Idaho National Engineering and Environmental Laboratory

INEEL/EXT-98-00725

September 1998

Fabrication, Inspection, and Test Plan for the Advanced Test Reactor (ATR) High-Power Mixed-Oxide (MOX) Fuel Irradiation Project

G. W. Wachs

LOCKHEED MARTIN

DISCLAIMER

INEEL/EXT-98-00725

Fabrication, Inspection, and Test Plan for the Advanced Test Reactor (ATR) High-Power Mixed-Oxide (MOX) Fuel Irradiation Project

Published September 1998

Idaho National Engineering and Environmental Laboratory
Lockheed Martin Idaho Technologies Company
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Office of Fissile Materials Disposition
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223

Fabrication, Inspection, and Test Plan for the Advanced Test Reactor (ATR) High-Power Mixed-Oxide (MOX) Fuel Irradiation Project

Revision 0

Approved by:

John M Ryskamp — 9/21/98

J. M. Ryskamp — Date
INEEL MOX Fuel Irradiation Project Manager/LMITCO

Concurred by:

S. A. Hodge via telcon, JMR — 9/21/98

S. A. Hodge — Date
MOX Project Manager/ORNL

SUMMARY

The Department of Energy (DOE) Fissile Materials Disposition Program (FMDP) has announced that reactor irradiation of Mixed-Oxide (MOX) fuel is one of the preferred alternatives for disposal of surplus weapons-usable plutonium (Pu). MOX fuel has been utilized domestically in test reactors and on an experimental basis in a number of Commercial Light Water Reactors (CLWRs). Most of this experience has been with Pu derived from spent low enriched uranium (LEU) fuel, known as reactor grade (RG) Pu. The High-Power MOX fuel test will be irradiated in the Advanced Test Reactor (ATR) to provide preliminary data to demonstrate that the unique properties of surplus weapons-derived or weapons-grade (WG) plutonium (Pu) do not compromise the applicability of this MOX experience base. The purpose of the high-power experiment, in conjunction with the currently ongoing average-power experiment at the ATR, is to contribute new information concerning the response of WG plutonium under more severe irradiation conditions typical of the peak power locations in commercial reactors. In addition, the high-power test will contribute experience with irradiation of gallium-containing fuel to the database required for resolution of generic CLWR fuel design issues. The distinction between "high-power" and "average-power" relates to the position within the nominal CLWR core. The high-power test project is subject to a number of requirements, as discussed in the *Fissile Materials Disposition Program Light Water Reactor Mixed Oxide Fuel Irradiation High-Power Test Project Plan* (ORNL/MD/LTR-125).

Oak Ridge National Laboratory (ORNL), acting as an agent for the Department of Energy Office of Fissile Materials Disposition (DOE-MD), leads the Test Project Office. Los Alamos National Laboratory (LANL) will supply the sealed fuel pin assemblies to the Idaho National Engineering and Environmental Laboratory (INEEL). The INEEL will assemble the capsules from hardware supplied by ORNL and will load the fuel pins into the capsules. The test assembly will contain up to nine capsule assemblies containing various fuel types as described in the *ATR Capsule Assembly Loading and Operational Schedule for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-132). Each fuel pin will be contained within a stainless steel capsule and placed in a 3 hole I-Basket with up to three capsule assemblies per hole. The loaded basket, as the test assembly, will then be loaded into the ATR in reactor irradiation position I-23. This Fabrication, Inspection, and Test Plan (FITP) for the INEEL Advanced Test Reactor (ATR) High-Power Mixed-Oxide (MOX) Fuel Irradiation Project describes the procedural approach for the fuel pin receipt, capsule fabrication (welding), capsule inspection, capsule loading into the basket, neutron dosimetry preparation, insertion into the ATR, irradiation, removal into the ATR canal, and final shipment to ORNL.

CONTENTS

FIGURES

ACRONYMS

ATM	Atmosphere
ATR	Advanced Test Reactor
CLWR	Commercial Light Water Reactor
CRD	Cycle Reference Document
DOP	Detailed Operating Procedure
ESAP	Experiment Safety Assurance Package
FCF	Facility Change Form
FITP	Fabrication, Inspection, and Test Plan
FMDP	Fissile Materials Disposition Program
GE	General Electric
GWd/MTHM	Gigawatt days per Metric Ton Heavy Metal
I4	International Isotopes Idaho Incorporated
INEEL	Idaho National Engineering and Environmental Laboratory
LANL	Los Alamos National Laboratory
LEU	Low Enriched Uranium
LMITCO	Lockheed Martin Idaho Technologies Company
MBA	Material Balance Area
MOX	Mixed Oxide
OMM	Operating & Maintenance Manual
ORNL	Oak Ridge National Laboratory
OSCC	Outer Shim Control Cylinders

PALM	Power Axial Locating Mechanism
PIE	Post-Irradiation Examination
PSAN	Plug Storage Area North facility
PPM	Parts Per Million
QA	Quality Assurance
RDAS	Reactor Data Acquisition System
RG	Reactor Grade
RML	Radiation Measurements Laboratory
SAR	Safety Analysis Report
SD	Standing Directive
SP	Standard Practice
SORC	Safety Oversite Review Committee
TBP	To Be Published
TBI	To Be Issued
TIGR	Thermally Induced Gallium Removal
TRA	Test Reactor Area
TSR	Technical Safety Requirements
USQ	Unreviewed Safety Question
WG	Weapons Grade

Fabrication, Inspection, and Test Plan for the Advanced Test Reactor (ATR) Mixed-Oxide (MOX) Fuel Irradiation Project

