QA: QA

Civilian Radioactive Waste Management System
Management & Operating Contractor

Waste Package Operations Fabrication Process Report

TDR-EBS-ND-000003 REV 01

September 2000

Prepared for:

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DISCLAIMER

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REVISION HISTORY

Revision 00 – Initial issue.

Revision 01 – This revision incorporates the Site Recommendation waste package, drip shield, and emplacement pallet designs. Also, this revision includes information from Fiscal Year 2000 closure weld mock-up fabrication.

Note: This report supersedes *Waste Package Fabrication Process Report* (BBA000000-01717-2500-00010 REV 03).

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ACRONYMS

ASME	American Society of Mechanical Engineers
CF	canistered fuel
CFR	Code of Federal Regulations
COC	Certificate of Conformance
CRWMS	Civilian Radioactive Waste Management System
DHLW	defense high-level waste
DOE	U.S. Department of Energy
FY	fiscal year
HLW	high-level waste
M&O	Management and Operating Contractor
MGR	Monitored Geologic Repository
MT	magnetic particle examination
NDE	nondestructive examination
NG	nuclear grade
OCRWM	Office of Civilian Radioactive Waste Management
PT	liquid penetrant examination
QA	Quality Assurance
QC	Quality Control
RT	radiographic examination
SDD	System Description Document
SI	International System of Units
SNF	spent nuclear fuel
UT	ultrasonic examination
UCF	uncanistered fuel
WP	waste package

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1. INTRODUCTION

The waste package (WP) fabrication task is part of a larger program to develop WP designs. The purpose of the larger Waste Package Department program is to develop nuclear waste disposal container designs that the U.S. Nuclear Regulatory Commission will find acceptable and will license for disposal of spent nuclear fuel (SNF) and vitrified high-level waste (HLW) within a Monitored Geologic Repository (MGR). Much of the SNF will arrive as individual fuel assemblies. An as-yet-to-be-determined amount of fuel may arrive in sealed canisters, i.e., canistered fuel (CF) ready for disposal, for example: DOE- (U.S. Department of Energy) owned SNF to be codisposed with HLW, canistered Naval SNF, and possibly, canistered commercial SNF. This report incorporates the Site Recommendation waste package, drip shield, and emplacement pallet designs.

The current design concept for the disposal of SNF, arriving as individual fuel assemblies, will require a complete disposal container consisting of an outer corrosion resistant barrier, an inner reinforcement cylinder, and an internal SNF structural support. This design configuration is called an uncanistered fuel (UCF) disposal container. Disposal of a CF canister will require placement of the sealed canister within a similarly configured disposal container (requires no internal basket). This design configuration is called a CF disposal container. The UCF disposal container and the CF disposal container are of similar design and size, use the same materials for the cylinders, and serve the same function of isolating the waste for the prescribed period of time. The defense high-level waste (DHLW) disposal container, used for disposal of HLW canisters plus one or more codisposal DOE SNF canisters, is configured much like the CF disposal container, although it may be somewhat shorter. Disposal container design concepts are described in more detail in Section 8 of this report. A brief introduction to the disposal container design is provided in the following paragraphs. It should be noted that once a disposal container is filled, sealed, and inspected, it is by definition a WP.

Over the repository lifetime, the WP, comprised of the inner reinforcement cylinder and outer corrosion resistant barrier, will perform various functions that will change with time. During the 100-year or longer operational period, the cylinders will function as the vessel for handling, emplacing, and retrieving (if necessary) the contents of the WP. The operational period will be followed by the 10,000-year containment period. The WP shall be designed, in conjunction with the Emplacement Drift System and the natural barrier, such that the expected annual radiation dose to the average member of the critical group shall not exceed 25 mrem total effective dose equivalent at any time during the first 10,000 years after permanent closure, as a result of radioactive materials released from the geologic repository.

Once the waste has been placed into the disposal container, the inner cylinder lid and the outer barrier lid will each be remotely welded into place and inspected (and post-weld stress relieved if required) in order to establish each cylinder as a contiguous unit. The measure of closure weld quality will be the weld and heat affected zone corrosion characteristics relative to the cylinder base materials as well as structural integrity. (Note that the WP is not intended to function as a pressure vessel.)

Next, the WP is placed on an emplacement pallet in the repository surface facility. The WP and emplacement pallet are then transported and placed in an emplacement drift. Prior to the closure of the repository, there will be drip shields placed in the emplacement drifts and over all WPs.

The WP engineering development program applies to the UCF disposal containers, CF disposal containers, non-fuel disposal containers, DHLW disposal containers, drip shields, and emplacement pallets. Within the WP engineering development program are several major development tasks, which, in turn, are divided into subtasks. The major tasks include: WP, drip shield, and emplacement pallet fabrication development; WP closure weld development; nondestructive examination (NDE) development; and remote in-service inspection development.

2. OBJECTIVE

The objective of this task is to identify various methods of manufacturing that may be used to fabricate the disposal container, drip shield, and emplacement pallet at whatever manufacturing facilities may have the fabrication contracts. It is not the intent of this task to limit the manufacturing expertise at the facility; rather, the task is to show that the disposal container, drip shield, and emplacement pallet can be fabricated. This report, the *Waste Package Operations Fabrication Process Report*, will provide recommended methods and alternative methods for these operations. The current disposal container presumption is based on the single corrosion resistant barrier with a structural reinforcement cylinder per *Design Analysis for UCF Waste Packages* (CRWMS M&O 2000a), *Design Analysis for the Defense High-Level Waste Disposal Container* (CRWMS M&O 2000b), or *Design Analysis for the Naval SNF Waste Package* (CRWMS M&O 2000c). The designs for the drip shield and emplacement pallet are from the *Design Analysis for the Ex-Container Components* (2000d).

3. SCOPE

The scope of the Waste Package Operations Fabrication Process Report is from initiation of fabrication to delivery of the disposal container, drip shield, and emplacement pallet to the repository. This report will not cover the closure welds of the disposal container; this topic is covered in the *Waste Package Operations FY-99 Closure Methods Report* (CRWMS M&O 1999a), and subsequent reports such as the one being developed in Fiscal Year (FY) -00.

4. REQUIREMENTS

All fabrication inputs that are identified in this report are for the preliminary design stage of the design process. This report will not directly support any construction, fabrication, or procurement activity.

4.1 PROJECT-LEVEL REQUIREMENTS

The WP development program, which is part of the larger engineering development program for WP, drip shield, and emplacement pallet manufacturing, directly supports the disposal container, drip shield, and emplacement pallet designs by demonstrating that the disposal container, drip shield, and emplacement pallet can be successfully fabricated.

