NUCLEAR CRITICALITY SAFETY PROGRAM
FOR ENVIRONMENTAL RESTORATION PROJECTS

BY

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Objective

The objective of this paper is to give an update on activities at the Fernald Site and to describe the Nuclear Criticality Safety issues that are currently being addressed.

Brief History And Site Description

The Fernald Environmental Management Project (FEMP), formerly known as the Feed Materials Production Center (FMPC), is located on a 1050 acre site approximately twenty miles northwest of Cincinnati, Ohio. The production area of the site covers approximately 136 acres in the central portion of the site. Surrounding the core production area is a buffer consisting of leased grazing land, reforested land, and unused areas.

The uranium processing facility was designed and constructed in the early 1950s. During the period from 1952 to 1989 the site produced uranium feed material and uranium products used in the United States weapons complex. Production at the site ended in 1989, when the site was shut down for what was expected to be a short period of time. However, the FMPC was permanently shut down in 1991, and the site's mission was changed from production to environmental restoration.

Facility Description

The environmental restoration processes which are a concern to the Nuclear Criticality Safety (NCS) Group consist of the former production area and production-associated equipment, including all above- and below-grade components. This includes all uranium-bearing or contaminated structures, equipment, drums, tanks, solid waste, waste product, effluent lines, K-65 silos and transfer lines, wastewater treatment facilities, scrap metal piles, feed stocks, and product. These structures, components, and equipment are largely idle and will be dismantled following stabilization/decontamination.

The structures of concern are Plants 1, 2/3, 4, 5, 6, 7, 8, 9, the Pilot Plant, and storage buildings. Plant 1, and 8 contain equipment that will be used to support overall site decontamination and decommissioning (D&D).

The following describes the former production functions of the plants which ceased manufacturing in 1989:

1. Plant 1 was primarily used for sampling and analyzing the isotopic content of fissionable materials. The plant also stored, decontaminated, and reconditioned drums.

2. Plant 2/3, the refinery, processed uranium ore concentrates and residual compounds. In addition to refining ore, Plant 2/3 also contains storage facilities, a control building, Nitric Acid Recovery Area, Maintenance Building, Incinerator, and other ancillary support buildings.
3. Plant 4 is referred to as the Green Salt Plant because the plant converted UO3 to UF4, Green Salt, which was to feed subsequent processes. The plant consists of processing, storage, and maintenance buildings.

4. Plant 5, the metals production plant, produced uranium metal from UF4. The metal was remelted, cast, and machined before transfer to Plant 6.

5. Plant 6 was the metals fabrication plant. This plant heat treated and machined uranium metal to prepare it for extrusion into tubes at other sites.

6. For two years Plant 7 housed a reduction process which converted uranium hexafluoride to uranium tetrafluoride. Since 1956 it has been used for storage, and is currently scheduled to be the first building to be dismantled.

7. Plant 8 is referred to as the Scrap Recovery Plant. Scrap from the production process or residues were processed in Plant 8 to remove moisture, oil, or metallic impurities. The uranium-bearing scrap and residues were then returned to Plant 2/3 for reprocessing. Plant 8 is currently used to treat wastewater from all the sumps on site. The Plant also contains a new rotary kiln to be used for drying contaminated materials.

8. Plant 9 is referred to as the Special Products Plant. Fuel was removed from unirradiated fuel rods in this plant.

9. Thorium and uranium were purified in the Pilot Plant. In addition to uranium heat treatment and aluminum jacket removal from unirradiated fuel rods, the Pilot Plant provided other small-scale treatment facilities. The plant housed heat treatment equipment and chemical treatment equipment including UF6 to UF4 reduction facilities.

