DECOMMISSIONING RESULTS AND LESSONS LEARNED AT THE UNIVERSITY OF VIRGINIA REACTOR FACILITY

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ABSTRACT

The University of Virginia Reactor Facility has completed the accelerated decommissioning that started in 2002. The facility consisted of two licensed reactors, the CAVALIER (Cooperatively Assembled Virginia Low Intensity Educational Reactor) and the UVAR (University of Virginia Reactor). The Decommissioning Plan actions and the Final Status Surveys necessary for unrestricted release of the facility are complete. Lessons learned relative to ALARA, field performance and personnel safety are described.

The CAVALIER began operation in October 1974 at a maximum power of 100 Watts. Before shutdown in 1988, the CAVALIER was operated for 3577 Watt-hours. The reactor fuel was removed in March 1988. The University submitted to the NRC, a dismantling plan in 1988 and a decommissioning plan in February 1990. In February 1992, the NRC Order authorizing the decommissioning of the CAVALIER was issued.

The UVAR operated at 1 MWt maximum power from June 1960 to January 1971. For the next 17 years the maximum power was 2 MWt. It was permanently shut down on July 1, 1998, with a 27 year operating history of 2559 MW-days. By February 2000, the fuel had been returned to the Department of Energy and a “possession-only” license issued. The decommissioning plan was submitted in February 2000. Late in 2001, a decommissioning and waste disposal contract was signed between the University of Virginia and CH2M HILL Constructors, Inc. In March 2002, the NRC issued a license amendment that approved the decommissioning of the UVAR Facility. The project team mobilized to the reactor site starting April 2, 2002.

In the next four months, the project team performed decommissioning actions that did not impact the higher activity items in the reactor pool. Preparation for the underwater segmentation and packaging of the reactor activated components in the reactor pool occurred. Investigation, disassembly, and screening for unrestricted release of 8,000 concrete blocks from shield walls and block houses was performed. The CAVALIER Decommissioning was completed by early July. The 21,000 pound mechanical draft cooling tower was removed from the roof for disassembly. The cooling tower contained asbestos containing structural materials, gaskets and "honeycomb" fill material along with redwood and structural steel.

During August the reactor activated components were removed from the reactor pool. The component segmentation process began with the placement of a cask liner in the reactor pool. Segmentation was performed underwater by divers using plasma arc cutting equipment. The liner was loaded underwater , the higher activity items were preferentially loaded nearest the center of the cask and the lower activity materiel loaded in the liner annulus to provide shielding. A CNS 8-120B shipping cask was used to ship the activated components to the Barnwell disposal site for arrival before the Labor Day weekend.

The removal of the pool components allowed the completion of characterization of the reactor room. Pond sediment characterization was performed. After site hydrology studies were completed, the pool was drained, and "hot particle" surveys performed. No hot particles were located. The reactor pool was decontaminated and the activated beam port liners removed. Characterization of the pool interior surfaces, soils under the pool floor and backfill behind the pool walls was performed. The reactor coolant heat exchanger and water treatment systems was removed. Extensive floor drain and buried piping work was performed. Independently, soils were characterized to determine the magnitude of soil remediation necessary when the underground radioactive storage tanks were removed in January 2003. Details of these and subsequent activities will be presented along with some of the lessons learned applicable to future decommissioning activities.

INTRODUCTION

The CAVALIER (Cooperatively Assembled Virginia Low Intensity Educational Reactor) began operation in October 1974 at a maximum power of 100 Watts. During the next fifteen years, the CAVALIER was operated for 3577 Watt-hours. In January 1988, operations ceased and the reactor fuel was removed in March 1988. The University submitted a dismantling plan in 1988 and a decommissioning plan [1] in February 1990. In February 1992, the NRC issued the Order [2] authorizing the decommissioning of the CAVALIER.

The UVAR (University of Virginia Reactor) first operated at 1 MWt in June 1960. In January 1971 licensed power was raised to 2 MWt. After 38 years of operations, estimated to be 2559 MW-days, it was permanently shut down on July 1, 1998. By February 2000, the fuel had been returned to the Department of Energy and the reactor license was amended to a possession only license. The University submitted a decommissioning plan in February 2000. In September 2001, a decommissioning and waste disposal contract was signed between the University of Virginia (UVA) and CH2M HILL Constructors, Inc. In March 2002, the NRC issued Amendment 26 [3] to the UVAR license that approved the decommissioning of the UVAR Facility. The project team mobilized to the reactor site starting April 2, 2002. This paper provides a summary of the site decommissioning activities performed and highlights the lessons-learned that had major impacts on the project performance.

