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# Sealing of Process Valves for the HEU Downblending Verification Experiment at Portsmouth

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At the Portsmouth Gaseous Diffusion Plant in Piketon, Ohio, USA, excess inventory of highly-enriched uranium (HEU) from U.S. defense programs is being diluted to low-enriched uranium (LEU) for commercial use. The conversion is subject to a "Verification Experiment" overseen by the International Atomic Energy Agency (IAEA). The Verification Experiment is making use of monitoring technologies developed and installed by several DOE laboratories. One of the measures is a system for sealing valves in the process piping, which secures the path followed by uranium hexafluoride gas ($UF_6$) from cylinders at the feed stations to the "blend point," where the HEU is diluted with LEU.

The Authenticated Item Monitoring System (AIMS) was the alternative proposed by Sandia National Laboratories that was selected by the IAEA. Approximately 30 valves were sealed by the IAEA using AIMS fiber-optic seals (AFOS). The seals employ single-core plastic fiber rated to 125°C to withstand the high-temperature conditions of the heated piping enclosures at Portsmouth. Each AFOS broadcasts authenticated seal status and state-of-health messages via a tamper-protected radio-frequency transmitter mounted outside of the heated enclosure. The messages are received by two collection stations, operated redundantly.

## INTRODUCTION

In the downblending of highly-enriched uranium (HEU) at the Portsmouth Gaseous Diffusion Plant (PORTS), gaseous uranium hexafluoride ($UF_6$) flows from feed stations to a blend point, where it meets a stream of low-enriched uranium (LEU) and is diluted to LEU. The overall approach to verify this conversion of HEU to LEU is presented in a separate paper.[1] Sealing process valves is just one of several measures required in the effort. It is required because the HEU feed stations and blend point are far apart, separated by complex piping that is mostly out of sight, with several branching possibilities.

### *Valves*

Valves in the complex maze of piping define the flow path between the feed stations and the blend point; a path potentially more than 400 m long. To fix this flow path, (closed) "boundary" valves, which could be used to divert HEU to destinations other than the blend point, are sealed. "In-line" valves, which control whether or not this flow path is actually open, are not sealed.

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The valves to be sealed are of several different types and sizes, but are all manually operated. Most are located behind insulating enclosure panels that keep the pipes heated to as much as +90°C. In many cases, the hand wheel for operating the valve is affixed to an extension handle ("lazy rod"), which is in turn connected to the valve shaft.

### *Criteria*

A method to seal the valves has to meet several criteria:

*Tamper indication:* The seal must indicate any change in valve position, or tampering with the seal itself. At least one full turn of the valve shaft would be required to open a closed valve enough to create a leak. Because it is possible to disconnect a valve from an extension handle and operate the valve directly, a seal must be applied to the valve itself, not just its extension handle.

*Verification:* Because the heated-enclosure panels are so difficult to remove, a seal must be able to be verified from outside an enclosure. Seal integrity would be verified by the IAEA during each short-notice random inspection.

*Environmental conditions:* Any part of the seal within a heated enclosure must function continuously at temperatures to 90°C (194°F). The radiation level is low, so no criterion is required for hardness to radiation exposure.

*Duration:* A seal should be effective for at least one year without replacement.

*Facility impact:* Any modifications to the facility required to install the seals should be minimal. Seals should not interfere with, nor be disturbed by, normal facility operations.

*Other:* The seals should be reliable, require no major development, and be low cost.

## APPROACH

Use of a fiber-optic loop seal is the preferred method, because an optical fiber is inherently able to be verified from outside the heated enclosure. A metal-wire seal, by contrast, must be inspected visually along its entire length, which requires that enclosure panels be removed.