1. INTRODUCTION

The Department of Energy (DOE) Fissile Materials Disposition Program (FMDP) has announced that reactor irradiation of Mixed-Oxide (MOX) fuel is one of the preferred alternatives for disposal of surplus weapons-usable plutonium (Pu). MOX fuel has been utilized domestically in test reactors and on an experimental basis in a number of Commercial Light Water Reactors (CLWRs). Most of this experience has been with Pu derived from spent low enriched uranium (LEU) fuel, known as reactor grade (RG) Pu. The High-Power MOX fuel test will be irradiated in the Advanced Test Reactor (ATR) to provide preliminary data to demonstrate that the unique properties of surplus weapons-derived or weapons-grade (WG) plutonium (Pu) do not compromise the applicability of this MOX experience base. The purpose of the high-power experiment, in conjunction with the currently ongoing average-power experiment at the ATR, is to contribute new information concerning the response of WG plutonium under more severe irradiation conditions typical of the peak power locations in commercial reactors. In addition, the high-power test will contribute experience with irradiation of gallium-containing fuel to the database required for resolution of generic CLWR fuel design issues. The distinction between "high-power" and "average-power" relates to the position within the nominal CLWR core. The high-power test project is subject to a number of requirements, as discussed in the *Fissile Materials Disposition Program Light Water Reactor Mixed Oxide Fuel Irradiation Test Project Plan* (ORNL/MD/LTR-125). This Fabrication, Inspection, and Test Plan (FITP) is a level 2 document as defined in the *Fissile Materials Disposition Program Light Water Reactor Mixed Oxide Fuel Irradiation High Power Test Project Plan* (ORNL/MD/LTR-125).

1.1 Program Needs

The primary focus of the irradiation test is to address outstanding technical issues for the deployment of MOX fuel cycles in CLWRs using weapons-derived plutonium. By performing this irradiation test, the FMDP will demonstrate the ability to manufacture the WG MOX experiment, ship the unirradiated experiment, irradiate the experiment, ship the irradiated experiment, and perform post-irradiation examination (PIE) on the experiment. The LWR MOX fuel irradiation test will irradiate MOX fuel produced in the Technical Area-55 (TA-55) facility at Los Alamos National Laboratory (LANL). Three types of WG MOX test-fuel types and one type of Low Enriched Uranium (LEU) fuel will be irradiated to investigate some unresolved generic fuel development/qualification issues. The key goal of this high-power test is mapping the evolution and behavior of gallium through the various fabrication processes and the high-power irradiation. The uninstrumented test assembly (no on-line continuous measurements) will be inserted in the ATR for irradiation. PIE will be performed in the Irradiated Fuels Examination Laboratory at Oak Ridge National Laboratory (ORNL). Further information about the entire project is contained ORNL/MD/LTR-125.

1.2 Purpose

The purpose of this Fabrication, Inspection, and Test Plan (FITP) for the Idaho National Engineering and Environmental Laboratory (INEEL) Advanced Test Reactor (ATR) High-Power Mixed-Oxide (MOX) Fuel Irradiation Project is to describe the documented approach for the assembly, loading, welding, inspection, and shipping of MOX fuel in the ATR. This FITP provides the sequence of operations to be utilized in fuel pin receipt, capsule fabrication (welding), capsule inspection, capsule loading into a basket, neutron dosimetry preparation, insertion into ATR, irradiation, removal into the ATR canal, and final shipping to ORNL. The operations are specified either by procedural reference or by direct incorporation for all aspects of this fabrication campaign from receipt inspection through shipment of the irradiated capsules to ORNL.

1.3 Scope

All INEEL activities will be conducted according to prescribed quality standards. An effective quality assurance program will be implemented and maintained, consistent with Title 10 Code of Federal Regulations, Part 830.120, *Quality Assurance Requirements*. In response to 10 CFR 830.120, Lockheed Martin Idaho Technologies Company (LMITCO), the primary contractor at the INEEL, has developed and received DOE approval of a *Quality Assurance Program Document (QAPD), Program Requirements Document, PRD-101*. ORNL has directed the use of the applicable portions of 10 CFR 830.120, *Quality Assurance Requirements,* as the baseline requirements document for developing and implementing quality assurance programs. Each of the activities has been evaluated to ensure appropriate QA requirements are applied. The test hardware nomenclature used throughout this document is consistent with that adopted by the project:

- Fuel pellet—individual pieces of ceramic MOX fuel
- Fuel pin assembly—Zircaloy tube with end caps containing a stack of 13 fuel pellets, 2 hafnium oxide shield pellets and a spring
- Capsule assembly—stainless steel tube (Type 304L)with end caps containing a fuel pin assembly
- Basket assembly—aluminum insert for the ATR I-hole with attached neutron shield
- Test assembly—basket assembly with up to nine capsule assemblies and neutron dosimetry.

Each capsule assembly consists of a stainless steel tube (Type 304L) with end caps containing a fuel pin assembly fabricated by LANL. Each fuel pin assembly contains a stack of 15 pellets (13 fuel pellets and 2 hafnium oxide shield pellets) within zircaloy tube and end caps. Each fabricated fuel pin assembly will have a spring at the top to maintain the fuel pellet stack configuration. INEEL will insert the fuel pin assemblies and complete the required seal weld on each capsule assembly using a qualified weld procedure. The capsule assemblies will be loaded into the basket assembly at the INEEL with attached neutron shield and neutron dosimetry. The overall test assembly consists of the basket assembly with up to nine capsule assemblies and neutron dosimetry.

Upon completion of the welding and inspection, the capsule assemblies will be loaded into the basket assembly in accordance with the referenced loading pattern described in the *ATR Capsule Assembly Loading and Operation Schedule for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-132). The test assembly will contain the fuel pins containing various fuel types as described in *Purchase Order: Fuel Pellets and Fuel Pin Assemblies for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-130). Each fuel pin assembly will be contained within a stainless steel capsule and placed in a 3 hole I-Basket (X2E801214A002) supplied by ORNL, with up to three capsule assemblies per hole. The test assemblies will be irradiated in the ATR, then transported to ORNL for post-irradiation examination. The INEEL will follow the same process for fabrication/assembly through reactor insertion acceptance as depicted in the *Fabrication, Inspection, and Test Plan for the Advanced Test Reactor (ATR) Mixed-Oxide (MOX) Fuel Irradiation Project* (INEEL/EXT-97-01066).