### Table 1 - Summary of Plant, Manufacturing Function and Building

<table>
<thead>
<tr>
<th>Plant</th>
<th>Manufacturing Function</th>
<th>Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sampling</td>
<td>1, 30, 66, 71, 72</td>
</tr>
<tr>
<td>2/3</td>
<td>Refinery</td>
<td>2, 3, 18, 39</td>
</tr>
<tr>
<td>4</td>
<td>Green Salt (Uranium Processing)</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Metal (Uranium) Production</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Metal (Uranium) Fabrication</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Reduction</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Recovery (of uranium wastes)</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Special Products (Uranium and Thorium Processing)</td>
<td>9, 81</td>
</tr>
<tr>
<td>Pilot</td>
<td>Uranium and Thorium Processing</td>
<td>13, 37, 54</td>
</tr>
</tbody>
</table>
FIGURE 1 - FERNALD SITE MAP
Change In Mission And Organization

The management of the environmental restoration at the Fernald Site was assumed by Fernald Environmental Restoration Management Corporation (FERMCO) on December 1, 1992. FERMCO is a team of four companies, Fluor Daniel, Inc., Halliburton-NUS, Nuclear Fuel Services, and Jacobs Engineering. Each of these companies bring their own expertise to the project. The Nuclear Safety Group was originally assigned to the Regulatory Programs Division but has recently reassigned to the Environmental Safety and Health (ES&H) Division. The Nuclear Criticality Safety (NCS) Program is a site-wide program, and other site organizations and personnel such as the Assistant Emergency Duty Officer (AEDO), Training Department, Operations, and Emergency Planning department have responsibilities for major portions of the program as summarized in Table 2.

Along with the change in mission, and change in management, there was also at this time a change in regulations in that DOE Order 5480.24 NUCLEAR CRITICALITY SAFETY (Ref 1) had been issued. The Nuclear Safety group was assigned to develop an implementation plan for the new Order and to submit it to the Department of Energy by January 15, 1993.

Setting Goals For The Nuclear Criticality Safety Program

In response to the new DOE Order, an Implementation Plan was submitted to the DOE on January 15, 1993. The implementation plan was based on a program to remove from the site most of the enriched material requiring restrictions or controls - usually referred to as enriched/restricted material at the FEMP. This program, scheduled to be complete within a few years, would negate the need for an extensive Nuclear Criticality Safety program as is mandated by the DOE Order. However, no exception from the requirements from the Order has been requested by FERMCO or granted by the DOE at this time. The Implementation Plan has been beneficial and constructive by providing the NCS Group with specific direction and definite goals. The specific goals and schedules are given in Table 3.

One of the objectives of the implementation plan was the rewriting and reissuing of the Site Nuclear Safety Requirements Document, FEMP-2117. From this document we were able to prepare a flow chart of what specific regulatory requirements applied to the FEMP and how these requirements flowed to the broad site requirement down to specific implementation project and division procedures. This flow chart is presented in Figures 2a thru 2h.
### Table 2 - Responsibilities Summary Nuclear Criticality Safety

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NCS STAFF IN ESH</th>
<th>LINE MGMT</th>
<th>AEDO</th>
<th>EMERGENCY PLANNING</th>
<th>TRAINING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish NCS Program</td>
<td>L</td>
<td>I</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Procedures (Specific in each Dept.)</td>
<td>L</td>
<td>L</td>
<td>S</td>
<td>LS</td>
<td>L</td>
</tr>
<tr>
<td>Documents NCS in SARs</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td>LI</td>
</tr>
<tr>
<td>CSAs</td>
<td>L</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSOAs</td>
<td>L</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design of New Facilities</td>
<td>L</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schedules Audits and Appraisals</td>
<td>L</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigation of NCS Incidents</td>
<td>L</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drills</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Shipping</td>
<td>SA</td>
<td></td>
<td></td>
<td></td>
<td>LI</td>
</tr>
<tr>
<td>NADs</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDAs</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage and Handling Procedures</td>
<td>S</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCS Limits Posting</td>
<td>L</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspections</td>
<td>L</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE KEY**

- **L** = Lead Responsibility
- **S** = Supports the Program
- **A** = Approves the Program
- **I** = Implements the Program
- **R** = Requirement
FIGURE 2a

10 CFR 830.360

DOE ORDERS

DOE Order 5480.11
Radiation Protection for Operational Workers

DOE Order 5480.20
Personal Selection, Qualification, Training and Safety Requirements at DOE Reactor & Non-Reactor Nuc. Facilities

DOE Order 5480.23
Nuclear Safety Analysis Reports

DOE Order 5480.24
Nuclear Criticality Safety

DOE Order 5480.3
Safety Requirements for the Packaging and Transportation of Hazardous Materials, Substances & Wastes

