ATTACHMENT 12

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Y-12 NATIONAL SECURITY COMPLEX

Project Report for the Model NMDFH-001 Uranium Disk Sealed Source

October 2010

Prepared by
Y-12 National Security Complex
Oak Ridge, Tennessee 37831

Managed by
Babcock & Wilcox Technical Services Y-12, LLC
for the
U.S. Department of Energy
under contract DE-AC-5-00IR22800

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B&W Y-12, LLC
FOR THE UNITED STATES
DEPARTMENT OF ENERGY
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Acronyms and Abbreviations

ATD	Applied Technologies Division
ANSI	American National Standards Institute
°C	degrees Centigrade
CFR	Code of Federal Regulations
DAC	Design Analysis and Calculation document
DDAA	Differential Die Away Analysis
DHS	U.S. Department of Homeland Security
DOE	U.S. Department of Energy
°F	degrees Fahrenheit
ID	identification
mA	milli-Ampere
MeV	megaelectron volts
min	minutes
microA	micro-Ampere
mrem	millirem
mSv	milli-Sievert
n	neutrons
NNSA	National Nuclear Security Administration
NRC	U.S. Nuclear Regulatory Commission
OSB	Operational Safety Board
PJB	Pre-Job Briefing
psia	pounds per square inch atmospheric
R	Roentgen
rem	Roentgen Equivalent Man
RFQ	Radio Frequency Quadrupole
sec	seconds
WAF	Work Authorization Form
YSO	Y-12 Site Office

1. Summary Information

The United States (U.S.) Department of Energy (DOE) National Nuclear Security Administration (NNSA) Y-12 National Security Complex is located in Oak Ridge, Tennessee. The U.S. Department of Homeland Security (DHS) Domestic Nuclear Detection Office (DNDO) has requested Y-12 National Security Complex to design a sealed source and to manufacture and distribute these sealed sources to a limited number of users (DHS subcontractors). This titanium encapsulated, highly enriched uranium (HEU) source, model number NMDFH-001, is the subject of this project report. The source is intended for distribution to DOE facilities and DHS subcontractors supporting DHS mission needs.

The radionuclides and maximum activities for the encapsulated U-235 sources are shown below.

Isotope	Maximum Activity (Ci)
^{232}U	1.96E-06
^{234}U	2.04E-02
^{235}U	6.29E-04
^{236}U	1.44E-04
^{238}U	5.24E-06

The source is a 3.95-inch circular disk of highly enriched uranium metal 0.078 inches thick. The HEU disk is encapsulated within two identical 4.5-inch diameter titanium disks 0.125 inch thick. Each titanium half-case has a 3.99-inch diameter circular cavity 0.046 inch deep to create the void for the uranium metal disk. The titanium half-cases with the HEU disk inside are sealed closed using electron beam welding.

Each disk will have a unique serial number for positive identification.

2. Conditions of Use

The Y-12 National Security Complex, under an agreement with the Department of Homeland Security (DHS), designed, tested and built Model NMDFH-001 uranium sealed sources for DHS. The design meets the technical requirements established in the American National Standards Institute (ANSI) standard ANSI/HPS N43.6-2007, *Sealed Radioactive Sources – Classification.*

The disk will be used inside various types of luggage and packing containers to simulate hidden special nuclear material (SNM) in a test of active interrogation systems. The systems being tested will expose the disk to either X-ray or neutron radiation and will measure the resulting generated radiation from the disk.

The disk will be used in the active interrogation systems using either bremsstrahlung X-ray (9 MeV with various radiation levels) or neutrons (up to 3 MeV of neutron average energy, at the flux of up to 10^{11} n/sec at the generator). Typical range of distance from the radiation source to the disk is about 4 feet to 12 feet when the disk is aligned with the source. The specific distance will vary between the four interrogation systems being tested. The disk will be used in a range of environmental conditions from the weather conditions in Boston to those at the Nevada Test Site (NTS) in Las Vegas. The range of temperature extremes the disk should experience will encompass the cold winter conditions (22 °F in January) in Boston to the hot summer conditions (104 °F in July) in Las Vegas. The disk will not be subjected to any physical stress or pressure during the test except that caused by the thermal and gas generation effects of the irradiation. The disk will reside in a specially made disk enclosure, and the enclosure will be placed in a cargo container mixed with other cargo materials.

The following is a summary of the irradiation properties for the four active interrogation systems.

1) L-3 neutron system: This system will use a radio-frequency quadrupole (RFQ) accelerator to generate neutrons at two different energies. The first is from 13C(d,n)14N at about 2 MeV, yielding 1.5×10^{11} neutrons at maximum current (50 microA). The second is from Be(d,n)B at approximately 3MeV, yielding 4×10^{9} neutrons at 50 microA.