Disposal container, drip shield, and emplacement pallet project level requirements are identified in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000e). Project-level requirements flow down from the *Monitored Geologic Repository Project Description Document* to the System Description Documents (SDD). There are currently several SDDs for the various disposal container configurations, drip shield, and emplacement pallet. SDD criteria applicable to the disposal container, drip shield, and emplacement pallet fabrication task will be augmented by design specifications and drawings that, in part, satisfy design requirements.

The following system design criteria are those directly applicable to the fabrication of the disposal container. These criteria are derived from the *Uncanistered Spent Fuel Disposal Container System Description Document* (CRWMS M&O 2000g) and are representative of the criteria for all of the various disposal container designs:

> "Disposal container shall consist of two cylinders; an inner cylinder that is stainless steel (alloy 316 NG) with a nominal thickness of 5 cm, and an outer cylinder that is alloy 22 material with a nominal thickness of 2 cm."
>
> Para. 1.2.1.4

> "The disposal container/waste package, excluding the labels, shall have an external surface finish Roughness Average of 250 µin (6.36 µm) or less."
>
> Para. 1.2.1.10

> "The disposal container/waste package shall have all external surfaces (surfaces exposed to the external environment after closing and sealing a disposal container) accessible for visual inspection and decontamination (e.g., no blind holes)."
>
> Para. 1.2.1.11

> "The disposal container/waste package shall have a label (or other means of identification) with a unique waste package identifier."
>
> Para. 1.2.1.12

The following system design criteria are those directly applicable to the fabrication of the drip shield and emplacement pallet. These criteria are derived from the *Emplacement Drift System Description Document* (CRWMS M&O 2000f):

> "The drip shield materials shall be Grade 7 Titanium, and a minimum of 15-mm thick at the time of emplacement."
>
> Para. 1.2.1.18

> "The materials that contact the surface of the WPs, as emplaced during the preclosure period, shall be the same material as the WP outer surface."
>
> Para. 1.2.4.12

4.2 QUALITY ASSURANCE REQUIREMENTS

This report was prepared in accordance with AP-3.11Q, *Technical Reports*, and the development plan for *Waste Package Operations Fabrication Process Report* (CRWMS M&O 1999b). The information provided in the report is to be indirectly used in the evaluation of the MGR WP and engineered barrier segment. The WP and engineered barrier segment have been identified as Quality Level 1 items in the QAP-2-3, *Classification of Permanent Items*, evaluations (e.g., *Classification of the MGR Uncanistered Spent Nuclear Fuel Disposal Container System*) (CRWMS M&O 1999c). The responsible manager has evaluated the report development activity in accordance with QAP-2-0, *Conduct of Activities*. Note that QAP-2-0, *Conduct of Activities*, has been superseded by AP-2.21Q, *Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities*; however, the Activity Evaluation, *WP Engineering and Fabrication* (CRWMS M&O 1999d) remains in effect. The results of that evaluation were that the activity is subject to the *Quality Assurance Requirements and Description* (DOE 2000) requirements. There is no determination of importance evaluation developed in accordance with Nevada Line Procedure, NLP-2-0, *Determination of Importance Evaluations*, since the report does not involve any field activity.

None of the work developed for this report used computer software. With regard to the development of this technical report, the control of the electronic management of data was evaluated in accordance with AP-SV.1Q, *Control of the Electronic Management of Information*. The evaluation (CRWMS M&O 2000h) determined that current work processes and procedures did not generate any electronic data to be managed for this activity.

5. TECHNICAL APPROACH

The technical approach will be to consider each design in turn, breaking the fabrication into components and then describing the assembly. Rationale for the fabrication methods described will be standard manufacturing techniques. The intent of this report is to describe how the waste disposal container, drip shield, and emplacement pallet can be manufactured by conventional means and to begin developing the guidelines to which they will be built. This will be supplemented with as much independent manufacturing information as can be obtained from commercial fabricators without officially submitting the design for bid. The designs covered here will be the UCF disposal container, the DHLW disposal container, the CF disposal container, the drip shield, and emplacement pallet. Once the manufacturing methods are established for the different types of disposal containers, the other containers vary only in size and not in manufacturing methods.

This information will not have a direct effect on other design organizations. The Waste Package Fabrication group will include the Surface Facility Design group in the distribution list for this report for interface information.

6. FABRICATION AND TESTING CONDITIONS

The Quality Assurance (QA) and Quality Control (QC) authority is the DOE Office of Civilian Radioactive Waste Management (OCRWM). The Civilian Radioactive Waste Management System (CRWMS) is administered for DOE OCRWM by the Management and Operating Contractor (M&O). The Supplier is the disposal container, the drip shield, and/or the emplacement pallet Fabricator. In the following, the phrase "submitted for approval" and other similar phrases mean submittal to the Purchaser, unless otherwise indicated (the Purchaser will be the M&O, or another DOE OCRWM designee).

The requirements listed here are not meant to be a complete and final listing. Rather, they are presented here to provide an initial listing upon which to base the fabrication process. It is expected that the list of requirements will be modified as the WP, the drip shield, and the emplacement pallet designs and the fabrication process progress. The requirements listed herein are requirements imposed upon the Supplier (typically by means of purchase order or contract). In certain cases, the requirement implies a design solution to a program level requirement (such as WP labeling), when, in fact, the final design solution has not yet been made. The sole purpose of such assumed requirements is to provide an input currently needed to guide the fabrication process evolution.

6.1 GENERAL CONDITIONS

The disposal container shall be fabricated and inspected in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB (Class 1 Components) (ASME 1995a) to the maximum extent practicable. Deviations from the Code shall be documented and submitted for approval. It is not the intent that this be an "N" stamped vessel but rather that the ASME Code be used as a standard for fabrication and inspection.

6.2 MATERIALS OF FABRICATION

6.2.1 The disposal container, the drip shield, and the emplacement pallet shall be fabricated from materials meeting ASME Code requirements, or approved specification. All internal structural materials shall have, at a minimum, ASME Code specified minimum yield and tensile strength values.

6.2.2 Alternative materials identified shall be submitted for approval.

6.2.3 Certified Material Test Reports shall be submitted for all materials.

6.2.4 Expendable materials, such as cleaning solvents, temperature indication sticks, tapes, NDE penetrant materials, and other materials that contact stainless steel or nickel alloy surfaces, shall be low chloride/halogen (less than 100 parts per million [ppm]) and shall not contain more than 200 ppm total of metal and metal salts such as zinc, lead, copper, cadmium, mercury, or other low melting metals. This concentration shall be determined as the net concentration of these metals, regardless of whether they are present as metals, alloys, salts, or other compounds. In addition, no halogenated cleaning agents or solvents shall be used on austenitic stainless steel or nickel alloy except technical grade trichlorotrifluoroethane.