### *System Description*

*AIMS:* The Authenticated Item Monitoring System (AIMS) comprises multiple sensor types, including fiber-optic loop seals, microwave motion sensors, infrared sensors, smoke detectors, door switches, and others. Sensors are battery-operated, so they can be placed wherever needed. Various "events" are reported remotely via radio frequency (RF) transmission at 900 MHz for central logging of events from all sensors in the system. State-of-health messages assure

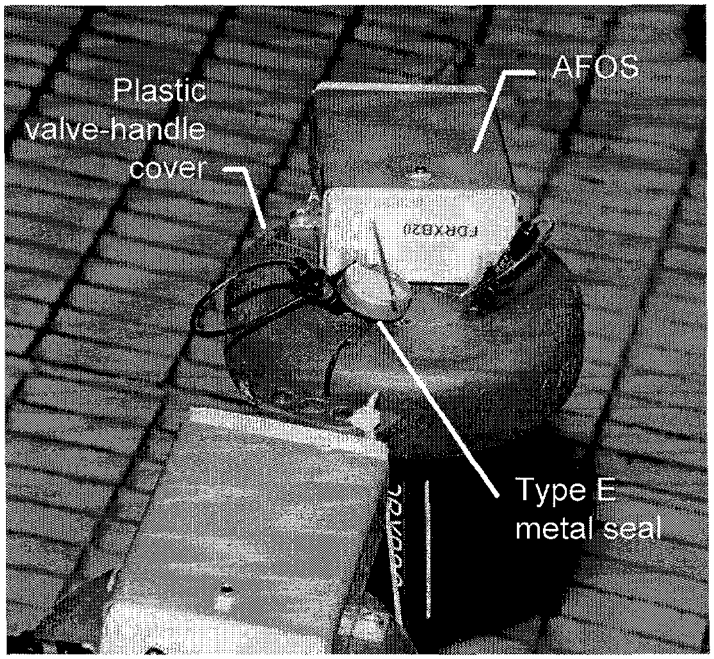

**Figure 1.** AFOS mounted to a plastic valve-handle cover atop a valve handle extension. Cap of type E metal seal is also visible. PORTS photo #98-048-19.

that each sensor is active and functioning properly. All messages are authenticated between the sensor and the data collection station, which assures us that the data originate from the expected sensor and have not been altered or counterfeited.

*AFOS:* The AIMS Fiber-Optic Seal (AFOS) is the only AIMS sensor type employed in the Portsmouth experiment. Figure 1 shows an example of an AFOS installed on a valve. Incorporating commercial electronics obtained from Inovonics, Inc., the sensor actively interrogates a closed loop of optical fiber once per second with an encoded message (light burst). If this signal is not detected, the sensor reports a "seal open" event; when the signal is detected once again, the sensor reports a "seal closed" event. The sensor has internal counters for these events, and sends the counter values with every transmitted report. The sensor operates on a lithium battery for several years without replacement.

The AFOS electronics are housed in a plastic box, protected by a specially-designed anodized-aluminum sleeve for tamper indication. A single screw that affixes the sleeve to the box also depresses a microswitch. If the microswitch is released, the sensor reports a "case tamper detected" event; when the switch is depressed again, the sensor reports "case tamper removed."

*Optical fiber:* The AFOS is fitted with a plastic optical fiber cable from Mitsubishi Corporation, rated to +125°C. One can easily cut and trim a fiber for connections using a special tool. Optical fiber ends are joined with in-line plastic connectors. Two in-line connectors join the pigtails from the AFOS to a custom-length fiber loop, about 30 cm outside of the AFOS electronics box.

*Repeater:* To extend the effective transmission range, a repeater receives RF messages from the AFOS units and promptly re-transmits them.

*Receiver and Receiver Processing Unit (RPU):* An AIMS receiver detects the RF transmissions and relays the messages via cable to an attached "Receiver Processing Unit" (RPU). (See Figure 2.) It is not necessary to protect the connecting cable, because the messages are authenticated. The RPU decodes, checks the authentication, and logs each message in a Random Access Memory (RAM). The RAM is maintained indefinitely by battery backup. The RAM capacity of 10,000 events is far greater than the system activity we anticipated at Portsmouth.