2) Passport system: This system will use a continuous wave bremsstrahlung source with about 9000 R/(min mA) at max 3.5 mA at the collimator.

3) Rapiscan Differential Die Away Analysis (DDAA) system: This system will use pulsed 9 MeV bremsstrahlung (1,000 R/min) to generate neutrons with D_2O. This system will generate both photons and neutrons at the target as fan beam.

4) Rapiscan PBAR system: Pulsed 9 MeV bremsstrahlung with 3000 R/min as a fan beam.

The testing requirement is to scan the cargo for up to 30 minutes to identify special nuclear material in very dense cargo (worst case). For less dense cargo the systems will complete the scan much faster.

3. Construction of the Product

The sealed source is a circular disk of highly enriched uranium (HEU) metal, diameter 3.953 inches ± 0.003 inches and thickness 0.078 inches ± 0.003 inch. The HEU disk is encapsulated within two identical titanium disks, diameter 4.50 inches ± 0.01 inch and thickness 0.125 inch ± 0.01 inch. Each titanium half-case has a circular cavity 3.990 inches ± 0.005 inch in diameter and 0.046 inch ± 0.005 inch deep to create the void for the uranium metal disk. The titanium half-cases with the HEU disk inside are joined and sealed closed using electron beam welding.

The HEU disk and the titanium cases are fabricated and the sealed source is assembled and welded in the Applied Technologies Division (ATD) facilities at the Y-12 National Security Complex in Oak Ridge, TN. The ATD utilizes a formal work planning and authorization process to ensure that the fabrication and testing of the disks is done properly and safely. This process is guided by a Y-12 procedure, "Planning and Authorizing Work in Applied Technologies," Y15-1500-003.

Each task (*e.g.*, electron beam welding, laser marking) has an associated Work Authorization Form (WAF) package which describes the task, identifies the type of work control (*e.g.*, procedure, skill of craft, special) and lists the workers approved to execute the task, along with an evaluation of the special concerns, training, permits, hazard analysis completion, waste issues, quality requirements, measurement and testing equipment calibration, and required records. The package is reviewed by the ATD Operational Safety Board (OSB) using a formal checklist. Also included in the WAF package is the Skill-of-Craft documentation that identifies minimum education and experience required to perform the activity, as well as job-specific training required and a list of approved candidates for the task. A formal "What-If" Hazard Analysis Worksheet is also completed and attached to the WAF package. A Pre-Job Briefing (PJB) is held the first time the task is performed. The OSB determines the frequency of PJBs for repeated tasks. If any unexpected events occur during the activity a Post-Job Briefing is held to discuss and evaluate these events and to determine if any changes are needed in the job planning or execution.

Electron beam welding the titanium disk assemblies was performed in accordance with, "Disk Assembly Welding Procedure Specification," WPS-EBW-DISK-1. The assembled disks were (or will be) leak tested in accordance with ISO 9978-1992E, *Radiation protection- Sealed radioactive sources – Leakage test methods.*

The following engineering drawings document design and construction of the disks:

T802054-0001, Test Plate Assembly
T802054-0002, Cover Plate Details
T802054-0003, Disk Details

The welded construction provides a robust containment for the HEU. Since the HEU is a solid metal there is essentially no likelihood of HEU escaping under normal conditions (22 to 104 °F) or expected abnormal conditions (accidental dropping from less than 10 feet onto an unyielding surface or onto a sharp point or edge).

The disk will be used inside various types of luggage and packing containers to simulate hidden special nuclear material. The disks will be used to test active interrogation systems which involve exposing the disks to X-ray and neutron radiation and measuring the generated radiation. The interrogation process will result in heat generation and gaseous products from radioactive decay within the disk cavity. An evaluation (Y-12 Design Analysis and Calculation document (DAC) T802054-0001, *Calculations to Support Certification of a Sealed Source*) estimates the upper bound for the pressure generated within the case to be ~6.7 psia after 30 years. This does not represent a serious threat to cause failure of the welded containment of the HEU disk.

The disk exposed to the X-ray beam will have a very small dose rate at the surface before and after the beam is turned off. That dose rate is due to the natural decay of the uranium (~0.016 rem/hr). The disk exposed to the neutron flux will produce fission products and will have a surface dose rate of ~191 rem/hr immediately following exposure. The fission products will decay with time. The surface dose rate will be ~6 rem/hr at one minute after irradiation; ~0.3 rem/hr at 10 minutes after irradiation, and ~0.04 rem/hr at 30 minutes after irradiation. These calculations are also in DAC T802054-0001.

Assuming only natural convection cooling, the disk will take approximately three hours to cool to 30 °C from its maximum temperature of 258 °C (496 °F) following neutron irradiation. The disk exposed to the X-ray beam is expected to reach a maximum temperature of only 35.9 °C (96.6 °F). Because of these elevated temperatures following neutron irradiation, the holder for the disk (to be provided by individual interrogation systems) should be designed to keep the disk out of contact with flammable materials and to prevent inadvertent human contact until the disk has cooled. Also, a radiological control technician should be available to determine when the irradiated disk is safe to handle from a radiation perspective.