6.2.5 Before use in fabrication, all materials shall be examined (per American Society of Mechanical Engineers [ASME] Code, Section V [ASME 1995d]) as follows:

- Ultrasonically inspected (cylinder materials only).
- Visually examined to ensure specified cleanliness and to detect obvious defects on all surfaces.
- Visually examined to verify that all materials are properly identified and in conformance with the material specifications and certifications.
- Verify material certifications meet the requirements of the procurement documents and specifications, and are traceable to the materials.
- Dimensionally examine all stock dimensions to verify that the materials meet the size for fabrication.

6.3 WELD FILLER MATERIALS

All filler materials used shall be specified in the fabricator's approved welding procedures and shall conform to Section II, Part C of the ASME Code (ASME 1995b). Each heat lot of weld filler materials shall be tested to verify chemical and mechanical properties by an independent, qualified materials testing laboratory. Filler materials for stainless steels shall be selected and controlled such that the delta ferrite content in the as-deposited weld filler metal is indicated by a ferrite number between 5 and 15. Welding methods and procedures shall be developed to specifically minimize the volume of sensitized material. Filler material shall be selected to be compatible with the base material. Submittal of weld filler material certification documentation is required as part of the Final Data Package (see Section 7.7).

6.4 QUALITY ASSURANCE REQUIREMENTS

The fabrication of the disposal container, the drip shield, and the emplacement pallet shall be performed by a qualified manufacturer operating in accordance with a QA program approved by OCRWM QA (see Section 7).

6.5 REPAIR OF DEFECTS

Rejectable defects in materials can be repaired by welding if the ASME Code, Section III (ASME 1995a) requirements are met and the repair has been approved by the Purchaser. Defective material that cannot be satisfactorily repaired will be rejected and replaced. All material defects and repairs will be appropriately documented on the Supplier's Nonconformance Report that requires the

Purchaser's concurrence before implementation.

6.6 ALTERNATE MATERIALS

In the event any material specified herein is not available, the manufacturer shall advise the Purchaser in writing before use, and request written approval to use an alternate material in accordance with the procedures specified in the manufacturer's QA program.

6.7 MATERIAL TRACEABILITY

The manufacturer shall maintain complete and accurate traceability records on all materials so that it will be possible to relate every component of the finished disposal container, drip shield, or emplacement pallet to the original certification of the material and the fabrication history of each component.

6.8 WELDING

6.8.1 Preheat and interpass temperatures shall be in accordance with the requirements of the ASME Code, Section IX (ASME 1995c). In no case shall welding of any kind be performed when the base metal temperature is lower than 32°F (0°C). Surfaces shall be visually dry with no evidence of condensation/moisture.

6.8.2 Preheat requirements also apply to tack welds, whether or not the tacks are removed, and to thermal cutting.

6.8.3 The maximum interpass temperature for austenitic stainless steel or nickel alloy shall be 350°F (175°C). The maximum interpass temperature of carbon steel shall be 500°F (260°C).

6.8.4 Preheat and interpass temperature shall be determined through the use of temperature indicating pyrometers, thermocouples, or other approved means. Temperature indicating crayons, paint, strips, or similar materials shall not be used on stainless steel or nickel alloy.

6.8.5 The surfaces or parts to be welded shall be visually clean and free of slag, scale, rust, oil, grease, and other deleterious foreign materials for a distance of at least one inch from the weld joint. Chemical cleaning agents for use on stainless steel or nickel alloy shall be approved by Purchaser before use.

6.8.6 Weld joint preparations shall be machined or ground at least one-sixteenth of an inch (1.6 mm) back to clean metal if they were thermal cut.

6.8.7 Each weld shall be in accordance with the symbol shown on the drawings and generally uniform in width and size throughout its full length. Weld preparations shall be in accordance with the requirements of the ASME Code, Section IX (ASME 1995c).

6.8.8 Each weld layer or weld pass shall be visually free of slag, inclusions, cracks, unacceptable porosity, and lack of fusion.

6.8.9 Weld splatter compounds may be used, provided the halide content is certified as being 100 parts per million, or less, and the compound is immediately removed after welding.

6.8.10 All welding shall be in conformance with written procedures according to Section IX of the ASME Code (ASME 1995c). The procedures developed for stainless steel must minimize corrosion sensitization.

6.8.11 The Purchaser and OCRWM or their designated inspectors reserve the option to review the performance qualification records of individual welders at the manufacturer's shop.

6.8.12 The following welding processes are permitted, provided satisfactory evidence is maintained that the processes/procedures are qualified for the material to be welded:

- Shielded Metal-Arc
- Gas Tungsten-Arc (Manual and Auto)
- Submerged Arc
- Gas Metal-Arc (Semi and Auto).

6.8.13 Weld repairs shall be in accordance with ASME Code, Section III (ASME 1995a), Article NB-4000.

6.8.14 Workmanship and surfaces of weld and weld repairs shall conform to the standards required by Section III (ASME 1995a), Division 1, Subsection NB-4000 of the ASME Code unless otherwise specified. Unacceptable defects, as defined in the applicable portions of the ASME Code, Section III, Division 1, Subsection NB, shall be repaired in accordance with Subsection NB.

6.8.15 Elimination of defects and surface preparation of welds by chipping, grinding, or gouging shall be performed in such a manner that will not reduce the base material thickness below the minimum specified.

6.8.16 The use of temporarily welded attachments during fabrication shall be limited to use on areas of excess material on the disposal container that will later be removed unless specific prior approval has been granted by the Purchaser. If they should be employed, they shall be of the same ASME Code class material and, when fabrication is complete, they shall be removed flush and the surface restored. A visual and liquid penetrant examination (PT) or magnetic particle examination (MT) shall be performed in accordance with the ASME Code, Section III, Division 1, Subsection NB (ASME 1995a).

6.8.17 Peening shall not be used without prior written approval from the Purchaser. The use of pneumatic tools for slag removal is not considered peening and is acceptable.

6.8.18 Tack welds used to secure alignment shall either be removed completely, when they have served their purpose, or their stopping and starting ends shall be properly prepared by grinding or other approved means so that they may be satisfactorily incorporated into the final weld. Tack welds shall be made by qualified welders using qualified welding procedures. When tack welds are to become part of the finished weld, they shall be visually examined and defective tack welds shall be removed.

