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Feasibility Study for the Development of a Test Bed Program for Novel Detectors and Detector Materials at SRS H-Canyon Separations Facility

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Abstract

Researchers at the Savannah River National Laboratory (SRNL) have proposed that a test bed for advanced detectors be established at the H-Canyon separations facility located on the DOE Savannah River Site. The purpose of the proposed test bed will be to demonstrate the capabilities of emerging technologies for national and international safeguards applications in an operational environment, and to assess the ability of proven technologies to fill any existing gaps. The need for such a test bed has been expressed in the National Nuclear Security Administration's (NNSA) Next Generation Safeguards Initiative (NGSI) program plan and would serve as a means to facilitate transfer of safeguards technologies from the laboratory to an operational environment. New detectors and detector materials open the possibility of operating in a more efficient and cost effective manner, thereby strengthening national and international safeguards objectives. In particular, such detectors could serve the DOE and IAEA in improving timeliness of detection, minimizing uncertainty and improving confidence in results. SRNL's concept for the H Canyon test bed program would eventually open the facility to other DOE National Laboratories and establish a program for testing national and international safeguards related equipment. The initial phase of the test bed program is to conduct a comprehensive feasibility study to determine the benefits and challenges associated with establishing such a test bed. The feasibility study will address issues related to the planning, execution, and operation of the test bed program. Results from the feasibility study will be summarized and discussed in this paper.

Introduction

The DOE/NNSA has recognized the need for the development and implementation of advanced detectors for safeguards applications. This need is acknowledged through the NNSA's Next Generation Safeguards Initiative (NGSI), where one of the main pillars is technology development. New detectors and detector materials open the possibility of operating in a more efficient and cost effective manner, thereby strengthening national and international safeguards objectives. In particular, such detectors could serve the DOE and IAEA in improving timeliness of detection, minimizing uncertainty and improving confidence in results.

In order to move novel detector technologies for nuclear material from the laboratory into operation, there is a need to find suitable locations to conduct field trials of these devices. As identified in the NGSI program plan, there is a lack of fully operational facilities that allow for full-scale testing of new technologies. H-Canyon on the DOE's Savannah River Site (SRS) has been identified as a possible location for establishing such a test bed. H-Canyon is unique in that it is the nation's only operational nuclear chemical separations plant and offers several areas where full scale testing could be conducted. Combined with the National Laboratory (SRNL), also located on site, the needed expertise for developing, deploying, testing, and evaluating advanced detector technologies is readily available.

SRNL researchers, along with key H Canyon personnel, are currently conducting a comprehensive feasibility study to determine the benefits and challenges associated with establishing such a test bed. The feasibility study is addressing issues related to the planning and execution of the test bed. Specific tasks have included completion of an H Canyon site survey and gap analysis, development of and implementation plan, and estimation of start up and operating costs.

H Canyon Background

H Canyon was constructed in the early 1950's and began operation in 1955. The facility's operations historically recovered uranium-235 (U-235) and neptunium-237 (Np-237) from aluminum-clad enriched-uranium used fuel from site nuclear reactors and other domestic and foreign research reactors using a chemical separations process.

The H Canyon facility is 835 feet long, 122 feet wide and 66 feet tall. It consists of both a warm and hot canyon divided into 18 sections/cells with several areas to accommodate the various stages of material stabilization. Between the canyon processing areas are control rooms to monitor equipment and overall operating processes, equipment and piping gallery for solution transport, and sampling aisles for process monitoring (Figure 1). So that worker exposure is minimized, work in the canyon, including maintenance, is remotely performed by unique overhead bridge cranes. Thick, dense concrete walls separate workers from the actual processing areas, providing added protection.[1,2]