1.4 Responsibilities

Programmatic organization responsibilities are depicted in the *Fissile Materials Disposition Program Light Water Reactor Mixed Oxide Fuel Irradiation High-Power Test Project Plan* (ORNL/MD/LTR-125). The ATR MOX fuel irradiation project manager is responsible for ensuring all aspects of the project are completed in accordance with: *Purchase Order: Capsule Assemblies for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-131, Rev.1), *Design, Functional, and Operational Requirements for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-134), *ATR Capsule Assembly Loading and Operation Schedule for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-132), and the MOX fuel testing work package.

Activities described in this FITP document are the responsibility of the INEEL ATR MOX fuel irradiation project manager; however, the project manager delegates activities to supporting organizations throughout LMITCO. Interface with LMITCO internal organizations will be required throughout the project. These internal organizations include Reactor Operations, Radiation Control, Quality Assurance, Safeguard and Security, Transportation, and Packaging and others.

The capsule assembly fabrication will be performed at the TRA Hot Cell by International Isotopes Idaho Incorporated (I4). Fabrication and inspection activities performed in the TRA Hot Cell will be under direct control of the LMITCO Quality Assurance Program, radiation control, and safety controls.

Once the basket assembly is inserted into the reactor, the project manager will coordinate all removal and re-insertion efforts through reactor operations personnel. Transportation of the irradiated capsule assemblies will be supported through a transportation subject matter expert, who will provide appropriate shipping documentation to complete the transportation off-site. Additional support will be provided as needed by LMITCO Applied Engineering and Development Laboratory (AEDL) engineering staff.

2. FABRICATION PROCESS

ORNL, acting as an agent for the Department of Energy Office of Fissile Materials Disposition (DOE-MD), leads the Test Project Office. LANL will fabricate and supply the sealed fuel pin assemblies and ORNL will fabricate and supply the capsule assembly hardware. The INEEL will complete the capsule assembly by loading, welding, and inspection in accordance with the requirements outlined in the *Purchase Order: Capsule Assemblies for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-131, Rev. 01), the *Design, Functional, and Operational Requirements for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-134), *ATR Capsule Assembly Loading and Operation Schedule for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-132, Rev. 01), and the requirements specified on the latest engineering drawings (X2E801214A010: ATR Capsule Assembly, X2E801214A011: ATR Capsule Body, X2E801214A012: Capsule Outer Tube, X2E801214A013: Capsule Bottom End Cap, X2E801214A015: Capsule Top End Cap). INEEL will assemble and deliver 24 capsule assemblies: nine (9) that are required to fill the basket assembly for the initial irradiation period; four (4) replacements for insertion before the second irradiation period; four (4) unirradiated archives that are to be shipped to ORNL following the initial test assembly insertion; and seven (7) spares.

Under the activities associated with fabrication, a statement of work will be supplied to the TRA Hot Cell manager. The statement of work will require the TRA Hot Cell to develop work releases to accomplish the majority of the capsule and test assembly activities. All activities associated with the fabrication and testing of the test assembly will be under the cognizance of the LMITCO QA Program, radiation control and safety controls. The TRA Hot Cell will be supplied with all items needed for fabrication including: the detailed inventories of MOX pins, glove box assembly, detailed drawings, welding procedure and equipment, neutron dosimetry and holder with installation directions, welding mockup, MOX fuel pin assemblies, basket assembly, capsule tubing, the *Purchase Order: Capsule Assemblies for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-131, Rev. 01), the *Design, Functional, and Operational Requirements for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-134), the *ATR Capsule Assembly Loading and Operation Schedule for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-132, Rev. 01), and the specified engineering drawings. In addition, quality inspection and QA support, radiation control support personnel, and safety support personnel will be made available.

This project will follow the same logic for the overall process for fabrication/assembly through reactor insertion acceptance as depicted in the *Fabrication, Inspection, and Test Plan for the Advanced Test Reactor (ATR) Mixed-Oxide (MOX) Fuel Irradiation Project* (INEEL/EXT-97-01066). Although the logic diagram provides additional steps well beyond the purpose of this document, meeting internal LMITCO requirements is necessary to ensure acceptance for insertion into the reactor. The details of this acceptance process are briefly discussed in this document. Specified procedures for each fabrication process will be provided to the Test Project Office for review, upon request.

2.1 Receipt

Fabricated hardware and fuel pins will be received at the TRA Hot Cell. Prior to commencement of new programmatic operations to be performed at the TRA Hot Cell, an Experimental Safety Assurance Package (TRA Hot Cell ESAP) will be required. The ESAP will ensure compliance with facility Safety

Analysis Report (SAR) and Technical Safety Requirements (TSR), engineering controls, and environmental waste restrictions (*TRA Hot Cell Experiments Safety Analysis Requirements,* Standing Directive 21.1.5). In addition, prior to receiving the fuel pins, the TRA Hot Cell will be required to address, as part of the ESAP, an Unreviewed Safety Questions (USQ) evaluation, (*Unreviewed Safety Questions*, Standard Practice 10.3.1.26).

The TRA Hot Cell will receive two Department of Transportation (DOT) certified 30-gallon 6M packages with the 2R insert each containing 12 MOX fuel pin assemblies. The total of 24 fuel pin assemblies will be stored at the TRA Hot Cell until all capsule assemblies are completed. The shipping drum will used to transfer the completed nine (9) capsule assemblies to the ATR main floor area for test assembly. The empty DOT 30-gallon 6M package with the 2R insert will be shipped back to LANL upon test assembly insertion.