6.9 BRUSHES AND GRINDING WHEELS

6.9.1 Only stainless steel brushes shall be used on stainless steel or nickel alloy components. Only aluminum oxide or silicon carbide abrasive wheels shall be used for grinding on stainless steel or nickel alloy components.

6.9.2 Stainless steel brushes or grinding wheels previously used on other materials (e.g., carbon steel) shall not be used for cleaning or working stainless steel or nickel alloy.

6.10 VISUAL INSPECTION OF WELDS

6.10.1 The finished surfaces of all welds on the disposal container, the drip shield, and the emplacement pallet shall be visually examined in accordance with the ASME Code, Section V, Article 9 (ASME 1995d), and Section III, Division 1, Subsection NF (ASME 1995a), to verify that the components are assembled in accordance with the engineering drawings and that the external components are free of nicks, gouges, or other damage.

6.10.2 The acceptance criteria for visually examined welds shall be in accordance with ASME Code, Section III, Division 1, NF-5360 (ASME 1995a).

6.11 LIQUID PENETRANT EXAMINATION

6.11.1 Welds that are identified as "PT" on the Engineering Drawings will be PT examined per the ASME Code, Section V, Article 6 (ASME 1995d).

6.11.2 Acceptance criteria for PT shall be in accordance with ASME Code, Section III, Subsection NB, Article NB-5350 (ASME 1995a).

6.12 MAGNETIC PARTICLE EXAMINATION

6.12.1 Welds that are identified as "MT" on the Engineering Drawings will be MT examined per the ASME Code, Section V, Article 7 (ASME 1995d).

6.12.2 Acceptance criteria for MT shall be in accordance with ASME Code, Section III, Subsection NB, Article NB-5340 (ASME 1995a).

6.13 ULTRASONIC EXAMINATION

6.13.1 Welds that are identified as "UT" (ultrasonic examination) on the Engineering Drawings will be UT examined per the ASME Code, Section V, Article 5 (ASME 1995d).

6.13.2 Acceptance criteria for UT shall be in accordance with ASME Code, Section III, Subsection

NB, Article-5330 (ASME 1995a).

6.14 RADIOGRAPHIC EXAMINATION

6.14.1 Welds that are identified as "RT" (radiographic examination) on the Engineering Drawing shall be RT examined per ASME Code, Section V, Article 2 (ASME 1995d). RT examined welds shall also be inspected by the PT or MT method.

6.14.2 Acceptance criteria for RT examined welds shall be in accordance with ASME Code, Section III, Subsection NB, Article NB-5320 (ASME 1995a).

6.15 IN-PROCESS CLEANING

6.15.1 Technical grade or better cleaning agents or solvents shall be used for in-process cleaning. Water base cleaning solutions shall be formulated using approved distilled water. No halogenated cleaning agents or solvents shall be used on austenitic stainless steel or nickel alloy except technical grade trichlorotrifluoroethane.

6.15.2 Chips, dirt, shavings, cutting fluids, and all foreign particles visible to the unaided eye shall be removed from all surfaces, including tubing, cavities, and internal areas.

6.16 TEST PERSONNEL

Inspections and tests shall be performed by qualified personnel and in accordance with written procedures. Inspection personnel shall be qualified in accordance with the ASME Code, Section III, Division 1, Subsection NB (ASME 1995a).

6.17 TEST AND INSPECTION REPORTS

All tests and inspection will require a certified inspection or test report meeting the following minimum requirements:

1. Manufacturer's name
2. Name of part and identification number
3. The type of observation and method of inspection/test
4. The inspection/test criteria, sampling plan, or reference documents (including revision levels) used to determine acceptance
5. Identification of the measuring and test equipment used during the inspection/test including the identification number and the most recent calibration date
6. Results of test or inspection and the actions taken in case of noted nonconformances

7. Personnel qualification/certification that identify the following:

   a. Date of certification
   b. Date of certification expiration
   c. Level of certification.

8. Identification of personnel performing the inspection/test and data recorder(s)

9. Identification of personnel accepting test and inspection results

10. Inspection/test data sheets which document inspection/test results and disposition

11. Inspection or test date.

7. QUALITY ASSURANCE AND QUALITY CONTROL OF SUPPLIER

7.1 GENERAL

Material procurement, fabrication, assembly, inspection, testing, preparation for shipment, and shipping shall be in accordance with the Supplier's approved QA program which meets applicable elements of the *Quality Assurance Requirements and Description* (DOE 2000) and shall be subject to verification by OCRWM QA personnel or their representatives to ensure compliance to the Supplier's QA program.

7.2 ACCESS

Purchaser, OCRWM, or other designee authorized by the Purchaser shall be provided free access to all areas where work is in progress. This requirement extends to the Supplier's subtier vendors. Suitable office space shall be provided for OCRWM and the Purchaser QA and QC personnel while they are in residence.

7.3 RECORDS

All records generated during the execution of this contract shall be available for examination by OCRWM and the Purchaser personnel or their representatives upon request.

7.4 COMPLIANCE

A Certificate of Conformance (COC) shall be furnished by the Supplier to the Purchaser with shipment of the container. The COC shall be prepared, reviewed, and approved in accordance with the OCRWM QA program. The COC shall at a minimum:

1. Identify the purchased item to the specific procurement document.

2. Identify the specific procurement document requirements met by the purchased item. The

procurement document requirements identified shall include any approved changes, waivers, or deviations applicable to the item.

3. Identify any procurement document requirements that have not been met together with an explanation and the means for resolving the nonconformance.

4. Contain signature or otherwise authenticated by a person who is responsible for this QA function and whose responsibilities and position are described in the Supplier's QA program.

7.5 PROCEDURES

All procedures used to fabricate, inspect, cleaning, testing/examination, and shipping the WP, the drip shield, and the emplacement pallet shall be submitted to the Purchaser for approval before use.

7.6 NONCONFORMING MATERIALS AND COMPONENTS

The Supplier shall submit a report of nonconformance to the Purchaser for approval, including recommended disposition and technical justification for the dispositions of "Use-As-Is" or "Repair." Additionally, the Supplier shall comply with the provisions of the Code of Federal Regulation, Title 10, Part 21, Reporting of Defects and Noncompliance (10 CFR 21). It is understood that nonconforming conditions may exist. These will be handled under the nonconformance process.

