2/g specific surface area limit to broken uranium metal in a manner that is quick and easy to use in the field.

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Attachment 1 TK!Solver Model and Results

Rules

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Tcenter-Twall=((R^2*rho*phi*SArea*dHrxn*K0*P^n)/(4*Kth))*exp(-Te/Tcenter)
P=P0*(Tcenter/T0)
Deriv=(Tcenter-Twall)*Te/Tcenter^2
HRate=SArea*dHrxn*K0*P^n*exp(-Te/Tcenter)
MaxQ=HRate*MaxM
RRate=SArea*MaxM*K0*P^n*exp(-Te/Tcenter)
ORate=RRate*32/238
OTime=MaxO/ORate
--------------------------------------------------------------------------------
```

HAC - 277 °F Wall Temperature

Input	Name	Output	Unit	Comment
	Tcenter	413.348	K	Temperature at the center of the can
409.3	Twall		K	Temp at the can wall
	HRate	.000472	W/gU	Rate of heat production (w/unlimited O2)
	MaxQ	16.9945	W	Maximum heat production (from max KgU)
36000	MaxM		gU	Maximum ES-3100 contents
3.01	MaxO		gO	Maximum ES-3100 Oxygen Content
	RRate	.003728	gU/s	Reaction Rate at given Conditions
	ORate	.000501	gO/s	Oxygen Use rate at given conditions
	OTime	1.66822	hr	Oxygen time to run-out
5.27	R		cm	Can radius
1	SArea		cm^2/gU	Specific Surface Area of U particles
	Deriv	.272221		d(Tcenter-Twall)/dTcenter
19	rho		gU/cm^3	Density of uranium
.26	phi			
				Packing density, U cm^3 / Can cm^3
4559	dHrxn		J/gU	Heat of Reaction
76086	K0		gU/(s*cm^2)	Reaction rate coefficient - Pearce <100%
11490	Te		K	Reaction rate coefficient - Pearce <100%
.3	n			
				Reaction rate coefficient - Pearce <100%
3.53	P0		kPa	Vapor pressure of water at T0
300	T0		K	Temperature for P0
	P	4.86373	kPa	Vapor Pressure of Water at Tcenter
.004	Kth		W/cm*K	Thermal Conductivity of U particle bed

NCT - 190 °F Wall Temperature

Input	Name	Output	Unit	Comment
-------	-------	---------	-------	------------
	Tcenter	360.969	K	Temperature at the center of the can
360.9	Twall		K	Temp at the can wall
	HRate	8.03E-6	W/gU	Rate of heat production (w/unlimited O2)
	MaxQ	.288991	W	Maximum heat production (from max KgU)
36000	MaxM		gU	Maximum ES-3100 contents
3.01	MaxO		gO	Maximum ES-3100 Oxygen Content
	RRate	6.34E-5	gU/s	Reaction Rate at given Conditions
	ORate	8.52E-6	gO/s	Oxygen Use rate at given conditions
	OTime	98.1015	hr	Oxygen time to run-out
5.27	R		cm	Can radius
1	SArea		cm^2/gU	Specific Surface Area of U particles
	Deriv	.00607		d(Tcenter-Twall)/dTcenter
19	rho		gU/cm^3	Density of uranium
.26	phi			Packing density, U cm^3 / Can cm^3
4559	dHrxn		J/gU	Heat of Reaction
76086	K0		gU/(s*cm^2)	Reaction rate coefficient - Pearce <100%
11490	Te		K	Reaction rate coefficient - Pearce <100%
.3	n			Reaction rate coefficient - Pearce <100%
3.53	P0		kPa	Vapor pressure of water at T0
300	T0		K	Temperature for P0
	P	4.2474	kPa	Vapor Pressure of Water at Tcenter
.004	Kth		W/cm*K	Thermal Conductivity of U particle bed

Attachment 2. Pyrophoric Size Limits on Small Uranium Metal Pieces

Specific Surface Area:		1.0	cm^2/g					
Uranium Metal Density:		19.0	g/cm^3					
Surface Area Multiplier:		3.0						
	The surface area multiplier is the ratio of the actual surface area							
	divided by the simple geometeric surface area.							
Spheres - Minimum Safe Diameter								
Limiting diameter		0.9474	cm	or	0.3730	in	8.459	grams
Rods - Minimum Safe Diameter								
	Length	**Diameter**						
	0.9 cm	0.9474	cm	or	0.3730	in	12.688	grams
	1.0 cm	0.9231	cm	or	0.3634	in	12.715	grams
	1.5 cm	0.8000	cm	or	0.3150	in	14.326	grams
	2.0 cm	0.7500	cm	or	0.2953	in	16.788	grams
	2.5 cm	0.7229	cm	or	0.2846	in	19.495	grams
	Infinite	0.6316	cm	or	0.2487	in		
Cubes - Minimum Safe Side Length								
Limiting side length		0.9474	cm	or	0.3730	in	16.155	grams
Square Cross-Section Rods - Minimum Safe Side Length								
	Length	**Side**						
	0.9 cm	0.9474	cm	or	0.3730	in	16.155	grams
	1.0 cm	0.9231	cm	or	0.3634	in	16.189	grams
	1.5 cm	0.8000	cm	or	0.3150	in	18.240	grams
	2.0 cm	0.7500	cm	or	0.2953	in	21.375	grams
	2.5 cm	0.7229	cm	or	0.2846	in	24.822	grams
	Infinite	0.6316	cm	or	0.2487	in		
Chips & Shards - Minimum Safe Thickness								
Length	**Width**	**Thickness**						
1.0 cm	0.5 cm	6.0000	cm	or	2.3622	in	57.000	grams
1.5 cm	0.5 cm	2.0000	cm	or	0.7874	in	28.500	grams
2.0 cm	0.5 cm	1.5000	cm	or	0.5906	in	28.500	grams
2.5 cm	0.5 cm	1.3043	cm	or	0.5135	in	30.978	grams
3.0 cm	0.5 cm	1.2000	cm	or	0.4724	in	34.200	grams
Infinite	0.5 cm	0.8571	cm	or	0.3375	in		
1.0 cm	0.6 cm	2.0000	cm	or	0.7874	in	22.800	grams
1.5 cm	0.6 cm	1.2000	cm	or	0.4724	in	20.520	grams
2.0 cm	0.6 cm	1.0000	cm	or	0.3937	in	22.800	grams
2.5 cm	0.6 cm	0.9091	cm	or	0.3579	in	25.909	grams
3.0 cm	0.6 cm	0.8571	cm	or	0.3375	in	29.314	grams
Infinite	0.6 cm	0.6667	cm	or	0.2625	in		
Infinite	Infinite	0.3158	cm	or	0.1243	in		

VI. References

1. Totemeier, Terry C. ANL/ED/95-2 "A Review of the Corrosion and Pyrophoricity Behavior of Uranium and Plutonium", June 1995, Argonne National Lab-West.

2. ASTM C-1454-00, "Standard Guide for Pyrophoricity/Combustibility Testing in Support of Pyrophoricity Analyses of Metallic Uranium Spent Nuclear Fuel", January 10, 2000, ASTM International.

3. M. Epstein, B. Malinovic, M. G. Plys, SNF-6192-FP, "Uranium Pyrophoricity Phenomena and Prediction", April 2000, Fluor Hanford, Richland Washington.

4. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot, "Transport Phenomena", 1960, John Wiley & Sons.

5. G. W. McGillivray, D. A. Geeson, R. C. Greenwood, "Studies of the Kinetics and Mechanism of the Oxidation of Uranium by Dry and Moist Air – A Model for Determining the Oxidation Rate Over a Wide Range of Temperatures and Water Vapor Pressures", June 1993, Journal of Nuclear Materials # 208 (1994) pg 81-97.

6. G. D. Scott, D. M. Kilgour, "The Density of Random Close Packing of Spheres", February 1969, British Journal of Applied Physics, Series 2, Volume 2, pp 863 - 866.

7. C. M. Kong, J. J. Lannutti, "Effect of Agglomerate Size Distributions on Loose Packing Fraction", March 2000, Journal of the American Ceramic Society, Volume 83, pp 2183 – 2188.

Appendix 1.4.11

EQUIPMENT SPECIFICATION, SPC M801580-0002, *ES-3100 ETHYLENE PROPYLENE DIENE MONOMER (EPDM) CONTAINMENT VESSEL (CV) O-RINGS*

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EQUIPMENT SPECIFICATION FOR ES-3100 ETHYLENE PROPYLENE DIENE MONOMER (EPDM) CONTAINMENT VESSEL (CV) O-RINGS

TABLE OF CONTENTS

1. SCOPE

This specification, the Company's drawings, and the documents referenced herein provide requirements for the materials, fabrication, inspection, examination, documentation, and testing of ES-3100 O-rings.

If conflicting requirements appear in these documents, the Manufacturer shall immediately notify the Company for resolution.

The Seller shall not deviate from the requirements of this specification without prior written consent from the Company. Requests for changes or deviations shall be submitted on the Request for Waiver or Deviation form, Attachment A.

2. APPLICABLE DOCUMENTS

The ES-3100 EPDM O-rings shall be fabricated, inspected, and tested according to the design drawings and the applicable referenced documents.