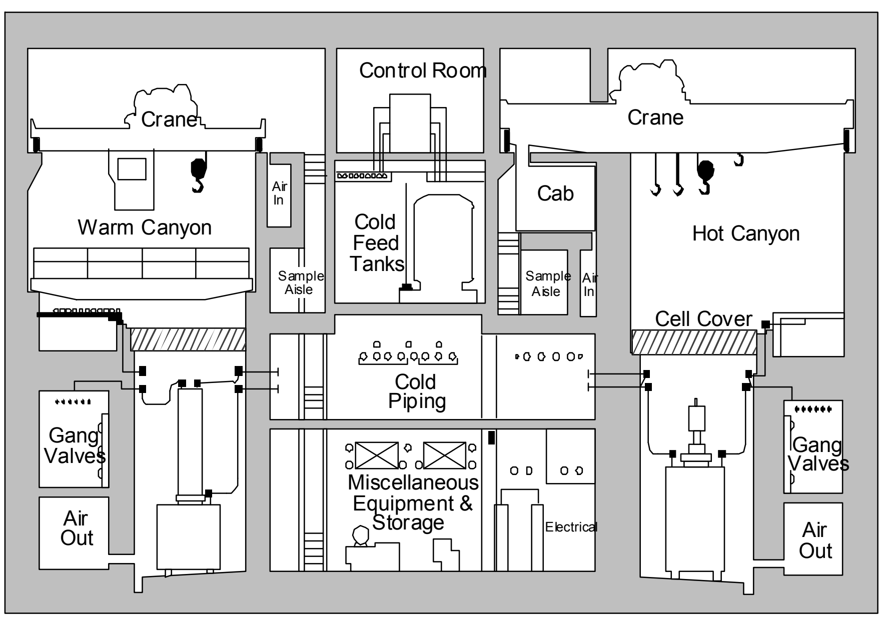

Figure 1. Cross-section of H Canyon.

The canyon process involves several stages (Figure 2). First of these is dissolving, where the fuel being reprocessed is dissolved in boiling nitric acid mixed with a mercuric nitrate catalyst. Multiple fuel assemblies are packaged in a fuel bundle and multiple fuel bundles are dissolved at a time. After cooling and inspection to ensure the fuel bundles have completely dissolved, the solution is transferred to an accountability tank for sampling. The next stage is the Head End process where the solution from the dissolver is purified and clarified. The solution is fed to an evaporator tank in batches where some of the liquid is allowed to evaporate, concentrating the feed stream. From here, the solution goes to a strike tank where it is mixed with gelatin to form a slurry. This slurry is then passed to centrifuges where the gelatin, which now contains silica from the dissolved fuel, is separated leaving a concentrated and clarified feed solution.[3]

The next stage is the solvent extraction process itself. The solvent extraction phase involves mixing the feed solution with either an organic or aqueous solution depending on what needs to be extracted at a particular point. Mixer-settlers are used to carry out these operations. Mixer-settlers flow two streams past each other; one being the feed solution and the other being an aqueous or organic solution depending on what is being removed in that cycle. The two steams mix to some extent as they flow past each other and the desired elements are extracted preferentially into one stream, separating them from the rest of the solution contents. The first cycle extracts uranium and neptunium from the feed solution. This occurs in three multi-stage mixer settler banks. The first extracts uranium and neptunium from plutonium, fission products and other impurities. The next separates the neptunium and uranium and the final stage strips the uranium into a nitric acid solution.[3]

Depending on the desired product from the reprocessing operation, both uranium and neptunium, or plutonium, solutions may be sent to a second cycle for further purification and extraction. The second product cycles involve another series of mixer-settlers that further concentrate and purify the desired elements. The outputs from the second cycle will be pure products. Both high and low activity wastes are generated during the process and each stream has its own cycle for processing and eventual discard as a waste.[3]

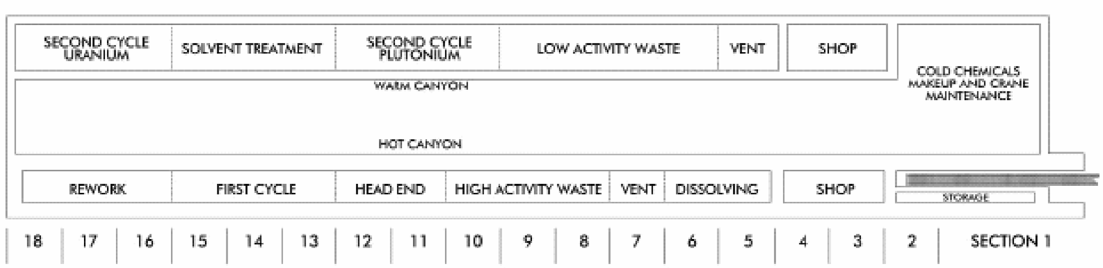

Figure 2. H Canyon processing sections on hot and warm side of canyon.

H Canyon Future Missions and Possible Scenarios for Safeguards Test Bed Program

H-canyon missions have changed overtime, historically being utilized for the Defense program (U/Pu separation). Missions have also supported NASA/military programs for Pu-238 separation for nuclear batteries. More recently, missions managed by DOE-EM have been in support of the clean up of legacy materials and domestic and foreign research and test reactor fuel recycling.