The University of Virginia has completed the decommissioning of the University of Virginia Research Reactor (License R-66). The residual radioactivity remaining results in a total effective dose equivalent that does not exceed the 25 mrem per year site release limit. The approved (License amendment 26, March 26, 2002) Decommissioning Plan was implemented essentially as written. Proposed changes and clarifications were evaluated and approved by the Reactor Decommissioning committee. One proposed change required approval from the NRC. There are two observable changes: the Reactor Room Ventilation system was left in place, after continuing characterization surveys indicated that the free release DCGL's were met and the system did not need to be removed as radioactive waste; and the Co-60 source is still stored at the facility.

The decommissioning was controlled through the use of project plans that invoked the controls necessary to implement the Decommissioning Plan. For instance, the training of personnel commensurate with their tasks, use of Radiation Work Permits, ALARA, radiological protection, general site training, respiratory protection training and use, approved supplier list, quality assurance audits, stop work authority, procedural controls, document production and approval, instrument calibration and controls, sampling and chain-of-custody protocols, record production and retention were all controlled through the project plan control system. This allowed the physical work to be performed safely under a consistent set of management and worker expectations.

Decommissioning Plan field work started with mobilization to the facility in April 2002 of CH2M HILL Constructors, Inc. (CH2M). Subcontractors Safety and Ecology Corporation (SEC) and Bartlett Services, Inc. (Bartlett) quickly followed. WMG and Underwater Construction Company mobilized in August for pool component removal. The project also was supported by Penhall Corporation (Concrete cutting), Parham Construction Co. (Heavy crane operation and earth moving), and NLB Corporation (Water jet cutting). The physical work was completed and Bartlett demobilized on May 30, 2003. SEC remained on-site to perform the Final Status Survey and demobilized on August 15, 2003.

Field Activities

Characterization that had not been completed at the time of the plan approval was performed. The results of the continuing characterization and in-process surveys of the UVAR facility, which consisted of a three level building attached to a three story reactor pool embedded into the hillside, were:

- The 102,000 square feet of facility external to the building was screened and 2500 square feet found to be radiological contaminated above the release limits;
- The 22,000 square feet of building interior contained 11,346 square feet of as-found free release area and 10564 square feet of as-found radiological contaminated above the release limits;
- No structural demolition of the building was required or performed since the facility was expected to be refurbished as engineering offices and laboratories after decommissioning.

All items or areas above the release limits were either decontaminated to levels below the release limits or were physically removed and processed as radioactive waste. As waste minimization on a cost-effective basis was implemented, some radioactive items were physically transferred to other licensed research reactors for their use.

Waste and Material Removals

Ten radioactive waste shipments were made. The ninth waste shipment to Envirocare was made on May 29, 2003. One shipment was made to Barnwell, S.C. in August 2002. These ten shipments comprise 270,127-lbs of waste shipped for disposal (260,832-lbs to Envirocare and 9295-lbs to Barnwell). Six 55-gallon drums containing 3511 pounds of radioactively contaminated soils and asphalt, manifested for disposal at Envirocare, are staged at UVA for shipment as part of a future UVA shipment.
Over 1,000,000 pounds of soil was screened and reused on site. Another 331,271 pounds of materials were surveyed and released for re-use, recycle, surplus sales or disposal as sanitary waste(chiefly as construction rubble).

Safety & ALARA

Over 36,000 man-hours were worked with zero lost-time injuries or OSHA recordable injuries. There were zero environmental releases from field activities with zero (0) environmental Notices of Violation.

The successful ALARA approach resulted in an official total project dose of 702 mrem as all dosimetry for the decommissioning has now been processed. This represents a significant reduction over the Decommission Plan's schedule adjusted prediction of 3000 mrem.

DECOMMISSIONING ACTIVITIES

Reactor Confinement Structure

The polar crane was re-certified for use in decommissioning and remained operational at the completion of decommissioning activities. The reactor confinement structure's loose items, the control room and instrument room were size reduced as necessary and removed to the bare walls. After the reactor pool had been emptied, the concrete floor was cleaned with a water jet cutting process. The floor drains were then inspected, decontaminated or removed as necessary. When all activities that might benefit from ventilation system operation were completed, the reactor ventilation system and the building plant off gas stack were surveyed and determined to meet the free release DCGL's. Accordingly, after review by the Reactor Decommissioning Committee, they were left in place and the ventilation openings required no special closures or monitoring.