7.7 FINAL DATA PACKAGE – DOCUMENTS REQUIRED UPON COMPLETION OF FABRICATION AND PRIOR TO SHIPMENT

1. Purchase order those applicable to all items or services subject to the QARD
2. Acceptance test report from organization(s) performing work
3. Actual "As Built" weight of each canister assembly
4. Nonconformance Reports
5. Completed inspection plan
6. COC
7. "As Built" drawings for each container
8. NDE reports
9. Dimensional inspection results
10. Visual examination results
11. Certification of weld consumables
12. Certification of nondestructive test materials
13. Certified material test report/material certification
14. Weld control record
15. Certification of expendable materials.

8. FABRICATION METHODS

Fabrication methods are discussed in this section. It is the intent to list options where they are known. These options have been and will continue to be narrowed down or expanded upon as the design matures. This fabrication process report will cover the outer corrosion barrier, reinforcement cylinder, and lids for all of the types of disposal containers, as well as the basket fabrication for the UCF disposal container. It is intended that this report not limit manufacturing options that may be explored by the manufacturer, but present a technically feasible manufacturing approach, which appears to be economically viable.

At this time, size of Alloy 22 plates for the outer cylinder varies among vendors for the same thickness. For example, Haynes International produces a 96"x150" plate while Special Metals Corporation produces a 96"x240" plate. These sizes of plate will require three plates to form the total length of a WP. It is anticipated from conversations with these vendors that larger plates will be available for actual fabrication of the WPs. The fabrication process stated in this report will use two larger plates for the fabrication of the outer cylinder.

DOE has specified that the WP design work be performed in SI units (International System of Units) (e.g., m, mm, kg, etc.). At present, DOE does not require that the design work be presented with dual dimensioning, that is SI units followed by English units as: SI (English). However, dual dimensioning is presented in this report for the convenience of the reader and as an aid when exchanging information with domestic commercial fabricators. Generally, conversion of meters and millimeters (using 25.4 mm/in.) to inches is presented to 1/1000th of an inch. The reader is instructed and cautioned not to treat the numerical conversion as representing required accuracy and/or tolerancing of dimensions. Dimensional tolerancing analysis of the design has yet to be performed; furthermore, such tolerancing will be performed in SI units. Only preliminary tolerancing is given in this report. The numerical dimensions given are typical of a representative disposal container for the purpose of material ordering comparisons and to facilitate the fabrication description and are not intended to actually represent the dimensions for any specific disposal container. Actual dimensions should be obtained from approved drawings or engineering sketches.

8.1 UNCANISTERED FUEL DISPOSAL CONTAINER

The UCF disposal container is presently one of the WP baseline designs and therefore is chosen here as the example for fabrication. The other disposal container types are fabricated in a similar fashion, although some dimensions vary. The UCF disposal container has an internal basket assembly to support the fuel assemblies. In the other types of disposal containers, the internal basket design varies (i.e., DHLW - see Paragraph 8.2) or is not present (e.g., Naval disposal container [CRWMS M&O 2000c]). The UCF disposal container uses both Neutronit A978 (borated stainless steel) and aluminum interlocking plates plus carbon steel tubes.

The 21-pressurized water reactor UCF disposal container (CRWMS M&O 2000a) consists of an outer cylinder of Alloy 22, 20 mm (0.787") thick. The inner reinforcement cylinder serves as an internal structural support to the outer cylinder and is 316 NG (nuclear grade) Stainless Steel 50 mm (~2"). There are lids on each end of the cylinder. The outer lids are Alloy 22, with a thickness of 25 mm (~1"). The inner lids are 316 Stainless Steel, and vary in thickness with a minimum of

50 mm (~2") due to structural considerations. The bottom lids are installed at the fabricator's shop and the top lids are shipped separately. The outside diameter is approximately 1564 mm (61.575") and the length is 4965 mm (195.472") without the trunnion collars or impact limiters on each end.

8.1.1 Outer Cylinder Fabrication

Forming the outer cylinder of rolled and welded plate requires two half-length cylinders due to the limitation of most, if not all, rolling fabricators. The plate would be ordered at approximately 5080 mm (200") long by 2540 mm (100") wide and 30 mm (1.181") thick. The extra thickness would permit machining (for rounding) after welding. The plate would be procured in accordance with Section 6.2. Once received by the fabricator, the plate would be receipt inspected, laid out to establish the developed length, and thermal cut to the layout. The plate would then be rolled to size.

The cylinder would then be adjusted to meet the required diameter and inside travel (inner circumference) taking into consideration the subsequent weld shrinkage of the longitudinal seam. The long seam weld preparations would then be machined and prepared for welding. The cylinder would then be strutted to minimize the weld distortion and welded by one of several processes listed in Section 6.8.12. Filler material shall be in accordance with Section 6.3. The struts would then be removed and the weld seam would be prepared for NDE that would include RT, UT, and PT testing. One end of the cylinder would be prepared for circumferential seam welding. In parallel with this, a second cylinder would be prepared in the same manner.

The two cylinders would then be joined and circumferentially welded by one of several processes listed in Section 6.8.12 with subsequent NDE (RT, UT, and PT) testing performed on the circumferential seam. The outer cylinder would then be inspected to verify that the inside diameter is within tolerance. The inside of the cylinder would then be machined as described in Section 8.1.8.

8.1.2 Inner Cylinder (Reinforcement) Fabrication

To make the inner cylinder, two plates of 316 NG stainless steel would be ordered to the dimensions sufficient to make one half of the inner cylinder length each. The full cylinder length would require two plates with dimensions of approximately 4978 mm (~196") wide by 2540 mm (~100") long by 64 mm (~2.5") thick each. Each plate would be cut and/or machined for size and longitudinal weld preparations. The plates would then be roll formed to make two half-cylinders and welded with one of the weld processes outlined in Section 6.8.12, with subsequent NDE (RT, UT, and PT) inspections performed. The weld preparations for the circumferential seam would then be machined, and the cylinder would be assembled and circumferentially welded with one of the weld processes outlined in Section 6.8.12. NDE (RT, UT, and PT) inspections would be performed on the circumferential weld, and the cylinder would then be machined as described in Section 8.1.8.