In February 2011, the SRS management company, Savannah River Nuclear Solutions (SRNS), was directed by DOE-EM to develop plans for placing H Canyon in a minimum safe condition by December 2011. However, DOE-EM also requested a list of potential future projects for the facility. In addition, other agencies at DOE are looking for future missions for the H-Canyon. Possible future missions for H Canyon include advanced fuel cycle technologies research development and demonstration, demonstration of commercial light water reactor used/spent fuel processing, proof-of-concept or pilot-scale demonstrations of advanced aqueous separations technologies, purification of Pu-238 to power the NASA Outer Planet Flagship Mission to Jupiter/Europa, and processing of Pu-238 targets and production of Pu-238 oxide.[1]

Future missions will help to preserve and maintain a national asset. The new role of H Canyon can be translated to a multifaceted facility that can accommodate processing, research and development, and test bedding. Under this new role H Canyon would be able provide the support to the proposed test bedding program.

While the future operational missions of H Canyon are still being decided, two possible scenarios for establishing the Safeguards Test Bed Program at the Canyon can be considered. In the first scenario, the Canyon would continue DOE-EM reprocessing missions allowing for instrument testing to be conducted in parallel with H Canyon operations. In the second scenario, H Canyon would still be in a minimum safe condition with the possibility of operating a mock-up cell for safeguards test bed demonstrations. The mock-up area could be established in one section of the canyon with tanks and jumpers (i.e., piping running between tanks and processing vessels) to simulate an operational environment. Dissolved fuel could then be kept in the tanks and transferred through the jumpers for testing purposes. The first scenario described is the preferred scenario since scenario two only simulates an operational environment and would cost considerably more to start up and operate the test bed program.

Site Survey: Areas Indentified for Possible Test Bed Instrumentation

During the process of the H Canyon site survey several areas in the Canyon were identified as possible test bed locations. These areas can be classified by location as, inside the Canyon processing area, inside the H Canyon facility, and outside of the H Canyon facility. For each location identified, detector requirements, installation paths and costs were considered. The requirements, cost associated with equipment installation and ease of installation and operation will vary according to location, as discussed below.

Test Bed Locations Inside Canyon Processing Area

Dissolvers/Processing Tanks and Transfer Lines

Various types of monitors could be installed in and around the dissolving and processing tanks. Appropriate technologies would include devices capable of determining fissile material in the tanks or moving through transfer lines and/or jumpers (i.e., piping), and devices to monitor off-gas from the tanks. Devices could be installed inside dissolver tanks using a probe, in-line between tank jumpers, and across the transfer lines (Figure 3). In-line detectors in these areas capable of determining fissile material content in real time or near real time would result in considerable savings in time and money for canyon operations by eliminating the need for obtaining samples for destructive analysis. Such instrumentation would also improve the safety of operations by reducing personnel dose. In addition, this location and type of detection would be a critical area for safeguards applications. For example, the ability to detect the movement of fissile material across the span of transfer line (Figure 3) in real time could provide information on the possible diversion of special nuclear material (SNM).