Reactor and Pool

The water contained in the pool was utilized to provide shielding during the segmenting and removal of the highly activated components in the pool. This work was performed using divers and dose reduction of 80% (from the planned in air evolution) was achieved. The component segmentation process began with the placement of a cask liner in the reactor pool.

Segmentation was performed underwater by divers using plasma arc cutting equipment. The liner was loaded underwater, the higher activity items were preferentially loaded nearest the center of the cask and the lower activity materiel (hardware, beam port nosepieces, etc) loaded in the liner annulus to provide shielding. A CNS 8-120B shipping cask was used to ship the activated components to the Barnwell disposal site for arrival before the Labor Day weekend. Since air sampling performed while segmentation was occurring demonstrated that airborne contaminants were not produced, a confinement structure was not required.

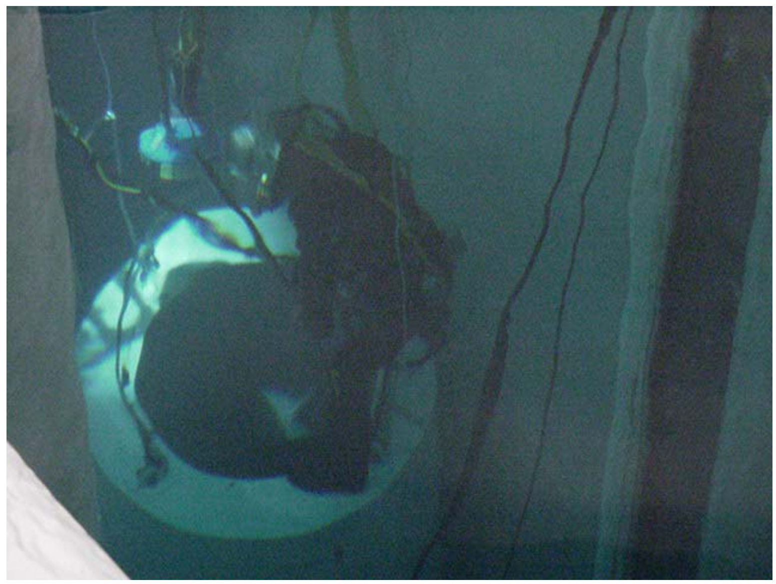

Fig. 1 Diver loading shipping cask liner – image courtesy K. K. Allen

After the shipment to Barnwell, the remaining pool water was sampled and confirmed suitable for discharge to the sanitary sewer. The discharge was from the pool through filters to a temporary surge tank, where a second pump, pumped the filtered water directly to the sanitary sewer. Using this system the pool discharge was about 63,000 gallons and about 35 gallons remained in the piping and pool to be processed by the routine liquid release pathway. The "empty pool" structure survey did not detect any "hot particles," so decontamination and cleaning of the pool surfaces began. A confinement structure was erected but air sampling performed while cleaning with a water jet cutting process demonstrated that airborne contaminants were not produced. Even though the confinement was not required for radiological reasons, it was used for cleaning water over-spray control. The cleaning water produce by the water jet cleaning was collected, large solids settled out, and the remaining water was evaporated off the concrete and epoxy fines. The solids were dried and disposed of as low level waste.

Once the pool surfaces had been cleaned to bare concrete, a structural evaluation was performed. No additional structural protection measures were required for the remainder of the decommissioning activities. Potential leakage paths were investigated. Concrete surface and interior core samples were evaluated for contamination/activation. The only activated concrete was detected radially around the beam tubes through the pool wall. Soil sampling under the pool floor and horizontally through the pool walls was performed. Repair of these sampling locations was not performed to allow access by the verification team since the structural analyses indicated it was not necessary to maintain the pool structural integrity.

The characterization results led to the removal of the entire west beam port tube liner in a 30" diameter cylinder of concrete. The east beam port tube liner was removed similarly for a depth of about 24 inches from the interior face of the pool. All metal in the pool that had been in direct contact with pool water was removed except for the embedded pool gate guides, which had coupons removed to investigate the portions that were in contact with the pool wall concrete. After these materials were removed, lowering background levels in the pool, the pool characterization survey was performed. Several small contamination areas were decontaminated and an embedded flange on the heat exchanger suction, located immediately under the reactor core, was removed due to contained activation products. The remaining heat exchange and drain lines were cleaned and left in place. The "knee wall" at the top of the pool was cut off flush with the floor. After the final status surveys of the pool interior were complete, industrial walkway grating was installed across the pool to eliminate fall hazards and maintain access for the verification team.