Material supplied from off-site suppliers will require material composition and fabrication documentation prior to test insertion into the ATR. All material requirements will be documented on the engineering drawings, and the fabrication data package will contain documentation confirming material compositions. Each fuel pin assembly shipped by LANL will be verified through receipt inspection planning per LMITCO Technical Procedure TPR-4960. The hardware supplied by ORNL to complete the capsule assembly will also be verified through receipt inspection, which will include review of material certification documentation. The QA organization will maintain original receipt inspection records as part of the overall receipt inspection documents.

The fuel pin assemblies will be received at the TRA Hot Cell with appropriate Safeguards and Security accountability forms. The fuel pin assemblies will be removed from the shipping container at the TRA Hot Cell prior to loading into the capsule assemblies. The fuel pin accountability reporting will be in compliance with the applicable Material Balance Area (MBA) requirements at TRA (*Un-irradiated Fissile Material Control Procedure*, Standard Practice 10.6.4.6). Specific requirements for record keeping will be documented (*Nuclear Materials Control and Record Keeping*, Test Reactor Area Hot Cell Operations Standing Directive 21.1.3). The capsule assembly hardware supplied by ORNL will be transported to TRA for receipt and inspection. Shipments of the non-irradiated fuel pins will comply with DOE-ID Order 5480.1, Chapter III, "Safety Requirements for the Packaging of Fissile and other Radioactive Materials".

2.2 Capsule Assembly

The changeout of capsules cannot be performed inside the reactor vessel, and the entire test assembly will have to be moved through the discharge chute to the canal to perform changeout. It is required that the test assembly remain within 45 degrees of vertical at all times so that the individual capsules maintain their orientation inside the basket assembly and do not fall out. The requirement on vertical orientation applies only to the fueled basket assembly, and does not apply to individual capsule assemblies. However, during capsule assembly, inspection and fabrication, the capsule assemblies will need to be "laid down" to perform most of the these activities. Once the capsule assemblies are loaded into the basket assembly, the completed test assembly will be maintained at all times in the required vertical position.

All capsule assembly activities will be performed at the TRA Hot Cell with the exception of the radiography, which will be performed at the QA radiography facility, located adjacent to the TRA Hot Cells. The specifics of the capsule assembly will be documented under assembly work release. All necessary assembly hardware will be placed into an approved glove box at the TRA Hot Cell. The glove box will ensure the atmosphere inside the stainless steel capsule to be helium at approximately 1 ATM pressure with a minimum purity level of 99.9%. Helium will be injected into the glove box until the calibrated oxygen measurement indicates less than <500 PPM. The oxygen measurement equipment will be calibrated in accordance with *Calibration Program*, Management Control Procedure, MCP-2391.

Prior to shutdown, each capsule assembly will be loaded into the test assembly under the capsule assembly work release at the TRA Hot Cell to verify proper fit. The capsule assemblies will be removed and the nine capsule assemblies chosen for the first irradiation cycle will be placed into the DOT certified 30-gallon 6M package with the 2R insert. These nine (9) capsule assemblies will be transferred in the DOT certified 30-gallon 6M package with the 2R insert for final loading into the basket assembly and complete the test assembly at the ATR main floor area during reactor shutdown. Each capsule assembly will be independently verified by QA for proper loading as required by ORNL drawings. Two (2) additional 10-gallon 6M packages with 2R inserts will be used to transfer the remaining capsule assemblies. One 10-gallon package will ship four archive capsule assemblies (archive capsule assemblies, No. 24, 33, 43, and 53) to ORNL in accordance with governing DOE Orders and DOT regulations. The remaining seven spare capsule assemblies and the four capsule assemblies (No. 21, 31, 41, and 51) needed for Phase II and III of the irradiation will be transferred to the Plug Storage Area North (PSAN) facility and stored. The DOT 10-gallon package will function as the approved storage device until needed at the ATR canal for loading in the basket assembly following irradiation. The TRA Hot Cell ESA will evaluate the transferring of the completed capsule assemblies to the ATR. The transfers to the ATR from the TRA Hot Cell are intra-TRA transports and will be conducted in accordance with the requirements of *TRA Unirradiated Fissile Material Control*, TRA Standard Practice 10.6.4.6.

2.2.1 Inspections

As part of the overall assembly process, a detailed listing of all inspections including dimensional, cleanliness, receipt documentation, nonconformance, leak tests, radiographic tests, dosimetry inspections, etc. through inspection hold points will be documented in the assembly work release. These inspection hold points are developed based on assembly drawings provided by ORNL. The assembly drawings provide clear direction for QA inspections to be performed. In addition, the capsule assemblies will be loaded as required in the referenced loading pattern described in the *ATR Capsule Assembly Loading and Operation Schedule for the High-Power Mixed-Oxide Irradiation Test* (ORNL/MD/LTR-132, Rev. 01). All non-conformances will be controlled in accordance with *Control of Nonconforming Items*, Management Control Procedure, MCP-538.

Special handling precautions will be incorporated into the assembly procedure. At no time will zircaloy components be permitted to come in contact with aluminum. Capsule loading will be performed per the loading drawings supplied by ORNL. Independent verification will be performed by QA. Inspection will be performed by qualified personnel for determination of quality (*Inspection and NDE Personnel Certification*, Management Control Procedure, MCP-535). Dimensional inspections will be performed as required and indicated in the ORNL drawings (*Inspection*, Management Control Procedure, MCP-2482).