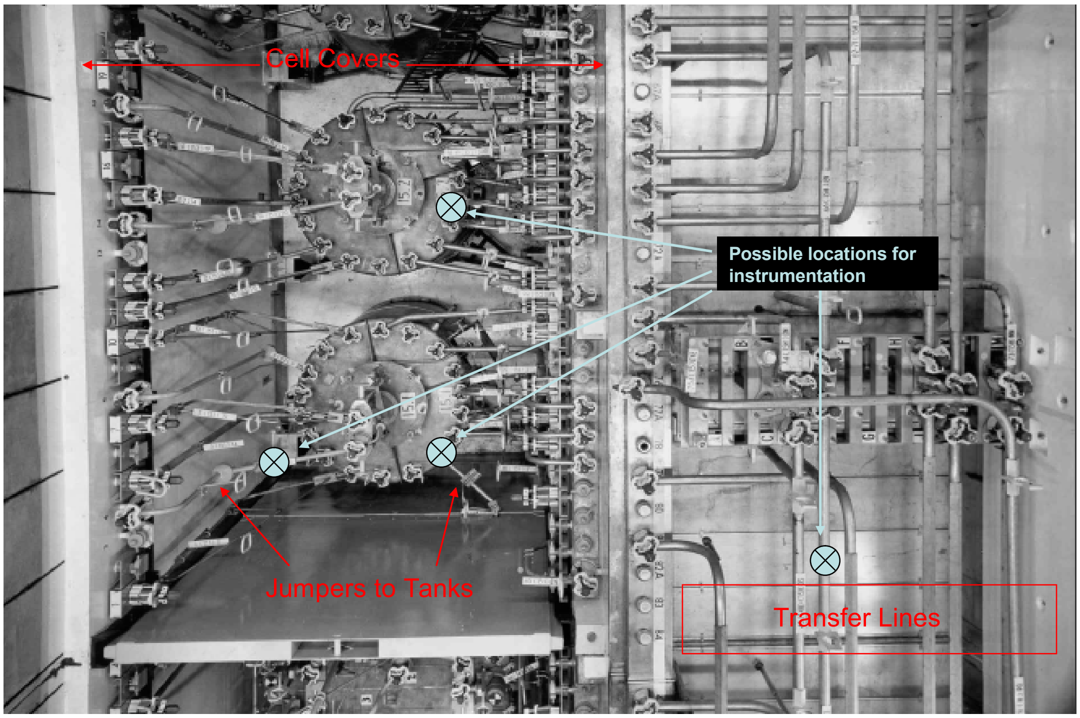

Figure 3. Typical hot canyon cell arrangement showing areas where detector equipment could be installed. Cell covers typically cover area above tanks as marked.

Monitoring of off-gas (i.e., fission gas release; Cs, Rn, Kr, H^3, others) from the dissolving process could also be conducted inside the dissolver tanks, or downstream from the dissolver at the exhaust stack (see below). Hydrogen monitoring in this location is a high priority for H Canyon operations. Tritium detection and/or isolation could also be performed in these locations. These types of detectors could serve as dual purpose, safety of operation and material balance control (safeguards), testing locations.

All instrumentation installed inside of the canyon processing area will require remote installation of all components via the overhead bridge crane. The requirements and cost for each detector technology to be tested will have to be evaluated on an individual basis, however, general requirements can be discussed at this point. Any instrument placed inside the canyon would be exposed to high irradiation fields and would therefore most likely require shielding. In addition, components placed inside the dissolver would be exposed to an acidic environment with high temperatures and would therefore need to be able to withstand such harsh conditions.

Additional equipment size requirements for instrumentation would also apply. Probes place directly into the tanks would be limited by the size of attachment nozzles (maximum of 3 inches), while instruments affixed to jumpers would be limited by the space available under the cell covers. The transfer lines are the only area inside the canyon that is located outside of the cell covers (Figure 3), which would allow for placement of larger equipment.

Mixer-Settler Banks

The mixer-settler banks were identified as a possible area where new detector technologies could be installed and current detection devices in use could be improved upon. Two types of detectors that could be utilized in this location are, in-line monitors to give information on concentration of isotopes in the aqueous and organic phases of separation, and neutron detectors for criticality measurements.

Currently, the Canyon uses modeling software to predict the separation of isotopes in the aqueous and organic phases of the separations process. A device that could give real-time feedback on the actual concentrations of isotopes in the different phases in the mixer-settler banks would allow for more accurate verification and monitoring. Modeling and simulation could also be integrated in the test bed program to better predict operational conditions, and support information driven safeguards.

Neutron detectors are currently used on top of the mixer-settler banks for criticality measurements. These devices are placed inside a specialized jumper running from second level to the top of the mixer-settler banks. The current devices are very sensitive to noise and vibration. A more stable and sensitive neutron detector would be desirable for H Canyon operations. In addition, this location would serve as an ideal location to test alternatives to ^{3}He neutron detectors. Instruments placed in this location would face many of the same requirements and restrictions discussed above for the dissolvers.

Waste Streams

Coming off of the mixer-settler banks are waste and product streams from the solvent extraction process (Figure 4). Currently, there is little monitoring of the waste streams, therefore these streams could serve as another possible testing location inside the Canyon. As shown in Figure 4, the 1AW waste stream is a result of the first separation step in mixer-settler bank A, and the 1BP waste stream is a result of the second separation in mixer-settler bank B. The 1AW waste stream contains Pu, while the 1BP waste stream contains Np. Measurement of the waste streams could be used to prove that all U had been removed in the solvent extraction process. Detector requirements and associated costs for this area would be similar to those discussed above (i.e., size limitations, etc.).