8.1.3 Lid Fabrication

The bottom outer cylinder lid would be fabricated from an Alloy 22 plate approximately 1900 mm (~75") wide and 3800 mm (~150") long. The plates would then be thermal cut to the correct diameter and edges cleaned to remove slag and scale. The bottom lid would be then machined to establish the weld preparation. The upper lid flat section would be fabricated in the same method except that the weld preparation would be machined to a smaller diameter. A vertical cylinder 25 mm (0.984") thick and 125 mm (4.920") wide would be fabricated. The vertical cylinder and flat cylinder would be joined. An extended lid reinforcement ring, made of Alloy 22, 50 mm (1.969") square, would be fabricated to fit the entire inner circumference of the vertical ring and rest on the flat plate. This would be then welded with a 50 mm (1.969") leg fillet weld top and bottom. A center lifting fixture would be fabricated from a plate 30 mm (1.181") thick. It is laid out and cut to size, deburred, and machined to the correct dimension. It is then welded to the center of the lid. Vent holes would be required in the area of the extended lid reinforcement ring and lifting fixture. The location and requirements will be determined later when the effect of the required venting has been analyzed. The top plate would be then annealed. The parameters for the annealing operation are discussed further in the section on the outer barrier annealing (Section 8.1.7).

The outer shell flat closure lid would be made from a plate 10 mm (0.394") thick. The plate diameter would be laid out and flame cut. The flame cut area would be then deburred. A center lifting fixture is fabricated from a plate 30 mm (1.181") thick. It is laid out and cut to size, deburred, and machined to the correct dimension. It is then welded to the center of the lid.

The inner cylinder lids would be fabricated from a 316 NG stainless steel plate approximately 1800 mm (~71") wide and 3600 mm (~142") long. The plate would be laid out for thermal cutting two circles. The plates would then be thermal cut to the correct diameter and edges cleaned to remove slag and scale. Both lids are then machined to establish the weld preparation.

8.1.4 Assembly of the Support Ring

A support ring is required to hold the inner cylinder in place once it is assembled into the outer cylinder. The ring would be made from plate 20 mm (0.787") thick. A piece would be cut 100 mm (3.94") wide, rolled into a ring, and weld preparations are machined on both sides. The ring would be fit to the inside of the cylinder at the bottom end and welded. The long seam weld in the ring is made at the same time to facilitate the fitting of the ring. The ring welds would be then machined flush to allow the bottom lid to set on the bottom of the ring and the inner cylinder to set on the top of the ring. The machined areas would be then PT inspected.

8.1.5 Assembly of Bottom Lids to Cylinder

Once the inner and outer cylinders are completed, the bottom lids must be welded in place. The assemblies would be set in the vertical position and the lids assembled to each cylinder. The welding would be then done in the flat position. The weld process could be subarc, gas metal-arc, or gas tungsten-arc welding for the inner reinforcement lid, and gas metal-arc or gas tungsten-arc for the outer cylinder. After the welding is complete, the inner and outer lid seam would be prepared and RT, UT, and PT inspected. RT and UT inspection is required to assure all detectable flaws, regardless of their orientation, are identified. PT inspection is required to assure that surface indications are identified.

8.1.6 Assembly of Trunnion Collar Sleeve

The trunnion collar sleeves are made of Alloy 22, 40 mm (1.580" thick). The plate would be cut to length and width and rolled into a cylinder. The cylinder is joined with one or two longitudinal welds. The cylinder would be then rounded and the inside diameter is machined to the outside diameter of the outer barrier. Two of these sleeves are required, one for the top and one for the bottom with slightly different dimensions. Sleeves would be heated to approximately 700°F, positioned over the outer barrier, allowed to cool, and welded in place per drawing description.

Note: Due to the information obtained from the FY-00 closure weld mock-up, the assembly sequence of the inner ring, bottom lid, and lower trunnion ring may need to be altered. Higher than expected distortion during the inner ring and lid welding may necessitate the assembly and partial welding of the lower trunnion ring prior to welding the inner ring and lower lid. The trunnion ring would thus provide reinforcement for the other welds and reduce the distortion. This will be investigated further in the future.

8.1.7 Annealing of the Outer Cylinder

The outer barrier will be annealed. Vent holes will be required in the trunnion rings and inner support. The location is optional, but three are required for each piece, and they must be in the above pieces and not the outer barrier. The outer cylinder would be heated to 1150^0C in a furnace. The furnace car would be then pulled out of the furnace and into a spray quench fixture that allows water to be sprayed both on the outside and the inside. The thermalcouples must be shielded so that a skin effect temperature of the water on the thermalcouples is not obtained. The optimum temperature decline path to obtain the required metallurgical and residual stress properties is still being determined. The quench, however, is basically done to bring the temperature from 1100^0 C to below 800^0 C as quickly as possible (approximately 4 min.). The cooling rate is then decreased to allow for the formation of compressive stresses on the outside. The quenching method is being demonstrated on the FY-00 closure weld mock-up with slight modifications, and this material will be tested later in the program.

8.1.8 Assembly of Uncanistered Fuel Disposal Container

The loose fit cylinder within a cylinder construction requires that the surfaces of the inner reinforcement cylinder and outer barrier be machined. Loose fit is defined as 0 - 4 mm (0.000"- 0.157") gap between the cylinders.

- The outer barrier and the reinforcement cylinder finished thicknesses must not be less than the prescribed minimum values (i.e., 20 mm, 50 mm).

- The inner diameter of the reinforcement cylinder must be maintained at the design value.

After both the outer barrier and inner reinforcement cylinders have been machined, they must be fit together. The outer cylinder is heated to approximately 700°F (371°C) to allow the inner reinforcement cylinder to be lowered into the outer cylinder. The heat is then removed, and the cylinders are allowed to cool.

The outer barrier and inner reinforcement top lids and the top container weld preparation would then be machined for the closure weld, to be conducted at a later time at the waste repository surface facility.

8.1.9 Basket and Internal Parts

The design calls for a combination of tubes and interlocking plates.

8.1.9.1 Tubes (21 required)

The tubes would be square A516 grade 70 carbon steel tubes approximately 5 mm (0.197 in.) thick. These tubes may be ordered from a manufacturer of steel tubing. The top of the tube needs to be flared to facilitate the insertion of the fuel assembly. This can be done by the tube manufacturer or the fabricator.

8.1.9.2 Side Guide (32 type "A," 16 type "B" required)

The internal side guide is part of the basket support structure. These parts would be made from A516 grade 70 carbon steel plate. These plates would be beveled on the long edges to fit the curvature of the container inner diameter. Stiffener plates (also A516 carbon steel) would then be welded on the side guides to strengthen them.

8.1.9.3 Basket Corner Guide Assembly (16 required)

The internal corner guide piece would be made from a flat A516 carbon steel grade 70 plate. The plate would be cut to size and beveled on the long edge. The plate could be thermal cut or sheared. The method of cutting would depend on the equipment available at the fabricator. All of these methods would be acceptable. The plate would then be put in a press brake and pressed into a 90° angle along the long dimension. Stiffener plates would also be welded on the corner guides for strength.