2.2.2 Welding

Specific hold points will be established to assure the capsule assembly is assembled per the ORNL drawings. Weld qualification will be completed prior to commencement of capsule assembly. Qualification will be performed on set-up pieces in the glove box in accordance with *The INEEL Weld Manual*, and in full compliance with the defined Construction Code *(ASME Section III Subsection NB)*. The set-up pieces will be inspected, and the welder will be qualified following acceptable inspections. Welding will be performed per an approved *INEEL Weld Procedure S4.2.* Welding of the production capsule will follow the same process parameters and be performed by the same personnel as in the weld qualification. Hold points will be established and documented in the assembly work release. Weld inspections per ASME Section III Class I are required to be performed on the capsules. The capsule assemblies will be filled with a minimum purity of 99. 9% helium and leak tested to assure the limit of 1×10^{-8} STD CC/sec is obtained (*Leak Test Procedure*, Technical Procedure, TPR-4976). Final inspection of the completed capsule assemblies will be performed by QA (*Radiographic Examination*, Technical Procedure, TPR-4970).

2.3 Documentation

The completed assembly work release will provide the quality record or history file for each capsule assembly through test assembly insertion into the reactor. The assembly work release will provide documentation in the following areas:

- Hardware and fuel pin receipt inspection
- Hardware and fuel pin cleaning
- Bottom end-cap welding
- Fuel pin loading
- Top end-cap welding
- Nondestructive examinations
- Packaging of the capsule assemblies for transport to ORNL
- Backfill gas analysis, Impurity concentrations in fill gas
- Material certifications
- Capsule assembly dimensional inspection reports
- Leak test reports

- Nonconformance reports.

All test assembly movements, including reactor transfers and insertions, canal transfers, and any test assembly changes at the ATR will be documented by reactor operations personnel and independently verified (see Section 3.2). In addition, all data that describe the core neutronic and thermal-hydraulic environment of the test will be available from routine ATR operating measurements. The core neutronic information includes lobe powers of the reactor, positions of the S3, S4, W1, and W2 outer shim control cylinders (OSCC), and positions of the SW neck shims. These data will be obtained from the Reactor Data Acquisition System (RDAS), which performs calculations based on core neutronic instruments, OSCC, and neck shim positions. The thermal-hydraulic information includes the reactor vessel core differential pressure (delta P), core inlet pressure, and core inlet temperature. These data will also be available from the RDAS. This data will be primarily used to perform in-core irradiation calculations. Neutron monitor measurements will be used to verify these results.

Thermal neutron fluence measurements will allow estimation of the fissile burnup (atom%) for the fuel pins. Three sets of neutron monitors will be located in the I-hole basket. Data generated from these measurements will be documented and made available through the TRA Radiation Measurements Laboratory (RML) following verification and validation processes. The neutron monitors will be removed following the specified time frame identified in the *Design, Functional, and Operational Requirements for the High-Power Mixed-Oxide Irradiation Test*: ORNL/MD/LTR-134. Two procedures primarily govern the measurement and analyses of the neutron monitors (*Routine ATR Neutron Fluence Rate Measurements*, RML-13, and *Handling/Tracking and Analysis of Neutron Monitors at the RML*, RML-25). However, procedure ACMM-3601, "MOX-ATR Irradiation Neutron Fluence Rate Measurements" of the Analytical Chemistry Methods Manual, will be followed for the flux wire measurements

Prior to each fuel/operating cycle, INEEL personnel will perform calculations to predict the linear heat generation rate for each capsule assembly as a function of time during the cycle. The results of these calculations will be provided to ORNL prior to cycle startup, and will also be included in the overall documentation for the test.

3. REACTOR INSERTION AND REMOVAL

ATR in-core reactor operations are controlled under specific Test Reactor Area (TRA) procedures. These procedures document the overall activities during reactor operations through shutdown. Routine changes to the core configuration include fuel elements, in-pile experiments, neutron monitors, and irradiation tests. During the shutdown period of the reactor, the test assembly will be transferred to operations by the project engineer for insertion into the reactor. Operations will verify the test assembly identification with the reactor loading record information. To support the insertion, additional documentation must be submitted and approved prior to acceptance and insertion of the test assembly into the ATR. Acceptable operating conditions for the beginning of the irradiation period include heat generation rates between 9 and 15 kW/ft. When it is anticipated that the planned power level of the South West quadrant (or lobe) power will result in a linear heat generation rate greater than 15 kW/ft as an average in any fuel pin, approval to continue the irradiation will be obtained from the cognizant ORNL project manager. If the predicted power level is unacceptable, or if linear heat rate of the capsule assemblies fall below the minimum 9 kW/ft, the entire experiment may either be moved to another small I-hole that will provide the acceptable neutronic conditions, be removed from the reactor until an acceptable position can be identified, or be reloaded into another basket assembly with a different neutron shield.

3.1 Test Irradiation Acceptance

INEEL Nuclear Operations Quality Assurance personnel cognizant of the ATR QA Program requirements have reviewed the ORNL and LANL QA Programs as they apply to the experiment. Insertion of the test assembly into the ATR is dependent upon INEEL concurrence with the adequacy of these programs. This review and acceptance has been performed and both programs were found to be acceptable.

The ATR Core Safety Assurance Package (CSAP) documents the core safety analysis for each reactor cycle (*Core Safety Analysis Preparation, Revision, Scheduling and Use*, Standing Directive, SD 11.2.19). The Safety and Operations Review Committee (SORC), an independent safety review committee, is established to provide oversite of any issue or item that has the potential to impact the safe and reliable operation of the facility. An Experimental Safety Assurance Package (ESAP) is a cradle-to-grave review performed to ensure that a proposed test falls within the safety analyses. The location and test assembly identification are documented in the ATR Reactor Loading Record (Standard Directive, SD 11.5.4). As part of the overall reactor operations acceptance process, a Facility Change Form (FCF) is required to be completed prior to reactor operations and is performed in accordance with *Facility Change Form Preparation and Use*, Standard Practice, SP 10.2.2.8. The FCF provides a documentation system that assures all internal reviews have been completed with the ATR Reactor Operations Manager giving final approval. These processes must be followed prior to acceptance of a test for irradiation.