DOE Order 5480.5
Safety of Nuclear Facilities

DOE Order 5000.3A
Occurrence Reporting and Processing of Operation Information

ANSI Standards Mandatory & Non-Mandatory

DOE Guidelines

SR-2117
Nuclear Criticality Safety Requirements
FIGURE 2b
FIGURE 2c

Non-Mandatory ANSI Standards

- ANSI 8.6 Subcritical Neutron Measurement In-situ
- ANSI 8.10 Criteria for NCS Controls in Operation with Shielding and Confinement
- ANSI 8.17 Criticality Safety Criteria for the Handling Storage and Transportation of CNR Fuel outside Reactors
- ANSI N13.3 Dosimetry for Criticality Accidents
- ANSI 8.9 Nuclear Criticality Criteria for Steel Pipe Intersection containing Aqueous Solutions of Fissile Material
- ANSI 8.12 Nuclear Criticality Control and Safety of Pu-U mixtures outside Reactors
- ANSI 8.20 NCS Training
FIGURE 2d
Operations

SOP-20-C-904
General Nuclear Safety Requirements

Moving/Handling Material

SOP-20-C-100
Moving and Storing Depleted, Normal, Enriched Uranium Materials <20%, and Thorium metals and Material

Guidance Specified in SOP-20-C-904. Specific Limits given in FMP-2112

Storage Limits

SOP-20-C-801
Storage of Enriched Material

In SOP-20-C-904 also in FMP-2112

Unknown Material

Material ID
RM-005
Temp Lot Marking and Color Coding System

Pyrophoric Material

Overpacking SOP-20-C-600

Spills SOP-20-C-601

SOP-20-C-910
Venting Potentially Explosive Drums

Safety Requirements

Spills SOP-20-C-600

SOP-20-C-600
Hazardous Material Spill Cleanup

SOP-20-C-620
Receipt Inspection, Storage, and Storage Inspection of Hazardous Waste

Vacuum Cleaners

SOP-20-C-602
Controlling Portable Ventilation Devices and Vacuum Cleaners

Hazardous Waste

FIGURE 2e
Radiation Detection Systems

PCN-SP-32-0002-11-01
rev. 1
Exchange of NMC Model
GA-6-Radiation Detection
Alarm Units

SP-P-32-007
rev. 3
Calibration of GA-6-
Radiation Detection
Alarms units

Operation of RDA
Central Computer Console

PCN-SP-P-32-003-01
rev. 0
Inspection and Service
of RDAs

ESH-P-32-008
rev. 0
Testing of RDA exit
lights and horns

FIGURE 2g
FIGURE 2h

Emergency Procedures

Emergency Response

ID-P-RTP-001
Nuclear Criticality Accident Response

SSOP-0088
Building Emergency Evaluation Response Procedure
Table 3 - Schedule

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>DUE DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue NCS Site Requirement Document to replace FMPC-2117.</td>
<td>03/30/93</td>
</tr>
<tr>
<td>Remove excess enriched material from laboratory and issue procedure for controlling future reintroduction.</td>
<td>03/30/93</td>
</tr>
<tr>
<td>Implement new Supervisor’s NCS training course.</td>
<td>03/30/93</td>
</tr>
<tr>
<td>Review adequacy of locations of Criticality Alarm System detectors and prepare storage area maps.</td>
<td>06/30/93</td>
</tr>
<tr>
<td>Issue CSAs for all enriched/restricted storage areas.</td>
<td>06/30/93</td>
</tr>
<tr>
<td>Complete Compliance Assessment of DOE Order 5480.24 and specified ANS Standards.</td>
<td>09/30/93</td>
</tr>
<tr>
<td>Establish an internal review system for the NCS Program.</td>
<td>09/30/93</td>
</tr>
<tr>
<td>Establish NCS Committee</td>
<td>09/30/93</td>
</tr>
</tbody>
</table>

**Nuclear Materials At The FEMP**

Although there is no longer uranium production at the FEMP, there are still three categories of material present which require a Nuclear Criticality Safety program. The three categories are:

1. Enriched/restricted uranium in storage.
2. Enriched but unrestricted uranium in storage.
3. Enriched uranium present as holdup in equipment.