As shown in Figure 2, the RPU case is itself sealed with an AFOS between inspections.

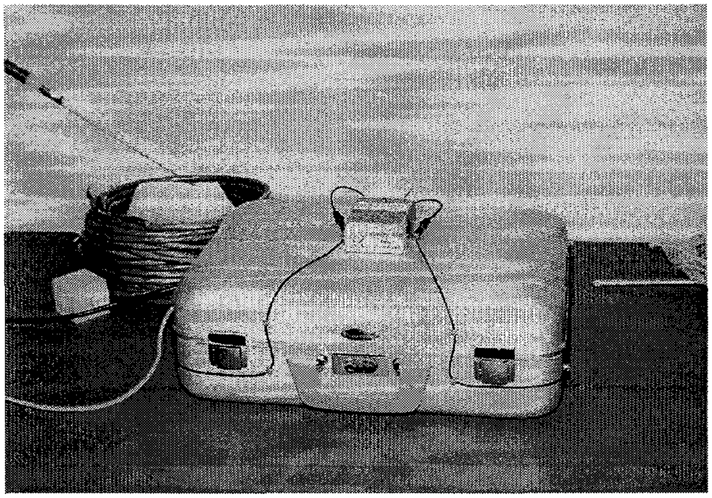

**Figure 2.** Primary RPU closed and sealed with AFOS. PORTS photo #98-038-06.

*Computer:* An inspector retrieves the collected data by opening the RPU, connecting the RPU to a laptop computer with a serial cable, and transferring the RPU "event history" to the computer. The data retrieved from the RPU are formatted as an ASCII text file, easily analyzed with a variety of commercial software tools. In particular, by importing the file into a spreadsheet, one can readily analyze even large numbers of events.

### Installation at PORTS

Figure 3 shows schematically how an AFOS optical-fiber loop seals a valve. To provide a uniform method for mounting the AFOS units, we attach each AFOS unit with sheet metal screws to a plastic valve-handle cover (those typically used for "lock-out/tag-out" applications). The optical fiber passes through holes drilled in the plastic cover, sleeved holes in the heated enclosure panel, and holes in the base plate of the extension handle. Minor loops keep the two halves of the valve cover together, and secure the extension handle to the valve. To fix the valve from turning, the loop encircles the $UF_6$ pipe. Approximately one-half turn of the valve shaft would be enough to break the optical fiber.

IAEA inspectors sealed each valve individually, with only one valve per AFOS loop. Type E metal wire seals were applied as a backup measure. (See Figure 1.) The wire seal follows the same path as the optical-fiber loop.

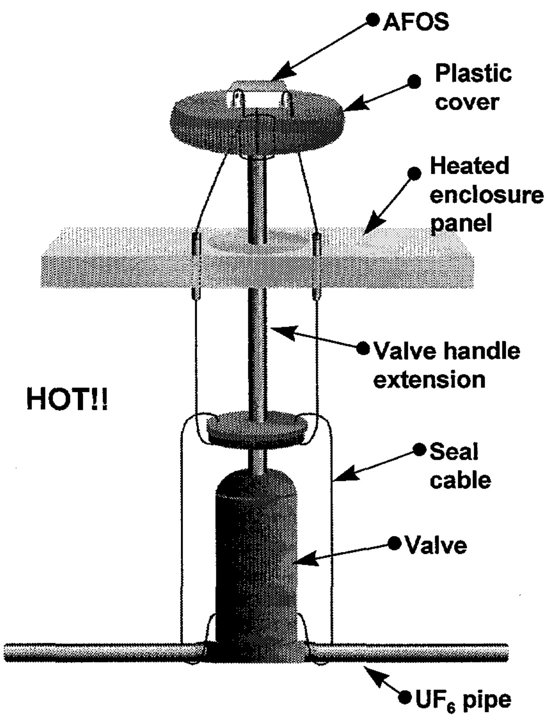

**Figure 3.** Routing of optical fiber to seal a process valve.

Figure 4 depicts the layout of AIMS at Portsmouth. For redundancy, the system has two RPUs, placed at opposite ends of the deployment area. A laptop computer stored inside the RPU case is used to retrieve the event history onto 1.44MB diskette. To ensure that messages from all AFOS are recorded by both RPUs, the system includes two repeaters in the middle of the area.