Following Operation's insertion acceptance of the test assembly, in-core reactor loading of the completed assembly will be performed. The checklist will document the insertion of the test assembly into the ATR irradiation position as directed by the Reactor Loading Record. Specific handling and loading instructions may be contained in the Cycle Reference Document, Section 13G (CRD-13G) for the capsule irradiation program. Loading changes and shutdown instructions will be placed in this CRD for special handing instruction, if necessary during the handling of the test assembly. The reactor loading record is attached to the Detailed Operating Procedure (DOP) for inventory prior to insertion. Dual verification insertion is performed versus the reactor position by initialing the reactor loading record. A second inventory will be performed for all affected positions as required in the Reactor Loading Record to ensure the capsule assemblies and baskets are properly "seated". Final signature on the DOP will represent completion of all reactor irradiation experiment changes. These procedures and documents will also provide documentation for removal following irradiation. The test assembly will be inserted into position I-23 (Southwest 1.5" I-Hole), as shown in the ATR Core Cross-section Diagram Figure 1.

3.2 Canal Transfer and Handling

The irradiated test will be transferred to the ATR canal following removal from the reactor. Canal operations are governed under specific procedures for handling these tests (*Experiment Handling in the Canal*, Operating Maintenance Manual, OMM 7.10.13.1.3). Transfer records will be maintained at the canal (*Canal Record Keeping*, Operating Maintenance Manual, OMM 7.10.13.1.5). Transfers from the reactor to the canal and back will be controlled (*Reactor/Canal Transfers*, Operating Maintenance Manual, OMM 7.10.13.1.2). Instructions related to the removal and replacement of capsule assemblies will be provided to the canal operations personnel by the canal loading record and through the project engineer. The changeout of capsules cannot be performed inside the reactor vessel, and the entire test assembly will have to be moved through the discharge chute to the canal to perform changeout. It is critical that the test assembly remains within 45 degrees of vertical at all times so that the individual capsules maintain their orientation inside the basket assembly. The canal handling and discharge instructions will provide the necessary direction for using the tools to ensure the basket remains in the vertical position during in-vessel and canal handling. ORNL will provide a small MOX capsule assembly carrier that can accommodate the capsule assemblies. If additional carrier capability is needed, a second identical carrier will be supplied. ORNL will provide, with INEEL concurrence of the design, tooling necessary to manipulate capsules during installation and removal from the basket. The MOX capsule assembly carrier will need to be analyzed to assure criticality concerns are addressed, during normal or off-normal operations.

The neutron dosimetry will be removed from the test assembly after the first cycle of operation and analyzed to compare with the neutronic analyses. Neutron dosimetry will include nickel wires (fast neutron) and cobalt aluminum wires (thermal neutron). The neutron dosimetry analysis will normally require a one to two-week decay time to limit radiation handling exposures. New dosimetry will be loaded into the test assembly for the second cycle of irradiation. Schedules for further neutron dosimetry removal will be determined after analysis of the first neutron dosimetry set and upon agreement between ORNL and INEEL, but as a minimum, the neutron dosimetry will be changed when the test assembly/capsule configuration is altered. Once the test assembly is transferred to the canal, the capsule assemblies and required neutron dosimetry will be removed in accordance with the instructions provided and documented in the canal loading records. The neutron dosimetry will be removed with a special removal tool designed by INEEL engineering staff. Following completion of the removal and insertion of new neutron dosimetry, the test assembly will be transferred to the reactor in-core operations personnel for insertion into the reactor irradiation position. The neutron dosimetry will be analyzed per Analytical Chemistry Methods Manual Procedure ACMM-3601 following removal, and appropriate decay time. The flux wires will be removed by the canal operators (*Experiment Handling in the Canal*, Operating Maintenance Manual, OMM 7.10.13.1.3), and the results will be provided to the project engineer when completed.

Four (4) capsule assemblies will be removed after reaching approximately 15 GWd/MTHM in the lead (highest burnup) capsule assembly and replaced with unirradiated capsule assemblies. When the lead capsule reaches 30 GWd/MTHM, the capsule will be replaced by a simulator stainless steel capsule supplied by ORNL. The loading records and ESAP will need to address the potential inclusion of non-fueled simulator assemblies in the test assembly. After the lead capsule assembly reaches an average burnup of about 45 GWd/MTHM, the experiment assembly will be removed from the reactor.