8.1.9.4 Internal Separator Plates (8 type "A," 8 type "B," 16 type "C," 8 type "D," 8 type "E")

The separator plates are designated A, B, C, D, and E. Plates A, B, and C are Neutronit A978 and all are approximately 7 mm (0.276 in.) thick. Plates D and E are aluminum type 6061 T4. The plates have different designations due to the differences in the width and the number and location of the slots.

Plates A and D have four slots on the bottom side parallel to the length with the slots equally spaced. Plates B and E have two slots on the bottom side parallel to the length. They also have two slots on the top side parallel to the length. Plate C has two slots on the bottom side.

These plates may be fabricated in one of two ways. The Neutronit A978 plates could be ordered from Böhler, a plate manufacturer, who would fabricate the plates, cut the slots, and send the plates to the fabricator in the finished condition. The plates could also be ordered in sheet form and cut to size by the fabricator. The fabricator would then laser cut or machine the slots in the plate. The aluminum plates would be sheared or laser cut.

8.1.10 Uncanistered Fuel Internal Assembly

Once the inner and outer cylinders and the bottom lids are assembled, the container is ready for the internals to be added. Once the cylinder is ready, the internal parts would be assembled to the inside. The cylinder would be laid out to establish the location of the internal corner guide assemblies and the internal side guides. The corner guide assemblies and the side guide assemblies would be put in place and welded using manual gas tungsten-arc welding. The bottom set of plates (the first of four sets) would be installed in an interlocking fashion followed by the three additional sets. The tubes would be inserted and the tube tops stitch welded together, if required.

The disposal container and the top lids would then be cleaned, wrapped, and protected for the shipment to the surface facility for storage until they are ready to be filled and sealed.

8.2 DHLW INTERNALS

The DHLW container is designed to dispose of the vitrified glass pour canisters. The DHLW disposal container sketches (CRWMS M&O 2000b) include a centrally located full-length tube supported by five full-length, radially oriented divider plates. This assembly forms a ring of five compartments or cells sized to accommodate five pour glass canisters. The central space within the disposal container, surrounded by the pour glass canisters, is sized to accommodate the DOE SNF canister. This is expected to be a one-piece assembly and would therefore be lifted and then lowered into the disposal container as a singular unit. The actual configuration of this structure has not been finalized, and the fabrication details will, therefore, not be expanded upon in the current revision of this document.

8.3 DRIP SHIELD

The drip shield (CRWMS M&O 2000d) is made of titanium Grade 7 and Grade 24 with the exception of the base, which is made of Alloy 22 to be compatible with the invert material. The drip shield shell is made from titanium grade 7 plate 15 mm (0.591") thick. The plate is laid out for the length of ~5485 mm (215.945") and a width sufficient to form the 1300 mm (51.181") radius to form the top section. The sides are made from the same thickness and type of plate for the same length and a width of ~2521 mm (99.252"), plus the stock to form the upper radius. Two side pieces are required. The support beams are made from 50 mm (1.969") thick plate of titanium grade 24. The support beams are laid out for a length of 1943 mm (76.496") long and 64 mm (2.520") wide. The end supports are made from titanium grade 24 plate and are 44 mm (1.732") by 50 mm (1.969") and 1943 mm (76.496") long. There are four of these pieces. The inner bulkhead supports are made of titanium grade 24 plate 25 mm (0.984") thick and ~50 mm (1.969") wide. They are formed to fit the 1300 mm (51.181") top radius. There are six of these. There are three drip shield connector guides, 50 mm (1.969") thick and 50 mm (1.969") wide. They are formed to fit the outside of the upper section's 1300 mm (51.181") radius. The drip shield connector plate is made from titanium grade 7 plate 15 mm (0.591") thick and 910 mm (35.827") wide and formed to fit the 1350 mm (53.150") outside radius of the connector guide outside diameter. The holes would be ~112 mm (4.410") in diameter. The side connector guide plate is made from 15 mm (0.591") thick titanium grade 7 plate, 610 mm (24.016") wide, with enough stock to form the radius at the junction of the side plate and the top plate and to extend under the connector guide plate. Two round connector guides would be fabricated from titanium grade 24 bar stock 112 mm (4.410") in diameter. These would be machined on a taper from 100 mm (3.937") diameter at the top to 111 mm (4.370") at the bottom. The bar is 200 mm (7.874") long, and the bottom is cut to drawing description to fit to the top plate of the drip shield. The lifting plate is cut to the drawing configuration from titanium grade 24 plate that is 50 mm (1.969") thick. The base is the only drip shield part that is not titanium. The base is made from Alloy 22 to be compatible with the invert. The base is made from Alloy 22 plate 10 mm (0.0394") thick. The plate is bent to form an "L" shape with ~ a 50 mm (1.969") vertical leg and a 100 mm (3.937") horizontal leg. The base is 5485 mm (215.945") long. All parts are inspected at this point for compliance to the drawing dimensions.

The assembly of the drip shield would be accomplished by welding the side panels to the top and grinding the welds flush. The support beams and end supports would be then welded to the sides. The connector posts and the lifting plates would be welded to the top and sides respectively. The connector guides are welded to the end and the drip shield connector plates, both the top and the sides are fit and welded. Two holes would be cut in the connector plate, one on each side centered ~175 mm (6.890") from the ends. The bulkhead supports are fit and welded to the inside of the top plate. The base would be assembled to the drip shield with either bolts or pins with welded washers. The drip shield would be cleaned, inspected, and prepared for shipment.

Many of the dimensions for the drip shield fabrication are listed as approximate. The designs for this hardware are still in development, and the values given are calculated values based on structural requirements. These will be refined in the future as the design matures.

The drip shield may require annealing. If this is the case, the annealing would be performed after the drip shield is assembled. The only sequence change is that the machining of the connector guide posts and the cutting of the holes would be done after the anneal.

Note: The drip shield may be fabricated as interlocking parts as described above. There is a possibility that the drip shield would be free standing. This does not present any major manufacturing problems. The connector section on the end would be eliminated and a plate would be welded on each end. This decision will be made at a later date depending upon the requirements of the program.

8.4 EMPLACEMENT PALLET

The waste package emplacement pallet (CRWMS M&O 2000d) would be made in a short or regular size. The fabrication methods for both are the same except the dimensions for them are different. For discussion purposes, the regular size pallet is described here.