Enriched/restricted material is enriched uranium-bearing material whose enrichment and concentration requires a Nuclear Criticality Safety Control. Enriched/unrestricted material is enriched material whose enrichment and concentration will allow it to be stored in unlimited quantities.

The enrichment of the material ranges up to 20% U-235 with the majority of the material having an enrichment under 2.0%. The enriched uranium is in the form of compounds, such as UO3, U3O8, and UF4; and uranium metal in the form of billets, ingots, derbies, and scrap. There is also a quantity of uranyl nitrate (UNH) awaiting processing at the site.

Two key issues for determining a criticality safe system is the determination of the form, composition and quantity of this material. The form and composition of the material is largely based on analytical data and process knowledge of the system. The quantity of the material is determined by a sampling and weighing program. The enrichment, form, and composition of material can be easily identified by a 10-digit lot marking and color coding system which is placed on all containers, skids, or equipment at the Fernald site.
Safe Shutdown Removal Program

The major element in the eventual decommissioning of the site is the Safe Shutdown Removal Program. When fully implemented, this program will inspect all shut down equipment, determine its inventory, and provide for its decontamination and eventual disposal. This activity will generate restricted material for packaging and shipment to a disposal site. The generation of nuclear materials associated with the Safe Shutdown Program is expected to continue through 1997. Much of the resources of the Nuclear Criticality Safety Staff will be devoted to these programs over the next few years.

The Safe Shutdown Removal Program was established to provide planning, engineering, and program control for the proper disposition of all uranium products and in-process residue materials, excess supplies, chemicals, and associated process equipment. The program will assure the proper characterization, emptying, and deenergizing of all existing, previously-operated production-related equipment.

This program is very structured in that for every item of work to be performed as a part of this effort a work package is produced by the program team members. These work packages will include all requirements such as applicable training, equipment and procedures that will be in place for the duration of that particular campaign. Prior to the approval and implementation of each package the Nuclear Criticality Safety personnel will review it and ensure that all necessary NCS controls and restrictions are in place.

Nuclear Criticality Safety Issues And Concerns At The FEMP

The probability of a criticality accident at the FEMP is very low, but not inconceivable. There are areas which are criticality concerns and require Nuclear Criticality Safety Controls. One of these areas is the Decontamination and Decommissioning Building, in which large machinery and structural components resulting from the Safe Shutdown Removal Program will be cleaned. Of particular concern is the possible wash down of enriched material to the building sump during the decontamination process.

Another nuclear criticality safety concern is the UNH Processing Facility. Some of the uranium is in a liquid form enriched to 1.3%. In this state it is subcritical, but should it precipitate out of solution, it could become a criticality concern. Calculations are under way to study this concern.

As discussed earlier, the focus of the FEMP is environmental restoration, and as a part of the Safe Shutdown Removal Program, the site is planning to sell excess uranium product from former production. The material to be sold is depleted, 0.95% and 1.25% enriched metals, both scrap and ingots; and 0.95% and 1.25% enriched compounds. The sale of the uranium would result in the cost effective removal and disposition of material that is excess to the Federal Government's needs, and would generate revenues for the United States Treasury, while providing a beneficial product to the commercial nuclear sector. Calculations are presently under way to support the Environmental Assessment (EA), and the Safety Analysis Report for Packaging (SARP) for the proposed shipping containers.
Conclusions

The mission of the FEMP is the safe, least cost, earliest, final cleanup of the Fernald Site within applicable DOE orders, regulations, and commitments, and in a manner which addresses stakeholder concerns. The NCS group at FERMCO supports this mission wholeheartedly and has endeavored to create a team approach to NCS concerns which includes both operations and other safety personnel.

While the NCS Group at the FEMP is small, and relatively isolated from the rest of the NCS Community, the program at the FEMP has been well thought out, is well managed, and the personnel maintain a presence with the rest of the community through seminars, courses, and American Nuclear Society meetings. The FEMP NCS Group is working at the forefront of the profession, and is presently addressing environmental restoration problems which other sites will be addressing in the future.

References

1. DOE Order 5480.24, "Nuclear Criticality Safety", August 12, 1992