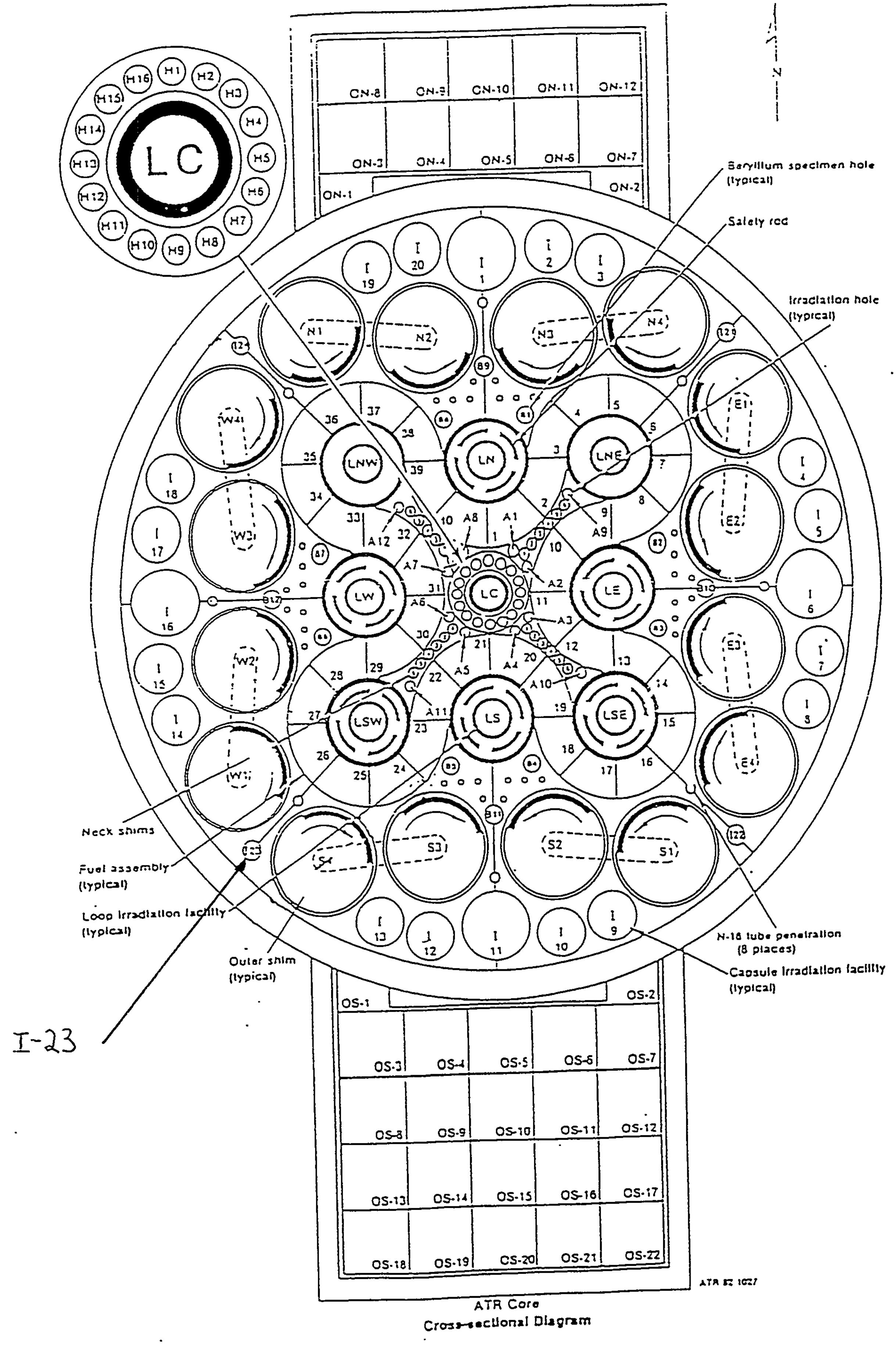

Figure 1. ATR core cross-section diagram.

4. CAPSULE SHIPMENTS

All of the irradiated fuel will be shipped to ORNL for post-irradiation examinations (PIE). The transportation tasks are divided into four sub-tasks: the assembly basket and empty capsules to INEEL, shipment of the fuel pins to the ATR, shipment of unirradiated capsules to ORNL, and shipment of irradiated capsules to ORNL for examination. The empty capsules and assembly basket will be packaged and shipped commercially from ORNL to INEEL. ORNL will lead the development of a Transportation Plan that describes the irradiated capsule shipments, identifies the candidate shipping containers, identifies the radioactive materials to be shipped, and describes the responsibility of each laboratory. The irradiated fuel pin shipments from the INEEL to ORNL will be coordinated by the INEEL.

4.1 Unirradiated Archive Capsule Assemblies

Shipments of the unirradiated capsule assemblies to ORNL will comply with DOE-ID Order 5480.1, Chapter III, "Safety Requirements for the Packaging of Fissile and other Radioactive Materials". The four (4) archive capsule assemblies (archive capsule assemblies, No. 24, 33, 43, and 53) will be shipped to ORNL, and the remaining capsule assemblies will be moved to the PSAN facility under Safeguards and Security controls until needed at the ATR canal for loading in the basket assembly following irradiation. The transfer to PSAN facility and the shipment to ORNL will involve using a 10-gallon 6M package with a 2R insert.

4.2 Irradiated Capsule Assembly

Shipping packages that are compatible with the ATR canal and ORNL's hot cells have been identified. The ESAP is required to review activities involving canal handling and packaging at the ATR facility. This assures the ESAP addresses the identification of the cask for off-site shipments in the cradle-to-grave approach. Currently the candidate casks to be used for transporting the irradiated capsules are the General Electric 100 and 2000 series casks. Shipments, loading and unloading, of irradiated capsules to ORNL using the GE-100 cask will be performed under an approved DOP (*Loading and/or Unloading the General Electric 100 Series Cask*, Detailed Operating Procedure, DOP 4.8.36). Shipments, loading and unloading, of irradiated capsule assemblies, the simulator capsule assemblies and other irradiated hardware, using the GE-2000 cask will be performed under an approved DOP (*Loading/Unloading the General Electric 2000 Series Cask*, DOP 4.8.4). The type of cask will determine if revisions will be required to existing DOP's for previously handled casks at the canal, or if new DOP's will be required if the cask has not been previously used at ATR. Once ORNL and INEEL agree upon the chosen casks, the INEEL will determine if additional revisions to existing DOP's will be needed or if a new DOP will be required.

5. REFERENCES

1. B. S. Cowell and S. A. Hodge, *Fissile Materials Disposition Program Light Water Reactor Mixed Oxide Fuel Irradiation High-Power Test Project Plan*, ORNL/MD/LTR-125, Rev. 01, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, July 1998.

2. 10 CFR 830.120, *Quality Assurance Requirements*, Latest version.

3. B. S. Cowell, *ATR Capsule Assembly Loading and Operational Schedule for the High-Power Mixed-Oxide Irradiation Test*, ORNL/MD/LTR-132, Rev. 01, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, July 1998

4. B. S. Cowell and S. A. Hodge, *Fissile Material Disposition Program Light Water Reactor Mixed Oxide Fuel Irradiation Test Project Plan*, ORNL/MD/LTR-78, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, July 1997.