There are 38 AFOS units in all: 30 seals are applied to valves, 2 seal the RPUs, and 6 are spares. An active spare is self-protecting, and can easily be substituted if an assigned AFOS malfunctions.

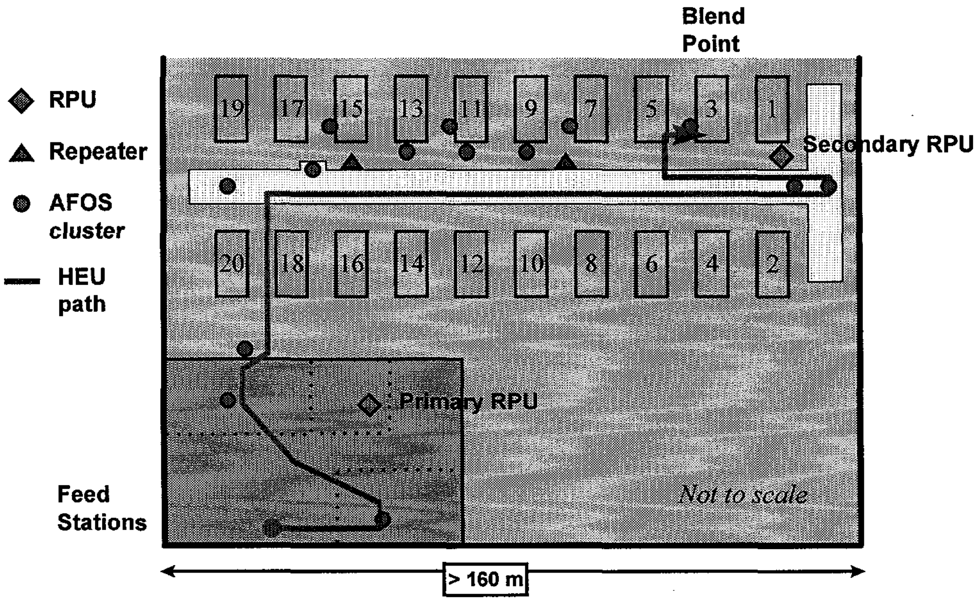

**Figure 4.** AIMS components deployed at Portsmouth, shown in relation to the HEU flow path; the LEU flow path is not shown. Shading identifies different relative elevations within the 26m-high building (darker = lower). Each "cluster" may represent from 1 to 5 AFOS.

### *Coordination with other aspects of the verification experiment*

The valve seals by themselves are not sufficient to know what happens in the piping. The following questions remain:

1) *Are the boundary valves closed?*
2) *Have we sealed the correct valves?*
3) *Are there any other paths not sealed?*
4) *Is the flow path actually open?*

To verify that all boundary valves are closed, the piping is alternately evacuated and pressurized. Moreover, by measuring the resultant pressure after a known quantity of gas is admitted into the evacuated pipes, it is possible to infer a piping volume. The measured volume can then be checked against the volume calculated from declared design drawings. This so-called "pressure-vacuum-volume check" is supplemented by random visual inspections of the piping. Taken together, these measures give us confidence that the correct valves have been sealed. Pressurizing the pipe and then opening the in-line valve closest to the blend point confirms the flow path, and shows that there is no obstruction between this last valve and the blend point. To check that HEU is flowing in the pipe requires non-destructive analysis (NDA) of uranium enrichment.[2]

## RESULTS

The AIMS was relatively easy to set up and operate. RF communication was reliable; we observed no interferences either to the AIMS or by the AIMS. Redundant RPUs worked well; both event logs were identical to within the time accuracy of the system (±4 s). Repeaters appeared not to be essential, despite appreciable transmission distances. We tested the system with both repeaters turned off, and observed that signals from all AFOS locations were received by both RPUs.