- ASTM D412, *Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension*
- ASTM D1329, *Standard Test Method for Evaluating Rubber Property Retraction at Lower Temperatures (TR Test)*
- ASTM D2000, *Standard Classification System for Rubber Products in Automotive Applications*
- ASTM D2240, *Test Method for Rubber Property – Durometer Hardness*
- MIL-STD-413C Notice 1, June 19, 1987, *Visual Inspection Guide for Elastometric O-Rings*
- Title 10 Code of Federal Regulations, Part 71, Subpart H, *Quality Assurance*

3. DEFINITIONS

Batch—A batch is defined as a homogeneous quantity of material compound mixed at one time.

LOT—A lot shall be a quantity of product of the same identity, cured in the same production run, and from the same batch.

First Article—Product that is submitted to the Company for evaluation prior to the seller being released to manufacture the remaining quantities in the subcontract. This product must be representative of production items by virtue of having been produced and inspected using the same facilities, testing, processes, and type of personnel planned for use in production.

First Article Evaluation (FAE)—An evaluation by the Company of the first article unit manufactured and the facilities, tooling, processes, etc. concerned with the manufacture and inspection.

4. REQUIREMENTS

4.1 Materials

4.1.1 The Manufacturer shall be responsible for supplying all materials, services, facilities, and equipment to meet the requirements of this specification and Company drawings unless otherwise noted.

4.1.2 The O-rings shall meet the requirements of ASTM D2000 specification M3BA 712 A14 B13 F17.

4.1.3 The O-ring material shall be ethylene propylene diene monomer (EPDM) rubber.

4.1.4 The O-ring color shall be black.

NOTE: The use for the O-rings is a static face seal.

4.2 Properties

4.2.1 The O-rings shall have a normal temperature service range of 302°F to -40°F. The low temperature capability of the O-ring shall be determined by conducting a TR-10 test specified in ASTM D1329. A quantitative test report certifying this low temperature capability shall be submitted for each lot of O-rings as Certified Data; see Attachment B.

4.2.2 The O-rings shall have a Shore A hardness of 70A ± 5 per ASTM D2240. A quantitative test report certifying this hardness shall be submitted for each lot of O-rings as Certified Data; see Attachment B.

4.2.3 The O-rings shall have a minimum elongation of 100% per ASTM D412. A quantitative test report certifying this elongation shall be submitted for each lot of O-rings as Certified Data; see Attachment B.

4.3 Fabrication

4.3.1 The O-rings shall be molded as a single piece.

4.3.2 Each O-ring's surface shall be smooth, non-porous, and free of skin defects and impregnated material to the requirements of MIL-STD-413C.

4.4 Packaging and Marking Requirements

4.4.1 O-ring packaging shall be accomplished under conditions which will ensure freedom from contamination by dust, oil, grease, and other extraneous matter.

4.4.2 Individual O-rings shall be packaged one to a sealed package.

4.4.3 The O-ring package marking shall be in accordance with Sect. 11.

4.4.4 O-ring packages, if packed in an outer container, shall be packed in such a manner that during shipment and storage, they will not be permanently distorted, and will be protected against damage from exposure to weather or any other normal hazard. Unless otherwise specified in the Purchase Order, the outer container shall be marked with no less that the following information:

- Purchase Order Number
- Manufacturer's Identification
- Part Number
- Date of Shipment
- Number of parts per container

4.5 Inspection

4.5.1 Dimensional requirements are specified on the Company Drawing M2E801580A013.

4.5.2 The Manufacturer's inspection shall include, as a minimum, the following.

4.5.2.1 All dimensions and tolerances require 100% inspection. In the event that inspection of a dimension or tolerance is not practical, the Manufacturer shall submit for approval an alternate plan for ensuring the features will meet requirements.

4.5.2.2 The O-rings shall be 100% visually inspected per MIL-STD-413C.

4.5.3 A certified written inspection report(s) shall be prepared and submitted to the Company in accordance with Sect. 9.1 and Attachment B.

4.5.4 Where inspection or test equipment yields quantitative readings, actual measurements and deviation from nominal readings shall be recorded.

4.5.5 A representative sample for each batch of material per paragraph 9.3 shall be provided to the Company for verification testing.

4.5.6 The seal material composition shall be verified by Fourier Transform Infrared (FTIR) Spectroscopy on a sample of two units taken from each batch of material. A report shall be provided to the Company.

5. NUMBERS OF PARTS

The total number of parts to be manufactured for First Article Evaluation (FAE) and production shall be specified in the Company's purchase order.

6. FIRST ARTICLE EVALUATION (FAE)

6.1 Primary Objective

The primary objective of a FAE is to verify that the product conforms to its requirements and that the facilities tooling, processes, controls, personnel, acceptance methods, etc. can consistently furnish product of the required quality and quantity. The FAE is conducted in two phases. The first phase is an evaluation at the Seller's site of all critical manufacturing, inspection, and testing operations and equipment. The second phase is an independent evaluation by the Company of the FAE parts of material received by the Company.

6.2 FAE Document Requirements

The Seller shall manufacture first article quantities that are representative of production units. All parts shall be produced, tested, and inspected using the same facilities, tools, processes, procedures, and type of personnel planned for use during production. It is the responsibility of the Seller to:

6.2.1 Notify the Company sufficiently in advance of the fabrication of the First Article Unit to permit the Company to witness the manufacture and inspection. Normally 10 days notice is required.

6.2.2 Furnish for review/approval copies of all procedures, follow sheets, data forms, processing records, etc., used by the Seller to define or control those aspects of the manufacturing and inspection operations that influence the quality of the finished product. These documents are to be furnished not later than the notification of the date of First Article production.

6.2.3 Furnish for each First Article Unit copies of all inspection and certification data required to be supplied for the production parts.

6.3 Verification Testing

The Seller shall be released for fabrication of production quantities when Stage II customer verification testing of the FAE is successfully completed.

6.4 Onsite Evaluation

The Company will perform an FAE of the first parts manufactured by production process and personnel. This evaluation shall be conducted on the FAE parts as received by the Company.

6.5 Results Notification

The Seller shall not proceed to manufacture parts beyond the initial FAE quantities until a successful FAE has been completed and notification to proceed has been received from the Company. The Seller shall be notified in writing by the Company of the results of the First Evaluation Article Evaluation. The FAE results will be reported in one of the following three categories:

6.5.1 Acceptable: Seller is released to initiate manufacture of production quantities.

6.5.2 Conditionally Acceptable: The Company will specify actions which the Seller must complete before being released for production quantities.

6.5.3 Not Acceptable: The First Article units have serious deficiencies, or the ability of the Seller to consistently furnish product of the required quality and quantity is subject to major uncertainty. The Company will specify the required action.

6.6 Documentation

The Seller shall provide the documentation as specified in Sect. 6.2.2. All process procedures as described by the above reference shall be submitted for review by the Company prior to the manufacture of FAE parts. Final approval of these procedures shall be made on successful completion of Company's evaluation of parts received. Any subsequent changes to these approved documents or processes will require notification be made to the Company. The Company shall then determine if a new FAE is warranted.

7. MANUFACTURING PLAN

7.1 General

The Seller shall manufacture parts in accordance with ASTM D2000, this specification, and the requirements standard set forth in Sect. 4 of this document.

7.2 Manufacturing Procedures

The Seller shall develop and implement written procedures, follow sheets, data forms, and processing records as required to document and control the manufacturing processes and to ensure consistency of all operations. In addition, the Seller shall prepare an inspection procedure as specified by Sect. 8.3.2 of this document for submittal to the Company for review and approval.

7.3 Equipment

The Seller shall have adequate manufacturing and test equipment to ensure compliance of the dimensional configuration and physical properties specified by the specifications referenced.

8. QUALITY ASSURANCE PROVISIONS

8.1 General

The Seller shall implement and maintain a quality control system that meets the requirements of this document.

8.2 Material Control

The Seller shall maintain an effective material control program which meets the requirements of this document and ensures that the following material controls are implemented and maintained:

8.2.1 Ensures that only material meeting the specified requirements is used in the fabrication of this product.

8.2.2 Provides for obtaining the supplier's certification of raw material called out in this specification and/or purchase order as necessary to meet the requirements of Sect. 4 of this document.

8.2.3 Ensures that all mechanical testing of specimens representative of the cured material has been done and quantitative test results obtained.

8.2.4 Provides traceability from as-shipped parts to the lot run and the batch of stock from which the parts were manufactured.

8.3 Inspection Requirements

8.3.1 The Seller's Quality Control program shall develop the necessary procedures and data record forms, and implement an inspection and test program which meets all the requirements specified below.

8.3.2 The Seller shall submit an Inspection procedure for Company approval a minimum of ten (10) days prior to manufacture of FAE parts. This procedure shall contain, as a minimum, a listing of inspection equipment used to inspect each dimension and all features and requirements specified by Sect. 8.3.4.

8.3.3 Prior to performing final inspection, the Seller shall perform all cleaning operations required to ensure parts are free of all fabrication and handling defects and that no foreign materials are present on the part's surface or features.