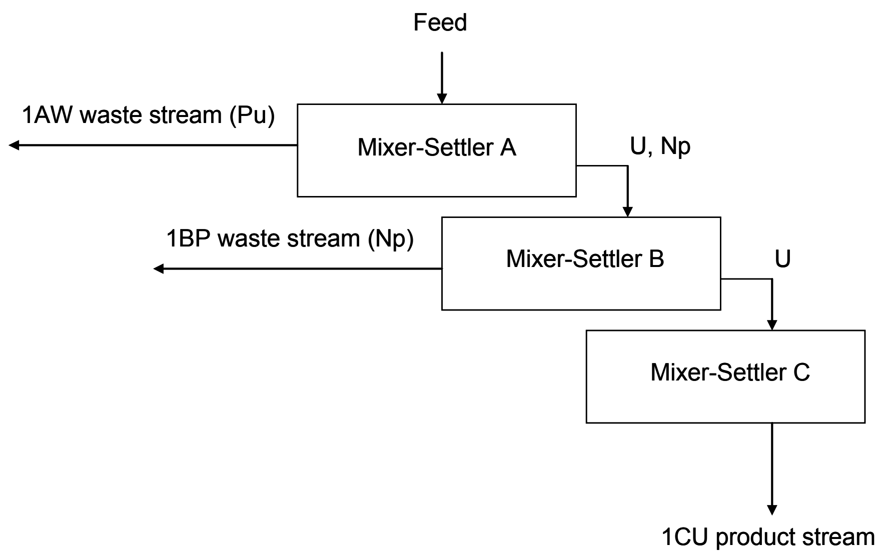

Figure 4. Diagram showing the waste and product streams coming off of the mixer-settler banks during the first uranium cycle.

<u>Test Bed Locations Inside H Canyon Facility</u>

Sampling Aisle

The H Canyon sampling aisle presents an opportunity to perform many of the same measurements for fissile material determination discussed in the section on the dissolvers and processing tanks. Sampling aisles are located on both sides of the canyon with 40 samplers per side. Figure 5 shows a picture on a typical sampler, with the right side image showing this inside of the sampler chamber. Sample solutions are pulled from accountability tanks and deposited in a glass vial. Samples taken are tested in the sampling aisle using spectrophotometry and colorimetry and in analytical laboratories using destructive analysis techniques.

One main advantage to using the sampling aisle as opposed to the tanks and jumpers is that the samplers are located outside of the canyon processing area (Figure 1). Instrumentation could be setup in the sampling aisle or coupled to one of the samplers. The samplers, however, are located in a contamination area and trained workers would be required for instrument installation and operation.

Figure 5. Picture of one of the samplers on the sampling aisle (left), picture of the inside of a sampler (right).

Spent Fuel

Spent fuel is received at the Canyon in casks via a railroad tunnel. This location offers the possibility of measuring the spent fuel in dry storage racks. New racks are currently being designed and before installation they could possibly be equipped with instrumentation for verification measurements. Another possibility would be to use a procedure currently used by Radcon, which involves hanging a detector from a crane hook.

<u>Test Bed Locations Outside H Canyon Facility</u>

Exhaust Stack

Monitoring of hydrogen off-gas and tritium detection/isolation from the dissolvers was mentioned in a previous section for test bed locations inside the canyon. However, because the dissolver has a direct route to the exhaust stack and is kept separate from the rest of the operations, it is possible to monitor off-gas downstream. Performing these measurements downstream could be beneficial from a cost savings perspective since the ease of installation and operation would be greatly simplified.

HEU-LEU Blend-Down Tanks

The HEU-LEU blend-down tanks were identified as a possible test bed location. The blend-down tanks are located outside of the H Canyon facility and could conceivably be one of the easiest places to set up equipment. Figure 6 shows a photograph of the enriched uranium storage tank; one of the several tanks used in the blend-down process. This area is also a desirable test bed location from a safeguards perspective. However, the current mission for HEU to LEU blend-down has been completed and it is not clear at this time whether this process area will be utilized in future missions.

Figure 6. Enriched uranium storage tank located outside of H Canyon facility.

<u>H Canyon Mock-up Facility</u>

A mock-up of the H Canyon facility is located in F area on SRS. Connected to the mock-up facility is the machine shop where the jumpers for H Canyon are fabricated. Jumpers are tested in the mock-up facility prior to installation to ensure that the components fit properly. We envision using this facility in the Safeguards Test Bed Program to test instrumentation prior to installation in the canyon locations. This will be necessary to ensure that detector components will fit properly and are in working order before entering any contaminated area, since it is unlikely that instruments will be retrievable after entering these areas.

Future Tasks

The next phase in the H Canyon feasibility study is to develop a plan for program implementation. This task is currently underway and involves developing a roadmap for bringing in users and installing devices, working through safety and security requirements, and determining training requirements. During this task logistical issues related to equipment operation and stations for instrument readout will also be addressed, as well as user responsibilities. Associated costs with each element of the implementation process will also be estimated.

Following the development of the implementation plan, a plan for opening the test bed to users will be developed. This will involve establishing how users will be notified and chosen for test bed participation, how many users will be allowed in the program per quarter/year, and how the test bed will be scheduled and operated. This will be followed by producing a detailed cost estimate document for program start up and operation.

Acknowledgements

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