Overall, the valve seals functioned well. The AIMS event history identified a seal where the optical fiber had been accidentally severed when panels to a heated enclosure were replaced. The break in the fiber was only obvious once the panels were removed.

The AFOS experienced at least two unexpected, adverse environmental conditions. A few units were exposed to leaking rainwater, and another few were "cooked" during installation when they were accidentally covered by blankets, placed temporarily over openings in the heated enclosures. All of these sensors continued to operate and survived.

The AFOS reported some false alarms, however. In one case, a section of the optical fiber, apparently of poor quality, degraded to the point where it appeared to be in a "seal open" condition. The manufacturer confirmed that occasionally bad sections had been seen in production before. In a second case, an improperly-installed connector eventually resulted in a "seal open" condition. And in another case, the set screw securing the tamper-indicating sleeve to an AFOS had not been adequately seated, and eventually deteriorated into oscillating "case-tamper" messages. The latter AFOS eventually had to be replaced with a spare unit.

In each case above, the sensor output oscillated every few seconds between two states: Seal Open/Seal Closed or Case Tamper Detected/Case Tamper Removed. (Such a repeating string of oscillating-state messages has not been observed in previous AIMS installations.) This problem twice overloaded the storage capacity of the RPU event history so that no further event data could be recorded, thus interrupting the continuity-of-knowledge of containment on the downblending system. We corrected the problem with a software "circuit breaker." The circuit breaker causes the RPU to ignore specific events from a particular sensor after some threshold (e.g., 500 events) is reached. (It suffices to know that a seal opened at all, let alone how many times it had opened.) The fix worked well in testing; however, no further oscillating events have happened at Portsmouth since the circuit breaker was installed.

## DISCUSSION

Applying the loop seals to the valves was a difficult operation, complicated by the harsh environment within the heated piping enclosures.

AIMS greatly simplified the procedure for verifying valve seals during a SNRI. Event data from all seals were retrieved quickly in a single visit to a central data-collection station. After reviewing the events, the inspector was well prepared to conduct a visual inspection of the seals, knowing where there may or may not be problems.

AIMS is based on commercial technology, but some components are no longer available. Some re-design would be required to adapt AIMS to currently-available components.

This field experience suggests various improvements to AIMS. Although we protected the *system* from being vulnerable to isolated instances of event-history overload, further modifications would be advisable to correct the problem at its source, i.e., the sensor. A better design for detecting case-tamper events for the AFOS units would alleviate false alarms and be easier to set up. An easy-to-install fiber-optic connector less prone to a fiber slipping loose, would also be desirable.

Remote monitoring is feasible for AIMS, but was not required for Portsmouth. With remote monitoring, the event-history overflow problem might have been spotted sooner. A telephone call to the plant, requesting that the one offending seal be disabled, would have sufficed. Without remote monitoring, responding to events depends on the frequency of site visits by inspectors.

## CONCLUSIONS

The AIMS fiber-optic seals have functioned successfully. Seal integrity has been easy to verify. Integrating the valve seals into a system via radio-frequency communication worked well. The central data collection has advantages, but measures must be in place to provide system redundancy and protect the system from being vulnerable to failures propagated from a single sensor.

## ACKNOWLEDGMENTS

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[1] D. M. Gordon, et al, "IAEA Verification Experiment at the Portsmouth Gaseous Diffusion Plant," INMM 39th Annual Meeting, July 1998.

[2] P. L. Kerr, et al, "Piping NDA Monitor for the Portsmouth Gaseous Diffusion Plant," INMM 39th Annual Meeting, July 1998.