4. Labeling

The labeling applied to the sealed source will be done by laser etching and will include the following information.

For all sources:
- Model Number – NMDFH-001
- Serial Number
- Distributor: Y-12
- Material
- Total Material Weight

For sources containing radioactive material (i.e. not surrogate material):
- Isotope
- Activity
- Date of Assay
- CAUTION – RADIOACTIVE MATERIAL
- Radioactive Symbol – Trefoil

For all sources, unless instructed otherwise:
- Y-12 National Security Complex Symbol
- Lot ID

5. Prototype Testing

The design meets the technical requirements established in the American National Standards Institute (ANSI) standard ANSI/HPS N43.6-2007, *Sealed Radioactive Sources – Classification*.

Testing was performed by Pacific Testing Laboratories on a series of prototype assemblies using a stainless steel disk in place of the HEU disk. The detailed test report is "Pacific Testing Laboratories Test Report, Babcox & Wilcox Y-12, L.L.C., Work Order: 41083," dated August 5, 2010.

The testing protocol established that each disk was not leaking prior to the test and then tested the disk for leakage following the test. Tests were run for temperature, external pressure, impact, vibration, puncture per the requirements of ANSI/HPS N43.6-2007. The prototype disks all passed all of the tests required by ANSI/HPS N43.6-2007.

6. Radiation Profiles

The isotopic composition and associated bounding activity of the HEU material in the sealed source are shown in the table below.

Composition of HEU		
Isotope	**Weight %**	**Maximum Activity (Ci)**
^{232}U	[redacted]	1.96E-06
^{234}U	[redacted]	2.04E-02
^{235}U	[redacted]	6.29E-04
^{236}U	[redacted]	1.44E-04
^{238}U	[redacted]	5.24E-06

The external radiation level from an assembled sealed source disk is estimated to be ~16 mrem/hr at the disk surface. This is well below the 50 mrem/hr @30cm and 1,000 mrem/hr @ 5cm which defines a "radiation area" in 10 CFR 20. The 10 CFR 20 definition of a radiation area is:

> Radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

7. Quality Assurance and Quality Control

The design, fabrication, and testing of this sealed source have been accomplished consistent with applicable DOE quality assurance requirements (DOE Order 414.1C, Quality Assurance) and the so-called Quality Rule, 10 CFR 830, Energy/Nuclear safety Management, Subpart A, Quality Assurance Requirements.

The design meets the technical requirements established in the American National Standards Institute (ANSI) standard HPS N43.6-2007, *Sealed Radioactive Sources—Classification*. The implementation of the Quality Assurance program at the Y-12 National Security Complex within the Applied Technology Division (the manufacturing element at Y-12 for the disks) will ensure that the associated ANSI/HPS requirements are met.

The titanium used to make the casings for the disks was procured from Titanium Metals Corporation as a certified material complying with the following specifications:

ASME SB 265-07	Grade 2
ASTM B 265-07	Grade 2
ASTM F 67-06	Grade 2
ISO 5832-2 09/15/93	Grade 2

During the fabrication of the disks all machined materials for use, or potential use, were marked with unique identification numbering or lettering for traceability reasons. All parts were given a unique identifications number, and those parts that were assembled for testing and finished products were marked using a laser for lifelong, legible identification.

Parts were marked using unique identification (ID) numbers and lettering for product control and process flow.

All data from the measuring process was also stored with the unique part IDs for future traceability reasons, if needed. Samples used for testing were marked in a similar manner as well.

8. Installation, Servicing, and Instructions to Users

Since the U-235 is totally encapsulated and sealed within the titanium casing of the disk and since the radiation from the uninterrogated encapsulated radiological material does not pose a significant radiation exposure threat to users, the uninterrogated disks can be contact handled using normal care not to expose the disk to forces which could compromise the casing.

The following conditions of use will be established:

During loading and pre-interrogation handling

1. The disk shall not be subjected to conditions or an environment which exceeds its ANSI N43.6-2007 classification testing requirements.
2. The disk shall not be exposed to an extremely corrosive (acidic or caustic) environment which could degrade or compromise the titanium casing.

During and following interrogation

1. The interrogated source shall be evaluated for radiation by a qualified radiological technician to determine when the radiation levels are low enough to allow safe contact handling for removal from the cargo simulation. This is a concern only for the systems using neutron interrogation.
2. The interrogated source shall remain in its holder for a period of three hours following neutron irradiation or until such time as it has cooled to a surface temperature ≤30 °C (86 °F).
3. When the source is no longer needed for interrogation investigations, the source disk shall be returned to Y-12.