5. B. S. Cowell, *Purchase Order: Fuel Pellets and Fuel Pin Assemblies for the High-Power Mixed-Oxide Irradiation Test*, ORNL/MD/LTR-130, Rev. 01, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, July 1998.

6. B. S. Cowell, *Purchase Order: Capsule Assemblies for the High-Power Mixed-Oxide Irradiation Test*, ORNL/MD/LTR-131, Rev. 01, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Rev. 01, July 1998.

7. K. R. Thoms, *Design, Functional, and Operational Requirements for the High-Power Mixed-Oxide Irradiation Test*, ORNL/MD/LTR-134, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, June 1998.

8. G. W. Wachs, *Fabrication, Inspection, and Test Plan for the Advanced Test Reactor (ATR) Mixed-Oxide (MOX) Fuel Irradiation Project*, INEEL/EXT-97-01066, Lockheed Martin Idaho Technologies Company, Idaho National Engineering and Environmental Laboratory, September 1997.

9. J. M. Ryskamp, *Project Management Plan for INEEL Portion of the Mixed Oxide Fuel Irradiation Test Project*, PLN-194, Lockheed Martin Idaho Technologies Corp., Idaho National Engineering and Environmental Laboratory, March 1997.

10. L. S. Dickerson, *Irradiated Test Fuel Transportation Plan for LWR MOX Fuel Irradiation Test Project*, ORNL/MD/LTR-101, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, (TBP).

11. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A001, Rev. 0, ATR Test Assembly (5 sheets).

12. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A002, Rev. 0, ATR Basket Assembly.

13. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A003, Rev. 0, ATR Basket Center Section (3 sheets).

14. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A004, Rev. 0, ATR Basket Outer Sleeve.

15. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A005, Rev. 0, Outer Sleeve Support.

16. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A006, Rev. 0, Sleeve Support Housing.

17. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A007, Rev. 0, Sleeve Support Web.

18. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A008, Rev. 0, Fuel Pellet Installer.

19. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A009, Rev. A, ATR Fuel Pellet.

20. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A010, Rev. A, ATR Capsule Assembly.

21. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A011, Rev. 0, ATR Capsule Body.

22. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A012, Rev. 0, Capsule Outer Tube.

23. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A013, Rev. 0, Capsule Bottom End Cap.

24. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A014, Rev. B (TBI), Fuel Pin Inner Tube.

25. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A015, Rev. B (TBI), Capsule Top End Cap (2 sheets).

26. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A016, Rev. 0, Helical Compression Spring.

27. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A017, Rev. A, ATR Fuel Pin Assembly.

28. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A018, Rev. A, Fuel Pin Bottom End Cap.

29. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A019, Rev. A, Fuel Pin Top End Cap.

30. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A020, Rev. 0, ATR Fuel Pin Flow Test Dummy (3 sheets).

31. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A021, Rev. 0, ATR Test Assembly Model 2 (5 sheets).

32. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A022, Rev. 0, ATR Basket Assembly Model 2 (2 sheets).

33. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A023, Rev. 0, ATR Basket Center Section Model 2 (4 sheets).

34. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A024, Rev. 0, Outer Sleeve Support Model 2.

35. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A025, Rev. 0, Sleeve Support Housing Model 2.

36. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A026, Rev. 0, Sleeve Support Web Model 2.

37. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A050, Rev. 0, MOX Capsule Assembly Carrier Assembly.

38. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A051, Rev. 0, MOX Capsule Assembly Carrier Cover Plate Detail.

39. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A052, Rev. 0, MOX Capsule Assembly Carrier Weldment.

40. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A053, Rev. 0, MOX Capsule Assembly Carrier Tube/Orientation Plate Detail.

41. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A054, Rev. 0, MOX Capsule Assembly Carrier Latch Details.

42. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A055, Rev. 0, MOX Capsule Assembly Carrier Seat Bayonet Detail.

43. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A056, Rev. 0, MOX Capsule Assembly Carrier Top Plate Weldment.

44. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A057, Rev. 0, MOX Capsule Assembly Carrier Lower Plate Details.

45. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A058, Rev. 0, MOX Capsule Assembly Carrier Side Plate Detail.

46. Lockheed Martin Idaho Technologies Corp., Idaho National Engineering and Environmental Laboratory, Drawing 501360, ATR MOX TEST FLUX MONITOR ASSEMBLY.

47. Lockheed Martin Idaho Technologies Corp., Idaho National Engineering and Environmental Laboratory, Drawing 501361, ATR MOX TEST FLUX MONITOR SUPPORT DISC.

48. Lockheed Martin Idaho Technologies Corp., Idaho National Engineering and Environmental Laboratory, Drawing 501362, ATR MOX TEST FLUX MONITOR HOLDER.

49. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A027, Rev. 0 (TBI), ATR Basket Assembly Model 3 (2 sheets).

50. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A028, Rev. 0 (TBI), ATR Basket Center Section Model 3 (3 sheets).

51. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A029, Rev. 0 (TBI), ATR Basket Outer Sleeve Model 3.

52. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A030, Rev. 0 (TBI), ATR Basket Assembly Model 4 (2 sheets).

53. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A031, Rev. 0 (TBI), ATR Basket Center Section Model 4 (3 sheets).

54. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A032, Rev. 0 (TBI), ATR Basket Outer Sleeve Model 4.

55. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A033, Rev. 0 (TBI), ATR MOX Capsule Neutron Absorber Pellet.

56. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A059, Rev. 0 (TBI), ATR MOX Capsule Long Insertion Tool Assembly.

57. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A060, Rev. 0 (TBI), ATR MOX Capsule Insertion Tool Assembly Details.

58. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A061, Rev. 0 (TBI), ATR MOX Capsule Long Insertion Tool Weldment Part Details.

59. Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Drawing X2E801214A062, Rev. 0 (TBI), ATR MOX Capsule Long Insertion Tool Rod Detail.