8.3.4 The Seller shall visually and dimensionally inspect all parts 100 percent. The Seller's inspection shall include, as a minimum, the following:

8.3.4.1 Part marking: Part marking as specified by Sect. 11 of this document.

8.3.4.2 Cleanliness: All parts submitted to the Company shall be inspected by the Seller to be free of all foreign materials. This shall include dirt; grease, curing compound, etc., which are attached to or adhere to the part surface or features.

8.3.4.3 Workmanship: The seals shall meet the workmanship requirements of MIL-STD-413C. There must be no defects or foreign materials in the rubber which will alter its ability to form a seal or endanger longevity by chemical interactions.

8.3.4.4 Dimensions: Inside diameter and width (cross-section) as specified by the purchase order shall be inspected.

8.3.5 The Seller shall establish and implement a plan to sample and test the physical properties of each batch of cured molding compound used for manufacture. The Seller shall test to ensure compliance to all criteria specified.

8.3.6 The Seller shall document the results of the inspection and/or testing on appropriate data record forms. Where inspection or test equipment yields quantitative readings, actual measurements or deviation from nominal readings shall be recorded.

8.3.7 Documentation of all inspection and test results shall be maintained by the Seller for a minimum of one (1) year after completion of the contract. The Company shall reserve the option to retrieve and review this data as deemed necessary to ensure compliance with all product specifications.

8.3.8 The Seller shall not ship nonconforming parts without prior approval by the Company. (Ref. Sect. 9.2.)

8.4 Acceptance Criteria

8.4.1 Batch Acceptance

8.4.1.1 Certification: The supplier shall certify that each batch meets the physical properties per ASTM D2000 of compound called out in this specification in Sect. 4.1.

8.4.1.2 Environment: Test specimen preparation and testing may be done at 18 to 30°C and 10 to 65% relative humidity (applies to Sects. 8.4.1.3–8.4.1.4).

8.4.1.3 Composition: The O-ring material composition shall be verified by Fourier Transform Infrared (FTIR) Spectroscopy on a sample of two units taken from each batch of material. A report shall be provided to the Company.

8.4.1.4 Density: The density (specific gravity) of the material shall be verified on a sample of two units taken from each batch of material.

8.4.2 Lot Acceptance

8.4.2.1 Inspection Report: The O-rings shall meet the inspection requirements as specified by Sect. 8.3.4.

8.4.2.2 Cure Certification: The supplier shall certify that each lot was cured according to the temperature and time parameter specified in the Seller's approved manufacturing plan.

9. CERTIFICATION DATA

9.1 Conforming Product

With each shipment of O-rings, the Seller shall submit the following certification data:

9.1.1 two (2) copies of a signed certification (Certificate of Conformance per Attachment C) that identifies, by batch and lot numbers, all O-rings included in the shipment and attest that all parts conform to all criteria of the purchase order and this specification;

9.1.2 two (2) copies of TR-10 test results per Sect. 4.2.1.

9.1.3 two (2) copies of the quantitative test results for physical property tests per Sect. 8.4.1.1;

9.1.4 two (2) copies of the FTIR Spectroscopy per Sect. 8.4.1.3;

9.1.5 two (2) copies of the quantitative test results for density per Sect. 8.4.1.4;

9.1.6 two (2) copies of the inspection report per Sect. 8.4.2.1; and

9.1.7 two (2) copies of the cure certification per Sect. 8.4.2.2.

9.2 Nonconforming Product

9.2.1 The Seller shall not ship nonconforming parts without prior approval by the Company. Any requested exceptions, deviations, or proposed changes to the requirements of a procurement specification by the Supplier after award and before acceptance shall be submitted using UCN-13816B, *Request for Waiver or Deviation (RFWD)*.

The Supplier shall contact the Subcontract Administrator to obtain a UCN-13816B form and submit a request for waiver and deviation to the Subcontract Administrator when one of the following nonconforming conditions is identified.

- Requirements in Supplier documents approved by the Company are violated.
- Nonconformances cannot be corrected by continuing the original manufacturing process except by reworking or repairing the item.
- The item does not meet original requirements, even though it can be restored to a fully functional condition.

See Attachment A for a sample form and instructions.

9.3 Test Material

For each lot of material used to fabricate, the Seller shall supply to the Company one piece of stock that is a minimum of 6" x 6" x 0.070" – 0.090" thick and has been cured with the parts from each batch. This piece shall be from the same material as the parts in the lot run. This test material shall be identified with the batch number of the material compound used and the production lot number represented, and shall be forwarded to the Company with the first shipment of parts fabricated from the material represented.

9.4 Cause for Rejection

Material certifications and/or any supporting test data as specified above cannot be waived. Failure to supply the required data may be cause for rejection.

9.5 Distribution and Number of Copies

Certification data shall be forwarded for each shipment of parts to the Company. One (1) copy shall be included with the shipment of O-rings and one (1) copy to be forwarded to the subcontract administrator.

10. CLEANING

Each part shall be thoroughly cleaned after the completion of all processing and prior to shipment.

11. PART MARKING

Each O-ring package shall be marked to identify the following information:

- Master Batch Number
- Lot Number
- Vendor or Company Part Number or Part Name
- Size or Code
- Compound
- Cure Date (Date of Mfg.)
- Expiration Date (4 years from date of manufacture)

12. SHIPMENT

The Seller shall ship parts in accordance with the delivery schedule as specified in the Company's Purchase Order.

13. FINAL ACCEPTANCE

Final acceptance of each part shall be based on inspection and testing performed by the Company at the receiving site. Any parts not meeting the requirements set forth in this specification or applicable part drawing will be returned to the Seller for rework or replacement. Any shipment that contains a nonconforming product may be returned to the Seller without a 100 percent inspection by the Company.

CNS | consolidated nuclear security, llc

CLICK HERE FOR INSTRUCTIONS

REQUEST FOR WAIVER OR DEVIATION (RFWD)

1. REQUEST TYPE	2. SHEET 1 OF ____
☐ DEVIATION (Supplier Initiated)	3a. NUMBER
☐ WAIVER (Supplier Initiated)	3b. SAP DMS NUMBER
☐ Change (CNS Initiated)	

4. SUPPLIER	5. P.O. NO. / ITEM NO.	6. PROGRAM / PROJECT	7. DOCUMENT NO. / REV.
8. COMPONENT NAME	9. PART OR IDENTIFYING NO.	10. ☐SERIAL or ☐ LOT NO.	11. LOT SIZE

	12. SPEC. REF. NO.	13. SPECIFICATION REQUIREMENTS	14. DESCRIPTION OF WAIVER/DEVIATION/CHANGE	15. SUPPLIER PLAN FOR CORRECTIVE ACTION
1)				
2)				
3)				
4)				

16. INITIATING ENTITY REPRESENTATIVE (print /sign)	17. TITLE	18. COMPANY	19. DATE

RESPONDING ENTITY EVALUATION (TO BE COMPLETED BY RESPONDING ENTITY EVALUATOR)

	20. SPEC. REF. NO.	21. EVALUATION COMMENTS	22. EVALUATOR (print/sign) / DATE	23. RECOMMENDED DISPOSITION
1)				☐ ACCEPT ☐ REJECT
2)				☐ ACCEPT ☐ REJECT
3)				☐ ACCEPT ☐ REJECT
4)				☐ ACCEPT ☐ REJECT

24. ARE DESIGN DRAWING(S), SPECIFICATION(S), DATA SHEET(S), INSPECTION PLANS(S), OR SURVEILLANCE PLAN(S), ETC. CHANGES REQUIRED? ☐ YES ☐ NO
IF YES, LIST DOCUMENTS REQUIRING CHANGES (TO BE COMPLETED BY CNS REPRESENTATIVE)

SAMPLE

Y60-015, 4.2,4.3,4.7,4.8 & 4.11
UCN-13816B (01-15)

ATTACHMENT A. REQUEST FOR WAIVER OR DEVIATION FORM

CLICK HERE FOR AN ADDITIONAL PAGE

SHEET ____ OF ____

APPPOVALS (CNS Approvals Require Same Affected Functions/Organizations Approval As Original Document)				
25. ENTITY	26. NAME (print/ sign)	27. DATE	28. APPROVE/REJECT RECOMMENDED DISPOSITIONS	
CNS Customer/Program Manager:			☐ APPROVED	☐ REJECTED
CNS Technical Representative:			☐ APPROVED	☐ REJECTED
CNS Design Authority Representative:			☐ APPROVED	☐ REJECTED
CNS Project Representative:			☐ APPROVED	☐ REJECTED
CNS Quality Engineer:			☐ APPROVED	☐ REJECTED
Design Engineering:			☐ APPROVED	☐ REJECTED
Product/Packaging Engineering:			☐ APPROVED	☐ REJECTED
Procurement Representative:			☐ APPROVED	☐ REJECTED
CNS Other (List):			☐ APPROVED	☐ REJECTED
Supplier Representative:			☐ APPROVED	☐ REJECTED

Y60-015, 4.2,4.3,4.7,4.8 & 4.11
UCN-13816B (01-15)

RFWD Completion Instructions

INITIATING ENTITY

The following fields are to be completed by the INITIATING ENTITY. The purpose of Block No.1 through 20 is the identification of the Waiver/Deviation/Change. For Waivers and Deviations, the Initiating Entity is the Supplier. For Changes, the Initiating Entity is Y-12.