Remaining Rooms and Structure

Approximately 8000 square feet of building including the primary heat exchanger, the demineralizer systems, the liquid waste storage tanks, hot cell, source and instrument storage areas, rabbit room and two laboratory rooms, one contaminated with Ni-65 and the other with Tc-99, remained. The rooms were cleaned to the bare walls of their reactor associated components or remaining contaminated items. For instance, the installed laboratory counters, sinks and hoods that met the free release criteria were left in place, while the potentially internally contaminated rabbit transfer system was removed completely and processed as low level waste. Contaminated surfaces were decontaminated or removed (exhaust blowers, filters and some ductwork). The contaminated laboratory hoods exhaust ducting through the wall to the outside met free release criteria and remain in place. The cooling tower on the roof of the mezzanine level was characterized and removed by a crane to the parking area. Characterization results allowed remediation of the asbestos as clean asbestos and remaining tower materials as clean construction debris. The 7000 Curie Co-60 source has decayed to about 1000 Curies and remains in the facility at this time. The hot cell lead-glass oil-filled window and manipulators were confirmed to met the criteria for free release and removed for reuse by another company.

Underground tanks and vaults

The outdoor spent fuel transfer tank was internally contaminated from previous transfer operations. It was enclosed in a ventilation containment to capture airborne contamination while it was size reduced with oxygen-acetylene torch cutting. Air sampling confirmed that respiratory protection was not required due to airborne radiological levels and the confinement simply served as a contamination dispersion prevention. The sand base for the tank was removed and processed as low level waste. Subsequent concrete basemat screening indicated the basemat met free release criteria.

Two large liquid waste tanks and two smaller hot cell drain tanks were excavated, removed and sized reduced for disposal as low level waste. The liquid waste storage tanks were size reduced outdoors in a similar confinement structure to that used for the spent fuel transfer tank. Some of the buried piping was removed as part of the removal operation of the tanks and associated vaults. The remaining underground pipe sections were surveyed and met the free release criteria. The block wall and gravel floor of the liquid waste tank blockhouse were contaminated and processed as low level waste. The poured concrete hot cell tank vault structure was surveyed and met the free release criteria, allowing disposal as construction debris. The structures were removed completely to bare soil.

The soils moved to uncover the tanks were surveyed and found to meet the free release criteria. That soil was staged for future replacement. Soil screening of the excavation confirmed the contaminated areas had been removed. The industrial hazards presented by the excavation opening and the stability of the adjacent roadway required mitigation. We chose to perform the Final Status Survey soil sampling per the Final Status Survey Plan and backfill with the staged soil until mitigation was achieved. Our NRC inspector witnessed the soil sampling, and sample splitting, and placement of the samples under Chain-of-Custody controls. Results of analysis are available for the verification team as are the split samples which are stored at the reactor facility. The excavation was then restored to a stable configuration and re-vegetated.

Outdoor Areas, Drains and Sewers

Storm drains, building drains and the sanitary sewer line were surveyed and none were found to exceed the free release criteria. The exterior piping access via well casings and manways remains in place for use by the verification team.

The previously contaminated soil outside the liquid waste storage tank blockhouse and the pond sediments were re-characterized and found to not require remediation. The only soil remediation required was performed when the underground liquid waste storage tanks were removed. The other outdoor area remediated was the asphalt pad just outside the reactor room roll up door. Six 55-gallon drums of Cs-137 contaminated asphalt were removed before the free release criteria were met. This contamination is believed to have come from a contaminated storage cask that been stored at this location.

Finally the investigation of the pool drain lines revealed a portion of the clay tile footing drains. Perched upon a foot of coarse gravel fill, their function was to maintain low external water pressures on the pool footing. All areas accessed indicated clean piping or less than the free release criteria. This pool footing drain combined with the roof drains and the combined flow discharged on the hillside above the pond and did not enter the storm drain system.

FINAL STATUS SURVEY

The Final Survey Plan was transmitted to the NRC on April 4, 2003 and the Final Status Survey Addenda were transmitted on June 18, 2003. At the completion of the physical decommissioning for each final survey plan area, surveys were performed. Eight areas were identified as having elevated activity, decontaminated as necessary, re-characterized and the final survey for that area performed. The results of the Final Status Survey are contained in the document "*Final Status Survey Report-- Evaluation of Radiological Results Relative to Termination of NRC License R-66, University of Virginia, Charlottesville, Virginia.”* This document confirms the remaining residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent to an average member of a critical group that does not exceed the 25 mrem per year site release limit.