The emplacement pallet is made from two materials. The tubes are 316 NG stainless steel and the balance of the pallet is made of Alloy 22. Four 316 NG stainless steel tubes are required to tie the two ends of the pallet assembly together. The tubes are 152.4 mm (6.000") square on the outside. The length is 410.8 mm (161.732"), and the thickness is 9.53 mm (0.375"). These tubes would be ordered from the vendor and cut to length. Plate number 1 is the bottom plate of which two are required. It is cut from a 9.53 mm (0.375") thick Alloy 22 plate. The plate would be laid out to the 2150 mm (84.646") length and the 552.4 mm (21.748") width. The plate would be burned to size and ground to smooth metal. Plate number 2 is the outer end plate. This plate would be cut from an Alloy 22 plate 22.2 mm (0.875") thick. The plate would be laid out to the 1864.26 mm (73.396") length and 468.53 mm (18.446") width. A sixty degree angle is laid out from what will be the top of the side plate, toward the opposite side. This is done from both ends to form the "V" for the pallet. A piece is cut out of each side 452.47 mm (17.814") by 152.4 mm (6.000"). This leaves the cover for the upper tube ends. These plates would then be cut to the layout and ground to a smooth surface. Plate number 3 is the inside side plate of which two are required. This is laid out to a 1845.2 mm (72.646") length and a 595.34 mm (23.439") width. The plate would be laid out for the angle the same as plate number 2. The plate would be cut to size and ground to smooth metal. Plate number 4 is the lower side plate of which four are required. It is made from an Alloy 22 plate 9.53 mm (0.375") thick. It is laid out with a length of 446.12 mm (17.564") and a width of 508 mm (20.000"). The plate is then cut to size and ground to smooth metal. Plate number 5 is the upper end plate, and four are required. These are made from an Alloy 22 plate 25.4 mm (1.000") thick. The plate is laid out for a 520.7 mm (20.500") length and a 79.9 mm (3.146") width. The plate is cut to the layout and ground to smooth metal. Plate number 6 is the top plate comprising the "V" which requires four plates. These four plates are laid out on a flat plate of Alloy 22, 25.4 mm (1.000") thick. The length is 1241.3 mm (48.870") and the width is 552.4 mm (21.748"). The plates are then cut to size and ground to smooth metal. Plate number 7 is the upper inside cover and is made from and Alloy 22 plate 22.2 mm (0.875") thick. There are four plates required and they are triangular in shape. They are laid out with the vertical leg 79.9 mm (3.146") long. The angle off the vertical leg is 60 degrees. These are roughed out and cut to fit at assembly. Plate number 8 is the upper tube bottom support. There are four of these and they are made from an Alloy 22 plate 6.35 mm (0.250") thick. The plate is laid out for a 542.87 mm (21.373") length and a 152.4 mm (6.000") width. The four plates are cut to the layout and ground to smooth metal. The last part is the "V" groove support tubes made of Alloy 22 plate. These can be made in two ways. The first is to order them from a vendor. This would require a tube 254 mm (10.000") by 76.2 mm (3.000") by 6.35 mm (0.0250") thick and 254 mm (10.000") long. Four of these tubes are required. The other method is to lay out the tubes on flat plate in two pieces, each comprising a short and long side. The plates are then press braked to a 90 degree angle and welded together to form the rectangular tubes. The tubes will have the required "V" cut in them to accept the top plates at assembly. All the above parts would be inspected for drawing requirements.

The assembly of the emplacement pallet starts with the number 1 bottom plate and the bottom tubes. The bottom plate is placed on the flat, and the two bottom stainless steel tubes are put in position and welded to the bottom plate. The outside end plates are then assembled to the bottom plates and the bottom tubes. The end plates are tacked in place. The upper tube bottom support plates are welded in place, and the upper tubes are placed in position and tack welded. The bottom and top side plates are placed in position and tacked. The "V" support tubes are placed in position and tack welded. The partial assembly is inspected for drawing dimensions and alignment. All of the above parts are then welded into position using care to assure that the alignment is not disturbed. All welds are now visually inspected. The top plates forming the "V" are put into place by cutting the "V" tube supports to accommodate them. The inside plates are tacked in place and the inside top plates are cut to fit and assembled. The welding is finished on the entire assembly. All welds are ground flush and the assembly is inspected for drawing dimensions and alignment. The assembly is cleaned and prepared for shipment.

9. ALTERNATE FABRICATION METHODS

The fabrication task includes discussions with various manufacturers and suppliers to ascertain new or improved manufacturing methods that might be technically superior to or more cost effective than the methods proposed by Waste Package Fabrication. In all, twenty manufacturers and six suppliers have been contacted for informal discussions on manufacturing techniques and material costs. In addition, the Nickel Development Institute sponsored a fabrication workshop during fiscal year 1998, which was attended by five fabricators from various parts of the U.S. The workshop included representatives from the national labs, the MGR consulting board, DOE, material producers such as Haynes, Krupp VDM, Inco, and Allegheny Ludlum, and various other groups. The five fabricators "American Tank and Fabricating of Cleveland, Ohio; Ranor Inc. of Westminster, Massachusetts; Nooter Corporation of St. Louis, Missouri; BWX Technologies of Mt. Vernon, Indiana; and Oregon Iron Works of Clackamas, Oregon" reviewed the proposed fabrication process and found the fabrication methods presented are viable and consistent with current industry practices. Another fabrication workshop is scheduled for October of FY-01.

Various methods to close the inner cylinder of WP are being investigated. The fabrication of these components if incorporated into WP design will be documented in latter revision of this report.

Various alternative methods of fabrication such as roll bonding, explosive clad, and others have been evaluated and rejected. These were reported on in previous revisions of this document.

10. COST ESTIMATES

Cost estimates are provided to form the Total System Life Cycle Cost and are reported in that document. The cost estimates will not be reported in this document.

11. CONCLUSIONS

The cylinder in a cylinder is a viable method of manufacture. The cylinder-within-a-cylinder design is the most economical of designs, and the fabrication process has been found viable and consistent with current industry practices by the five manufacturers at the fabrication workshop during FY-98. The change to Alloy 22 has not altered the process significantly. The drip shield and the emplacement pallets do not present any major challenges in the fabrication process. Issues that may present difficulties, such as annealing of the outer barrier, are part of the ongoing closure weld development program for FY-00, and have been accomplished. Refinement and further testing of these procedures are planned to be accomplished as the optimal temperature curve is established.

One of the restrictions for the use of this report is that this report will not directly support any construction, fabrication, or procurement activity. The other restriction of the use of this report is that the information developed from this report will not have a direct effect on other design organizations.

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