1. **REQUEST TYPE** – Check the appropriate block:
   - DEVIATION (Supplier initiated, prior to production)
   - WAIVER (Supplier initiated, during or after production)
   - CHANGE (Y-12 initiated, after award of contract)

2. **SHEET/FORM PAGES** – Complete Page of Page(s), including any attachments or supporting documents. Each page's Sheet/Form block must be completed (i.e., Page 1 of 2; Page 2 of 2; Page 3 of 3; Pages 10 of 10, etc.).

3. **3.a NUMBER** – An identifying, sequential numbering system acceptable to supplier and Y-12 (e.g., Purchase Order Number + sequential number – [examples 430001234-1, 430001234-2,etc].
   3.b SAP DMS NUMBER – Y-12

4. **SUPPLIER** – Supplier Name associated with the Waiver, Deviation, or Change.

5. **PURCHASE ORDER (P.O.) NUMBER/ITEM NUMBER** – From the Y-12 issued P.O. and the item number associated with the P.O.

6. **PROGRAM/PROJECT** – Program or project name, if applicable.

7. **DOCUMENT NUMBER and REVISION** – Drawing or Specification Number and Revision.

8. **COMPONENT NAME** – Name take from Y-12 design document(s).

9. **PART OR IDENTIFYING NUMBER** – Part Name or unique reference number.

10. **SERIAL OR LOT NUMBER** – Check the appropriate box and enter the Serial Number or Lot Number, if applicable.

11. **LOT SIZE** – Total quantity of parts affected by the WAIVER/DEVIATION/CHANGE.

12. **SPECIFICATION REFERENCE NUMBER** – Paragraph number or drawing reference/location of characteristic(s) to be waived/deviated/changed (each characteristic requires individual line).

13. **SPECIFICATION REQUIREMENT** – Requirement(s) extracted from the specification/drawing.

14. **DESCRIPTION OF WAIVER/DEVIATION/CHANGE** – Written explanation of what characteristic is to be waived/deviated/changed (e.g., technical or material requirement is violated, requirement in supplier document is violated, nonconformance cannot be corrected by continuing the original process or rework, item does not conform to the original requirement, but can be restored to condition that it will function unimpaired, Y-12 is directing the Supplier to make a change to what is specified in the contract document(s), etc.).

Y60-015, 4.2,4.3,4.7,4.8 & 4.11
UCN-13816B INST (01-15)

RFWD Completion Instructions (continuation)

15. **SUPPLIER PLAN FOR CORRECTIVE ACTION** – Written explanation of corrective action(s) taken or planned to address each waiver/deviation characteristic identified which may include disposition recommendations such as accept/use-as-is, rework to specification, repair to usable condition, return to vendor, reject/scrap, etc., if applicable. This block does not apply to Y-12 initiated changes. (NOTE: If more SPEC. REF. NOs. are needed , a TAB key at the last entry of Block No.15 will insert an additional line, else "mouse click" to Block No. 16).

16. **INITIATING ENTITY REPRESENTATIVE** – Name (print/signature) of the authorized representative of the Initiator (Supplier or Y-12) submitting the Waiver/Deviation/Change.

17. **TITLE** – Title of the Initiating Entity Representative from Block No.16.

18. **COMPANY** – Company affiliation of the Initiator (Y-12 or Supplier).

19. **DATE** – Date Waiver/Deviation/Change initiated.

<u>Responding Entity Evaluation</u>

The following fields are to be completed by the RESPONDING ENTITY EVALUATOR. The purpose of Block 20 through 23 is the evaluation of the proposed Waiver/Deviation/Change. For Waivers and Deviations, the Responding Entity is Y-12. For Changes, the Responding Entity is the Supplier.

20. **SPECIFICATION REFERENCE NUMBER** – Item(s) transposed from Block No.12 above, to be evaluated.

21. **EVALUATION COMMENTS** – Written evaluation of each Waiver/Deviation/Change requested by the Initiating Entity.

22. **EVALUATOR/DATE** – Name (print/signature) of the Evaluator for the responding Entity and the Date of the evaluation. The Evaluator is one who is technically qualified to evaluate the proposed Waiver/Deviation/Change.

23. **RECOMMENDED DISPOSITION** – Based on the evaluation and the comments provided in Block 21, the Evaluator's recommendation to either Accept or Reject each Waiver/Deviation/Change Item. For Waivers and Deviations, this represents the Y-12 Evaluator's intended recommendation to other Y-12 functions/organizations for acceptance or rejection of each proposed waived/deviated item. For Changes, this represents the Supplier's intended acceptance or rejection of each proposed change initiated by Y-12.

<u>Y-12 Representative</u>

24. **ARE DESIGN DRAWINGS(S), SPECIFICATIONS, OR DATA SHEET(S) CHANGES REQUIRED** – Indicate (Yes or No) if changes to the original contract documents or supporting/operational documents are warranted because of the Waiver/Deviation/Change.

Y60-015, 4.2,4.3,4.7,4.8 & 4.11
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RFWD Completion Instructions (continuation)

Approvals

Y-12 approvals require the same affected functions/organizational approval as the original document (Applicability is determined by the original document approvals and the governing document procedures). The Technical Representative is responsible for identifying and obtaining the appropriate approvals and processing the RFWDC form.

25. **ENTITY** – The required list of approvers may include:
    - Y-12 Customer/Program Manager (i.e., end user)
    - Y-12 Technical Representative
    - Y-12 Design Authority Representative, as applicable (otherwise, N/A)
    - Y-12 Project Representative, as applicable (otherwise, N/A)
    - Y-12 Quality Engineer, as applicable (otherwise, N/A)
    - Design Engineering, as applicable (otherwise, N/A)
    - Product/Packaging Engineering, as applicable (otherwise, N/A)
    - Procurement Representative, as applicable (otherwise, N/A)
    - Y-12 Other – List additional function positions required to approve, if applicable.
    - Supplier Representative – Person with overall responsibility and authority to approve information and dispositions as documented on this form.

26. **NAME** – Name (print/signature) of each person fulfilling the roles denoted in Block No. 25.

27. **DATE** – Date of approval signature.

28. **APPROVE/REJECT RECOMMENDED DISPOSITION** – Based on the information provided in Block No. 21, each Approver is to approve or reject the Recommended Disposition noted in Block No. 23. Checking the Approved block means the Approver accepts <u>all</u> recommended dispositions provided in Block No. 23. Checking the Rejected block means the Approver <u>rejects one or more</u> of the recommended dispositions provided in Block No. 23.

Note: Communication between the supplier and Y-12 for RFWDC's must be handled by the Y-12 Subcontract Administrator.

ATTACHMENT B. CERTIFIED DATA – MANUFACTURER EQUIPMENT SPECIFICATION		Page 1 of 1
Manufacturer's Data Requirements		
Item No.	**Data Submittal—Purpose and Description**	**Specification or Reference**
	CERTIFIED DATA – Manufacturer	
	Items shall be supplied as specified in Sect. 9.1	
1.	TR-10 test report	4.2.1
2.	Hardness test report	4.2.2
3.	Elongation test report	4.2.3
4.	Inspection reports	4.5.3
5.	FTIR report	4.5.6
6.	Cure certificate	8.4.2.2
7.	Certificate of Conformance	9.1.7
8.	Request for Waiver or Deviation forms (if applicable)	9.2.1
9.	6" x 6" material sample	9.3

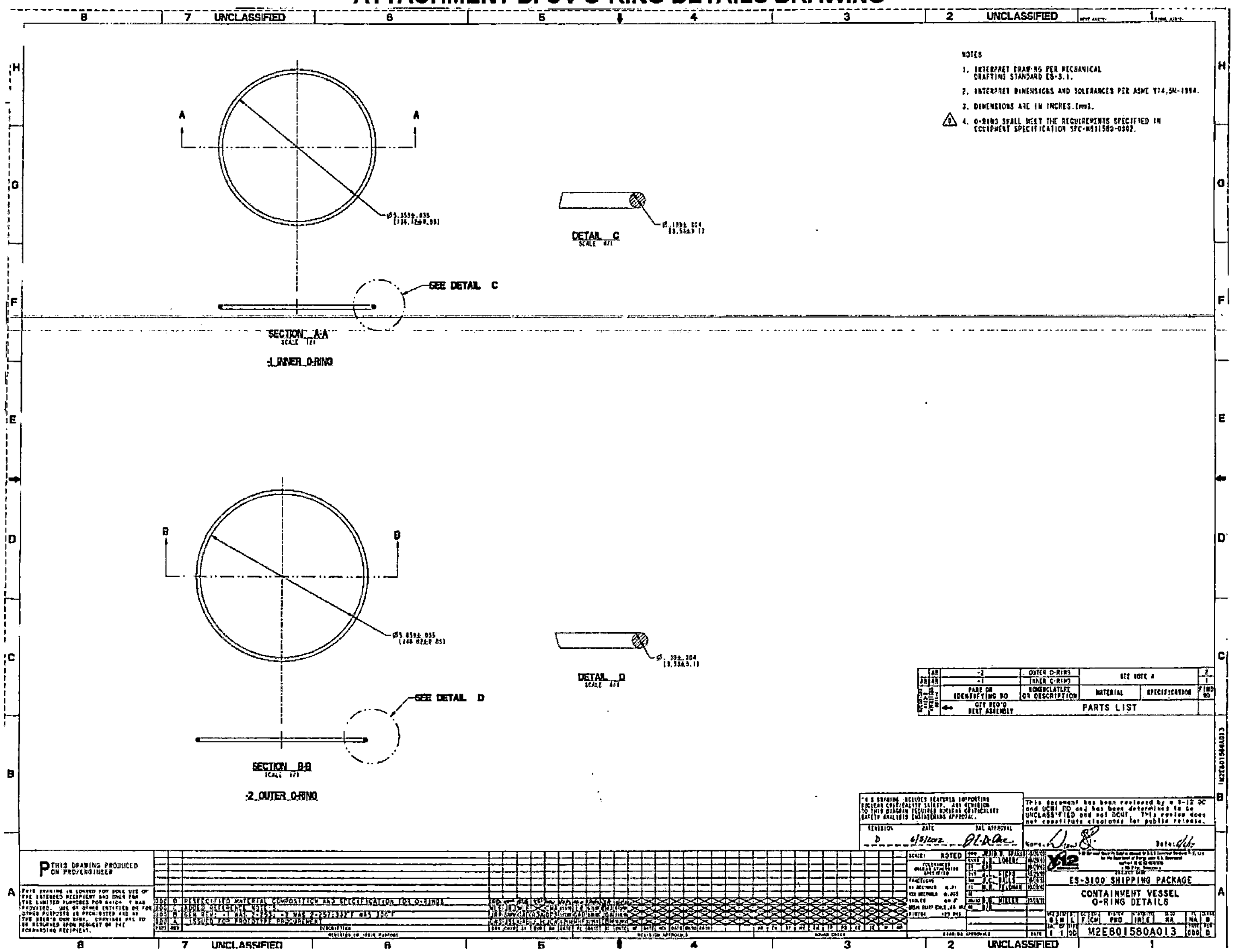
ATTACHMENT C. CERTIFICATE OF CONFORMANCE REQUIREMENTS

A Certificate of Conformance (CoC) shall be submitted after completion of project. The CoC shall conform as follows:

1. The CoC shall identify the purchased material or equipment, by the purchase order number.
2. The CoC shall identify the specific procurement requirements met by the purchased material or equipment, such as codes, standards, and other specifications. This may be accomplished by including a list of the specific requirements or by providing to Y-12 a copy of the purchase order and the procurement specifications or drawings, together with a suitable CoC.
3. The CoC shall identify any approved changes, waivers, or deviations applicable to the subject material or equipment.
4. The CoC shall identify any procurement requirements that have not been met, together with an explanation and the means for resolving the request for waiver or deviation.
5. The CoC shall be signed or otherwise authenticated by a person who is responsible for this quality assurance function and whose function and position are described in the quality assurance program of the Supplier.
6. The Supplier's certification system, including the procedures to be followed in filling out a CoC and the administrative procedures for review and approval of the certificates, shall be described in their quality assurance program.
7. If the CoC is for Commercial Grade Survey (CGS), the certificate shall identify the programs, process, and controls, including revision level evaluated and approved by the company, and attest to the implementation thereof.
   - QMS Manual, Rev J
   - P720-01, Rev C, *Planning of Product Realization*
   - P753-01, Rev B, *Handle, Store and Issue Materials*
   - W720-01, Rev D, *Create Production Plans (Work Orders)*

   If any document revisions differ from those listed, the Company shall review and approve through RFWD process prior to use.

ATTACHMENT D. CV O-RING DETAILS DRAWING



SECTION 1 REFERENCES

10 CFR 71, *Packaging and Transportation of Radioactive Material*, Jan. 1, 2015.

49 CFR, *Transportation*, Oct. 1, 2014.

ASME Boiler and Pressure Vessel Code, An American National Standard, Rules for Construction of Nuclear Facility Components, Sect. III, Div. 1, Subsection NB, American Society of Mechanical Engineers, New York, 2001 ed. with 2002 and 2003 addenda.

ASTM D-2000, *Standard Classification System for Rubber Products in Automotive Applications*, American Society for Testing and Materials, Philadelphia, current revision.

Byington, G. A. et al., "Fireproof Impact Limiter Aggregate Package Inside Shipping Container," U.S. patent 6,299,950 B1, Oct. 9, 2001.

DG-7003 (Proposed Revision 2 of Regulatory Guide 7.9), *Standard Format and Content of Part 71 Applications for Approval of Packaging for Radioactive Material*, U.S. NRC, December 2003.

MIL-D-6054F, *Drum, Metal—Shipping and Storage*, June 30, 1989.

NUREG/CR-3854, *Fabrication Criteria for Shipping Containers*, Lawrence Livermore Natl. Lab., March 1985.

Regulatory Guide 7.10, rev. 1, *Establishing Quality Assurance Programs for Packaging Used in the Transport of Radioactive Material*, U.S. NRC, June 1986.

Regulatory Guide 7.11, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)*, U. S. NRC, June 1991.

NUREG-1609, *Standard Review Plan for Transportation Packages for Radioactive Material*, U. S. NRC, March 1999.

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2. STRUCTURAL EVALUATION

The ES-3100 package is used to ship highly enriched uranium (HEU) in the following forms: oxide; bulk and broken metal shapes; and uranyl nitrate crystals. Content will be packed in various size convenience cans made of stainless, tin-plated carbon steel, or nickel alloy, and polyethylene, or Teflon FEP bottles. The cans shall have a diameter of ≤12.7 cm (5 in.) and heights of ≤25.4 cm (10 in.). Containment vessel arrangements that utilize closed metal cans with a diameter greater than 10.8 cm (4.25 in.) will not contain any materials that off gas at the temperatures associated with Normal Conditions of Transport (NCT) or Hypothetical Accident Conditions (HAC). Any combination of these cans shall be allowed in a single package, as long as the total length of the can stack (with spacers when required) does not exceed the inside working height of the containment vessel. Any closure on the convenience can is allowed. When space is available inside the containment vessel, stainless-steel metal scrubbers will be placed on the top and bottom of this partially canned assembly or an empty convenience can will be placed on top of this assembly inside the containment vessel. Polyethylene bags may be used inside or outside any convenience can as long as the loading restrictions in Sect. 1.2.3.8 are met. The amount of polyethylene bagging and lifting slings used inside the ES-3100 containment vessel is limited to 500 g. For the structural evaluation, the maximum payload inside the containment vessel will be as follows and as shown in Table 2.1: (1) 24 kg oxide or compounds (up to 100% enrichment in ^{235}U); (2) HEU oxide shall be in the form of UO_2, UO_3, or U_3O_8; (3) 24 kg of uranyl nitrate crystals; (4) 35.2 kg of uranium metal and alloy (up to 100% enrichment in ^{235}U); (5) HEU metal and alloy may be in the form of broken pieces, ingots, buttons, or small castings; and (6) the maximum weight of all contents, including nuclear material, convenience containers, polyethylene bags, spacers, slings, etc., shall not exceed 40.82 kg (90 lb). There is no minimum payload weight requirement. Uranium and transuranic isotopic allowances are defined in Sect. 4. Mass limits and total weights for each shipping arrangement are defined and described in Sect. 2.1.3. The 40.82-kg (90-lb) maximum containment vessel content weight and 35.2-kg (77.60-lb) HEU content weight limits have been established as a bounding case for the maximum structural, thermal, and containment limit for the shipping package. The above content masses and forms used for the proposed content do not take into consideration limits based on shielding and subcriticality.

As described in the following sections, design analysis, similarity, drop simulations, and the full-scale testing documented herein demonstrates that the ES-3100 package is in compliance with the requirements of Title 10 Code of Federal Regulations (CFR) 71 and Title 49 CFR 100–178 when it is used to ship contents described above. The maximum bounding activity of the contents (35.2 kg of HEU) is 3.2328×10^{-1} TBq (8.737 Ci) when the maximum activity-to-A_2 value is reached at ~70 years from material fabrication. The corresponding maximum number of A_2s carried is 293.99. This information is further discussed in Sect. 4.

Table 2.1. Proposed HEU contents for shipment in the ES-3100

Form	Chemical or physical description	Total weight of HEU contents kg (lb)
HEU oxide	UO_2, UO_3, U_3O_8	24 (52.91)
Uranyl nitrate crystals	$UO_2(NO_3)_2 + 6H_2O$	24 (52.91)
HEU metal and alloy	Specific geometric shapes (spheres, cylinders, square bars or slugs) or broken metal pieces	35.2 (77.60)

2.1 DESCRIPTION OF STRUCTURAL DESIGN

2.1.1 Discussion

The principal structural members of the shipping package consist of the following: the drum assembly, the containment boundary, packaging material, and the contents. Each of these will be described and discussed in the following sections.

2.1.1.1 Drum assembly

The drum assembly of the shipping package is defined as the structure that maintains the position of and provides protection to the impact and thermal barrier surrounding the containment boundary. Preserving the location of the containment boundary within the packaging prevents reduction of the shielding and subcriticality effectiveness. The drum assembly for the ES-3100 consists of an internally flanged Type 304L stainless-steel 30-gal modified drum with two type 304L stainless-steel inner liners, one filled with noncombustible cast refractory insulation and impact limiter (Kaolite) and one filled with noncombustible cast neutron absorber (Cat 277-4), a stainless-steel top plug with cast refractory insulation, silicone rubber pads, silicon bronze hex-head nuts, and a stainless-steel lid and bottom (Drawing M2E801580A031, Appendix 1.4.8). The nominal weight of these components is 131.89 kg (290.76 lb).

The drum's diameters (inner diameter of 18.25 in.) and corrugations meet the requirements of Military Standard MS27683-7. All other dimensions are controlled by Drawing M2E801580A004 (Appendix 1.4.8). Modifications to the drum from MS27683-7 include the following: (1) the overall height was increased; (2) the drum was fabricated with two false wire open ends; and (3) a 0.27-cm (12-gauge, 0.1046-in.)–thick concave cover was welded to the bottom false wire opening (Drawing M2E801580A005, Appendix 1.4.8). Four 0.795-cm (0.313-in.)–diameter equally spaced holes are drilled in the top external sidewall to prevent a pressure buildup between the drum and inner liner. The holes are sealed with a plastic plug to provide a moisture barrier for the cast refractory insulation during Normal Conditions of Transport (NCT). The cavity created by the inner liners is a three-tiered volume with a 37.52-cm (14.77-in.) inside diameter 13.26 cm (5.22 in.) deep, a 21.84-cm (8.60-in.) inside diameter 5.59 cm (2.20 in) deep, and an additional 15.85-cm (6.24-in.) inside diameter 78.31-cm (30.83 in.) deep. The volume between the mid liner and the drum and the top plug's internal volume is completely filled with the noncombustible cast refractory insulation called Kaolite 1600 from Thermal Ceramics, Inc. Kaolite properties, such as mechanical, thermal conductivity, and impact, are presented in Appendix 2.10.3. The volume between the most inward liner and the mid liner wall is completely filled with a noncombustible neutron absorber (poison) from Thermo Electronic Corp. called Cat 277-4. Cat 277-4 properties, such as thermophysical, mechanical, and neutron activation, are

presented in Appendix 2.10.4. BoroBond4, another noncombustible neutron absorber, was used only in prototype test packages instead of Cat 277-4. The drum body, inner liners, and lid are fabricated from 0.15-cm (16-gauge, 0.0598-in.) thick Type 304/304L stainless-steel sheet. A rolled stainless-steel flange with a 5.08 × 5.08 × 0.64-cm (2 × 2 × 0.25-in.) thick modified stainless-steel structural angle is welded around the top of the mid inner liner. The mid inner liner is then welded to the inside surface of the drum along this flange. Eight ⅝-11-UNC-2A studs welded to the drum and silicon bronze nuts provide the structural attachment for the drum lid, and are torqued to 40.67 ± 6.78 N·m (30 ± 5 ft-lb) at assembly. The drum lid's diameter and shape meet the requirements of Military Standard MS27683-61. All other dimensions are controlled by Drawings M2E801580A006 and A007, Appendix 1.4.8. The welded angle ring (Find Number 3 on Drawing M2E801580A006, Appendix 1.4.8) provides the lid with an inner flange. The welded angle ring was incorporated in the ES-3100 package for use during handling and transport to protect the lid closure studs and nuts. During transport, the welded angle ring helps position drum tie-down adapters that are used for tie-down of a single unit configuration in Safe-Secure Trailers/Safeguards Transporters (SSTs/SGTs) in accordance with U.S. Department of Energy (DOE) Order 5610.14. The drum is marked by two stainless-steel data plates. The data plate lettering and mounting requirements on the drum are shown on Drawings M2E801580A010 and M2E801508A031 (Appendix 1.4.8), respectively. Painting and marking requirements for the drum are shown on Drawing M2E801508A001 (Appendix 1.4.8). Two lugs are welded to the mid inner liner and project through the drum lid at assembly. Each lug has a 0.953-cm (0.38-in.)–diameter hole through which a tamper-indicating device (TID) can be threaded.

The volume between the drum and mid-liner is filled with a lightweight noncombustible cast refractory material called Kaolite 1600. The top plug is also filled with this material and represents the thermal insulation and impact limiting barrier. The material is composed of portland cement, water, and vermiculite and has an average density of 358.8 kg/m^3 (22.4 lb/ft^3). The procedure for manufacturing and documenting the installation of this material, JS-YMN3-801580-A003 (Appendix 1.4.4), is referenced on Drawings M2E801580A002 and M2E801580A008 (Appendix 1.4.8) for the drum assembly weldment and top plug weldment, respectively. The insulation has a maximum continuous service temperature limit of 871°C (1600°F) due to the presence of the vermiculite and portland cement.

The volume between the most internal liner and the mid-liner is filled with a noncombustible cast neutron absorber (poison) material from Thermo Electronic Corp. called Cat 277-4. The material is a high alumina borated concrete composed of aluminum, magnesium, calcium, boron, carbon, silicon, sulfur, sodium, iron and water. The final mixture has an average density of 1681.9 kg/m^3 (105 lb/ft^3). The procedure for manufacturing and documenting the installation of this material, JS-YMN3-801580-A005 (Appendix 1.4.5), is referenced on Drawing M2E801580A002 (Appendix 1.4.8). This neutron absorber material has a maximum continuous service temperature limit of 150°C (302°F) in order to retain the bound mass of water in the final cured mixture for subcriticality control.

The top plug is fabricated in accordance with Drawing M2E801580A008 with an overall diameter of 36.50 cm (14.37 in.) and a height of 13.41 cm (5.28 in.). The plug's rim, bottom sheet, and top sheet are fabricated from 0.15-cm (16-gauge, 0.0598-in.) thick Type 304/304L stainless-steel sheet per ASME SA240. Four lifting inserts are welded into the top sheet for loading and unloading operations. The internal volume of the top plug is filled with Kaolite 1600 in accordance with JS-YMN3-801580-A003, Appendix 1.4.4.

Three silicone rubber pads complete the drum assembly. One pad is placed on the bottom of the most internal liner to support the containment vessel during transport. Another pad is placed on the top shelf of the mid-liner to support the top plug during transport. The final plug is placed over the top of the containment vessel during transport. The pads are molded to the shapes as defined on Drawing M2E801580A009 (Appendix 1.4.8). The material is silicone rubber with a Shore A durometer reading of 22 ±5.

2.1.1.2 Containment boundary

The containment vessel's body, lid assembly, and inner O-ring provide the containment boundary (Fig. 1.3). Two methods of fabrication may be used to fabricate the containment vessel body of the ES-3100 package as shown on Drawing M2E801580A012 (Appendix 1.4.8). The first method uses a standard 5-in., schedule 40 stainless-steel pipe per ASME SA-312 Type TP304L, a machined flat-head bottom forging per ASME SA-182 Type F304L, and a machined top flange forging per ASME SA-182 Type F304L. The nominal outside diameter of the 5-in schedule 40 pipe is machined to match the nominal wall thickness of 0.100 in. Each of these pieces is joined with circumferential welds as shown on sheet 2 of Drawing M2E801580A012 (Appendix 1.4.8). The top flange is machined to match the schedule 5-in. pipe, to provide two concentric half-dove tailed O-ring grooves in the flat face, to provide locations for two 18-8 stainless-steel dowel pins, and to provide the threaded portion for closure using the lid assembly. The second method of fabrication uses forging, flow forming, or metal spinning to create the complete body (flat bottom, cylindrical body, and flange) from a single forged billet or bar with final material properties in accordance with ASME SA-182 Type F304L. The top flange area using this fabrication technique is machined identically to that of the welded forging method. The lid assembly, which completes the containment boundary structure, consists of a sealing lid, closure nut, and external retaining ring (Drawing M2E801580A014, Appendix 1.4.8). The containment vessel sealing lid (Drawing M2E801580A015, Appendix 1.4.8) is machined from Type 304 stainless-steel bar with final material properties in accordance with ASME SA-479. The containment vessel closure nut (Drawing M2E801580A016, Appendix 1.4.8) is machined from a Nitronic 60 stainless-steel bar with material properties in accordance with ASME SA-479. These two components are held together using a WSM-400-S02 external retaining ring made from Type 302 stainless steel. The sealing lid is further machined to accept a ⅜-16 swivel hoist ring bolt to facilitate loading and unloading, to provide a leak-check port between the elastomeric O-rings, and notched along the perimeter to engage two dowel pins. The lid assembly, with the O-rings in place on the body, are joined together by torquing the closure nut and sealing lid assembly to 162.70 ± 6.78 N·m (120 ± 5 ft-lb). The sealing lid portion of the assembly is restrained from rotating during this torquing operation by the two dowel pins installed in the body flange. An evacuation port is located between the O-rings in the containment vessel to facilitate a pressure rise or drop leakage test following assembly or 10 CFR 71 compliance testing. This port is sealed during transport using a modified VCO threaded plug. Only the inner O-ring is considered a part of the containment boundary.

There are no penetrations of, connections to, or fittings for the sealed containment boundary. To meet the requirements for package certification, the containment boundary must remain intact during all conditions of transport. This integrity must be demonstrated by test or other acceptable methodology for NCT and Hypothetical Accident Conditions (HAC) as described in 10 CFR 71.

2.1.1.3 Packaging materials

Contents will be packed in various size convenience cans made of stainless steel, tin-plated carbon steel, or nickel-alloy, and polyethylene bottles or Teflon FEP bottles. The cans shall have a diameter of ≤12.7 cm (5 in.) and heights of ≤44.5 cm (17.5 in.). Any combination of these cans shall be allowed in a single package, as long as the total length of the can stack (with spacers and pads as

required) does not exceed the inside working height of the containment vessel (~31 in.). Any closure on the convenience can is allowed. Multiple short cans may be tack brazed together. Containment vessel arrangements that utilize closed metal cans with a diameter greater than 10.8 cm (4.25 in.) will not contain any materials that off gas at the temperatures associated with NCT or HAC. When space is available inside the containment vessel, stainless-steel metal scrubbers will be placed on the top and bottom of this partially canned assembly or an empty convenience can will be placed on top of this assembly inside the containment vessel. The polyethylene bottles have a diameter of ~12.54 cm (4.94 in.) and a height of ~22.1 cm (8.7 in.). A total of three polyethylene bottles may be loaded into the containment vessel. The Teflon FEP bottles have a diameter of ~ 11.91 cm (4.69 in.) and a height of ~23.88 cm (9.4 in.). A total of three Teflon FEP bottles may be loaded into the containment vessel. Polyethylene bags may be used inside or outside any convenience can or bottle. In some packing arrangements, silicone rubber pads will be used between convenience cans. Also, some arrangements will require spacers between cans. These spacers are thin stainless-steel cans filled with the noncombustible cast neutron poison. Each convenience can and spacer is equipped with a stainless-steel band clamp and nylon coated wire for loading and unloading operations. The spacers are ~10.11 cm (3.98-in.) in diameter by 4.45 cm (1.75 in.) in height and a maximum weight ~0.58 kg (1.27 lb). In order to minimize displacement of convenience containers during transport, stainless-steel scrubbers or polyethylene bags may be added on top of the last can or bottle in the containment vessel. If partial loading configurations are employed and empty cans or bottles are used, these empty cans or bottles will be loaded last and will require a minimum 0.32 cm (⅛ in.) diameter hole to be placed through the lid.

2.1.2 Design Criteria

2.1.2.1 General standards for all packages

The general design standards for all packages in accordance with 10 CFR 71.43(a) through (e), (g) and (h) are addressed in the following paragraphs.

10 CFR 71.43(a)

Requirement: The smallest overall dimension of a package shall not be <10 cm (4 in.).

Compliance: The drums' outside diameter over the rolled rings is 49.20 cm (19.37 in.), and the outside height including the lid is 110.49 cm (43.50 in.). The minimum outside diameter of the ES-3100 containment vessel is 13.36 cm (5.26 in.), and the overall height is 82.30 cm (32.40 in.). Therefore, the packaging meets this requirement.

10 CFR 71.43(b)

Requirement: The outside of the package must incorporate a feature, such as a seal, that is not readily breakable and that, while intact, would be evidence that the package has not been opened by unauthorized persons.

Compliance: The removable drum head is attached to the body by eight ⅝-11-UNC-2B silicon bronze nuts and ⅝-in. nominal washers. Two 0.51-cm (0.20-in.)-thick lugs with 0.953-cm (0.38-in.)-diam holes (Drawing M2E801580A005, Appendix 1.4.8) project through slots in the drum lid and provide attachment for tamper-indicating devices (TIDs). These TIDs consist of a stainless-steel cable with an aluminum crimp closure or equivalent. The requirement is satisfied by the TIDs, which are installed as specified in Sect. 7.1.2.2. The TID is only required when the containment vessel has HEU in the package. It is not required for empty shipments.

10 CFR 71.43(c)

Requirement: Each package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by pressure that may arise within the package.

Compliance: The fastened lid on the drum with tamper-indicating features provides assurance that the drum assembly will not be unintentionally breached. The containment boundary is sealed using the lid assembly and closure nut to ensure that this boundary will be breached only through a deliberate effort, and then only after the drum assembly is breached. The design of the containment boundary is analyzed in Appendix 2.10.1 for a differential pressure of 699.82 kPa (101.5 psi) internal and 150 kPa (21.7 psi) external. The internal design pressure exceeds the maximum differential pressure of 175.20 kPa (25.410 psi) and 479.56 kPa (69.555 psi) attained during NCT (Sect. 2.6.3) and HAC (Sect. 3.5.3), respectively. In addition, calculation results are provided in Sects. 2.6.1 and 2.7.4.3 to demonstrate that the stresses in the containment boundary and closure nut threads do not exceed the stress limits established by the ASME code for NCT and HAC. Therefore, the containment boundary will not be breached during any mode of transport due to pressurization of the containment boundary.

10 CFR 71.43(d)

Requirements: A package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents including possible reaction resulting from inleakage of water, to the maximum credible extent. Account must be taken of the behavior of materials under irradiation.

Compliance: Compliance with the regulatory requirements are discussed in Sect. 2.2.2.

10 CFR 71.43(e)

Requirement: A package valve or other device, the failure of which would allow radioactive contents to escape, must be protected against unauthorized operation and, except for a pressure relief device, must be provided with an enclosure to retain any leakage.

Compliance: No penetrations, connections, or fittings into the containment vessels exist; therefore, the requirements of 10 CFR 71.43(e) are not applicable.

10 CFR 71.43(g)

Requirement: A package must be designed, constructed, and prepared for transport so that in still air at 38°C (100°F) and in the shade, no accessible surface of a package would have a temperature exceeding 50°C (122°F) in a nonexclusive use shipment or 85°C (185°F) in an exclusive use shipment.

Compliance: Since the components to be shipped have a calculated maximum decay heat load of 0.4 W, thermal analyses were conducted for the ES-3100 package; results are summarized in Appendix 3.6.2. The predicted temperatures, while the package is stored at 38°C (100°F) in the shade, for the drum lid center, and the containment vessel flange, are approximately 38.3°C (101°F). The analysis shows that no accessible surface of the package would have a temperature exceeding 50°C (122°F). Therefore, the requirement of 10 CFR 71.43(g) would be satisfied for either transportation mode (exclusive or nonexclusive use).

10 CFR 71.43(h)

Requirement. A package must not incorporate a feature intended to allow continuous venting during transport.

Compliance. No penetrations, connections, or fittings into the containment vessel exist that would allow venting during transport. The materials of package construction do not provide any pressure buildup during transportation. Four vent holes through the drum are covered with a plastic plug during NCT. Therefore, the requirements of 10 CFR 71.43(h) are satisfied.

2.1.2.2 Component design criteria

The ES-3100 packaging/content combination addressed in this safety analysis report is intended to ship contents with a maximum activity of 3.2328×10^{-1} TBq (8.737 Ci) at 70 years from initial fabrication; the maximum number of A_2s carried is 293.99 at 70 years following initial fabrication (Table 4.4). Based on the guidance from Regulatory Guide 7.11, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)*, this package is classified in NUREG-1609 (Table 1.1) and Table 2.2 as a Category II shipping package. However, since the ES-3100 may be used for future contents that exceed 3000 A_2 (under a different SAR and certificate), this package has been classified as a Category I shipping package. Therefore, the containment vessel is designed (using nominal dimensions for each component), fabricated, and inspected in accordance with the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, Sect. III, Division I, Subsection NB. The design and subsequent verification comply with the requirements of 10 CFR 71. The structural requirements for the packaging under NCT are addressed in Sect. 2.6. The structural requirements for the packaging under HAC are addressed in Sect. 2.7.

Table 2.2. Category designations for Type B packages

Contents Form/ Category	Category I	Category II	Category III
Special Form	Greater than 3,000 A_1 or greater than 1.11 PBq (30,000 Ci)	Between 3,000 A_1 and 30 A_1, and not greater than 1.11 PBq (30,000 Ci)	Less than 30 A_1 and less than 1.11 PBq (30,000 Ci)
Normal Form	Greater than 3,000 A_2 or greater than 1.11 PBq (30,000 Ci)	Between 3,000 A_2 and 30 A_2, and not greater than 1.11 PBq (30,000 Ci)	Less than 30 A_2 and less than 1.11 PBq (30,000 Ci)

The drum assembly of the shipping package is defined as the structure that maintains the position of and provides protection to the impact , thermal barrier, and neutron poison surrounding the containment boundary. Because the location of the containment boundary within the packaging is stable, the shielding and subcriticality effectiveness of the package is not reduced. The drum assembly for the ES-3100 consists of an internally flanged Type 304L stainless-steel 30-gallon modified drum with two Type 304L stainless-steel inner liners, one filled with noncombustible cast refractory insulation and impact limiter and one filled with noncombustible cast neutron absorber; a stainless-steel top plug with cast refractory insulation, silicone rubber pads, silicon bronze hex-head nuts, and a stainless-steel lid and bottom (Drawing M2E801580A001, Appendix 1.4.8). The drum assembly is maintained when there are no breaches in the drum surface, the lid remains attached, the relative position of the containment

boundary is not altered significantly, and no substantial amount of insulation is exposed following testing stipulated in 10 CFR 71.71 and 73. The drum assembly's design requirements for compliance testing are as follows:

1. The drum lid shall remain attached to the drum under all loading conditions.

2. No opening in the drum shall occur large enough to pass a 10-cm cube [10 CFR 71.43(a)].

3. The outer drum's effective diameter shall exceed requirements to maintain subcriticality and shielding effectiveness.

4. The drum assembly shall provide the structural and thermal protection needed to ensure the containment vessel meets the test leakage criteria for both NCT and HAC of $\leq 1.0 \times 10^{-7}$ ref-cm^3/s.

5. Neutron poison remains in place and retains the amount of water needed to maintain subcriticality.

In accordance with NUREG/CR-3854, Part 4.3, for a Category I shipping package, an acceptable specification for a drum used in any of the component safety groups is U.S. Department of Transportation (DOT) Specification 17C or better. The drum used in the ES-3100 is fabricated in accordance with the dimensional requirements of MS27683-7 (MIL-D-6054F) and modified as shown on Drawing M2E801508A004 (Appendix 1.4.8). Material, fabrication, and quality control criteria are generally equivalent to those imposed for a DOT Specification 17C drum. The drum weld seam is pressure tested to 68.95 kPa (10 psi) gauge and a rough handling test in accordance with MIL-D-6054F is conducted. As discussed in Sect. 1.2.1.1, the drum used for the ES-3100 is equivalent to or better than that stipulated by NUREG/CR-3854 for a Category I shipping package. In accordance with DOE, a performance-based package is an approved, quality-controlled, hazardous material container that has been tested or analyzed to demonstrate its ability to maintain confinement and/or containment of its contents under both normal use and credible accident conditions as stipulated in 10 CFR 71. The drum assembly and containment boundary have been maintained for the ES-3100 shipping package as demonstrated by test results documented in the test report (Appendix 2.10.7) and the analytical comparisons discussed in Sects. 2.6 and 2.7.

The codes and standards used for design, analysis, and fabrication of the containment vessel's components are satisfied by complying with the appropriate paragraphs in Sect. III, Div. 1, Subsection NB, and Sect. IX of the *ASME Boiler and Pressure Vessel Code*. Nominal dimensions, not minimum dimensions, were used in the design analysis of the containment vessel components. Though not explicitly expressed, the load combinations and tests stated in Regulatory Guide 7.8, *Load Combinations for the Structural Analysis of Shipping Casks* are used in the structural evaluation of the containment vessel for both NCT and HAC as depicted in Table 2.3. Acceptance criteria for the containment vessel stresses are shown in Table 2.4 and locations are depicted in Fig. 2.1.

The design internal pressure of 699.82 kPa (101.5 psi) gauge for the containment boundary was generated based on its stress capability before the *ASME Boiler and Pressure Vessel Code* evaluation shown in Appendix 2.10.1 was started. The containment vessel is tested with an internal pressure of 1034.21 kPa (150 psi) gauge or 1.48 times the design pressure, which exceeds the requirement stipulated in Sect. III, Paragraph NB-6221 (a minimum hydrostatic test pressure of 1.25 times the design pressure) and the regulatory requirement of 10 CFR 71.85(b) (1.5 times the

Table 2.3. Summary of load combinations for normal and hypothetical accident conditions of transport

Normal or accident condition	Applicable initial condition: Ambient temperature		Insolation		Decay heat		Internal pressure		Fabrication stresses	SAR reference
	38°C	-29°C	Max	0	Max	0	Max	Min		
Normal conditions (analyze separately)										
Hot environment (38°C ambient temperature)			X		X		X		X	Sect. 2.6.1
Cold environment (−40°C ambient temperature)				X		X		X	X	Sect. 2.6.2
Increased external pressure (20 psia)		X		X		X		X	X	Sect. 2.6.4
Minimum external pressure (3.5 psia)	X		X		X		X		X	Sect. 2.6.3
Vibration and shock:	X		X		X		X		X	Sect. 2.6.5[a]
Normally incident to the mode of transport		X		X		X		X	X	
Free drop:	X		X		X		X		X	Sect. 2.6.7[b]
1.2-m drop		X		X		X		X	X	
Compression test	X		X		X		X		X	Sect. 2.6.9[a]
		X		X		X		X	X	
Penetration test	X		X		X		X		X	Sect. 2.6.10[a]
		X		X		X		X	X	
Accident conditions (apply sequentially)										
Free drop: 9-m drop	X		X		X		X		X	Sect. 2.7.1[c]
		X		X		X		X	X	
Crush: 9-m drop	X		X		X		X		X	Sect. 2.7.2[c]
		X		X		X		X	X	
Puncture: 1-m drop onto bar	X		X		X		X		X	Sect. 2.7.3[c]
		X		X		X		X	X	
Thermal: fire accident	X		X		X		X		X	Sect. 2.7.4

[a] This condition was conducted at room temperature with atmospheric pressure inside the containment vessel.

[b] This condition was conducted at ambient temperature at the time of the test except for Test Unit-2. The containment vessel was at atmospheric pressure except for Test Unit-2. Justification for compliance with the environmental requirements of Reg. Guide 7.8 is provided in Sect. 2.6.

[c] This condition was conducted at ambient temperature at the time of the test except for Test Unit-2. The containment vessel was at atmospheric pressure except for Test Unit-2. Justification for compliance with the environmental requirements of Reg. Guide 7.8 is provided in Sect. 2.7.

Table 2.4. Containment vessel allowable stress

Stress Category	Maximum allowable stress	
	Level A (NCT)	**Level D (HAC)**
Primary membrane stress intensity	S_m	Lesser of 2.4 S_m and 0.7 S_u
Primary membrane + primary bending stress intensity	1.5 S_m	Lesser of 3.6 S_m and S_u
Range of primary + secondary stress intensity	3.0 S_m	Not applicable
Fatigue stress range	S_a @ 10^6 cycles	2 S_a @ 10^6 cycles
Buckling	No buckling	No buckling

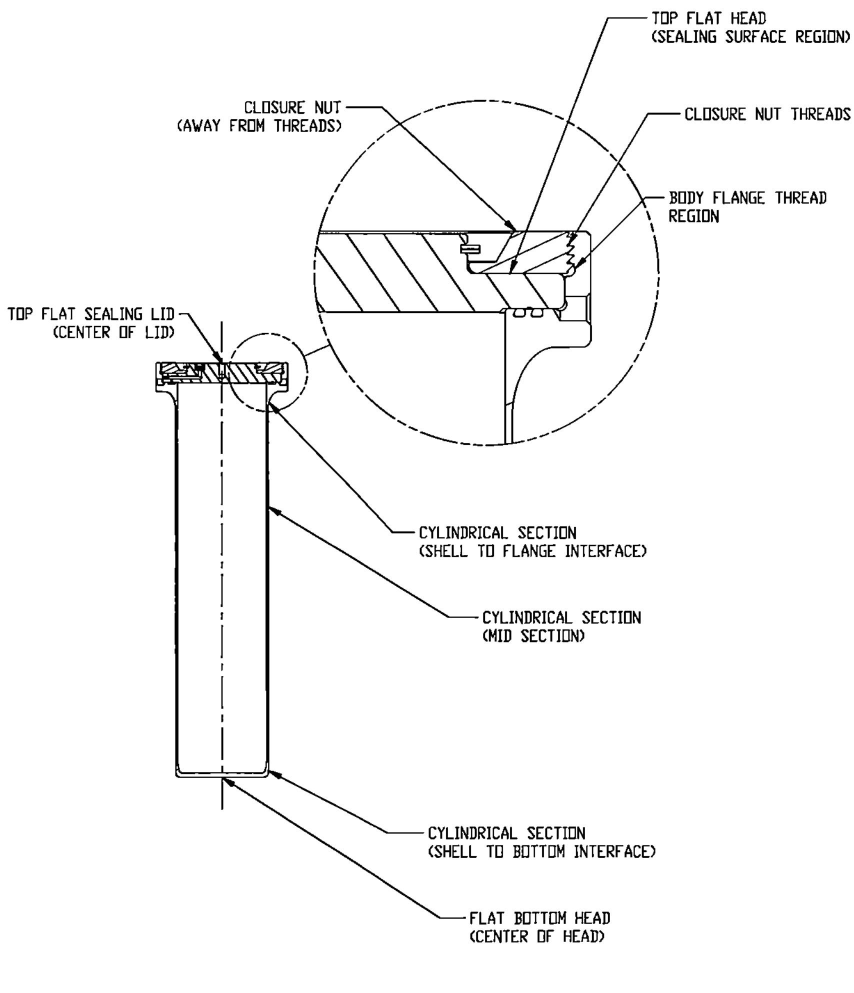

Fig. 2.1. Containment vessel calculated stress locations.