CULTURAL, MANAGEMENT, AND PERFORMANCE LESSONS LEARNED

The "culture" of the institution or organization that is responsible for the successful completion of the reactor facility decommissioning and ultimately reactor license termination is very important. Culture impacts start taking effect before the decommissioning plan is submitted.

Facility "cultural" knowledge is transferred principally by people, documents and procedures. The decision to retain critical staffing though the decommissioning should be made early. This decision maintains the current "corporate knowledge" and provides an avenue of contact for obtaining the assistance of former staff and faculty that have knowledge of the construction and operational history of the reactor.

Fig. 2 Paul Benneche (Reactor Supervisor) identifies experimental configurations to survey team.

The benefit of access to accurate as-built and as-modified drawings of the building and facilities can not be over emphasized For neutron irradiated or contaminated facilities and equipment a historical record of their use improves the characterization process. At every step of the decommissioning, as tanks, rooms, and blockhouses are opened, these experienced personnel are able to clarify the situation that is being encountered by the entry team.

Lesson: Demonstrating management commitment to performing technically sound decommissioning, lowers costs and minimizes schedule.

Pre-decommissioning activities allowed by the existing license are not restricted by the decommissioning plan and can be very beneficial. Items that are clearly no longer needed for current tasks or for the decommissioning process, but not including those that cannot be removed until the decommissioning plan is approved should be disposed of, released as institutional surplus, or gifted to other facilities. Transfer of clean or contaminated items to other institution's licenses is normally less expensive than disposal under the decommissioning plan. The costs incurred may be potentially considered as part of the operating budget.

The removal of temporary shielding and experimental setups allows more immediate access to the facility systems by the selected contractor. Typically these removals and releases are performed using the facility free release criteria, which may be less restrictive than criteria imposed as part of the decommissioning plan approval process.

Lesson: Performing as much "pre-decommissioning" as possible generally will improve the decommissioning schedule and lower overall decommissioning costs.

The specific details of each individual item to be addressed during the decommissioning require either access to the item to allow intensive investigation or the content knowledge of an experienced person at the facility. For example, formerly used experimental equipment—without content knowledge, the items have to be investigated to determine materials, presence of activation products, contamination levels and type, and internal material contents. The deliberate process to investigate, if complicated (e.g. by high radiation fields) can be slow to perform and receive results. Some articles are uncovered by the removal of other known components.

This can have significant schedule impacts versus "That was Joe's experimental setup, it is a cadmium plate welded inside an aluminum box". Similarly, field personnel that can distinguish between hazardous and reactive metals and items can efficiently investigate unexpected field conditions in real time.

Fig. 3 Martin Latta (Decommissioning Foreman) evaluates unexpected condition (lead plates).

Lesson: Assignment of individuals with historical process and facility knowledge improves the overall schedule and minimizes the cost to determine the proper disposal of items.

The estimated quantities used for the proposals will have variance from the actual quantities in the field. Expect to see more lead bricks, more concrete blocks, additional contaminated areas, asbestos nearly everywhere, more soil to screen. Concrete rubble will be of larger volumes and strange shapes. Reverse engineering of specific situations will likely occur.

Lesson: Provide a contract vehicle that allows the flexibility to deal with changes without stopping the field crew from performing the decommissioning efficiently.

The original decommissioning plan had described the disassembly of the hot pool components remotely and the loading of the shipping container to be performed by a series of dry (in air) material transfers.

The evaluation of the proposed process for removing those components, and loading a shipping cask liner indicated that significant dose savings could be realized by implementing a different approach.

The chosen method used a diver to segment components underwater, at arms length, with a plasma arc torch and to hand load the segments into the shipping cask liner. The combined benefits of close working distances and improved visibility, reduced the handling times for the components compared to in-air methods. Reduced handling times and the shielding provided by the intervening water resulted in much lower personnel doses compared to in-air methods.

Lesson: Considerable dose savings (>90%) may be realized by underwater methods, their use should be evaluated carefully before draining the pool.

Characterization is a continual process. That said, it is desirable to obtain a very good (complete) characterization as soon as possible, either before the decommissioning plan is submitted or as soon as practical thereafter. Specifically, give more thought and pre-planning to how piping will be remediated. An inventory of piping should be performed in the pre-decommissioning and a well thought out plan should be developed for how piping will be surveyed and or removed in the field. Research may need to be performed to discover all the methods that are available to address this issue. The decommissioning plan should be written with flexibility to allow piping as well as other process equipment to be addressed in the most economical manner. Write the plan carefully to allow maximum flexibility of decommissioning activities including the process of release for unrestricted use.

Lesson: Aggressive characterization will assist in minimizing long-lead planning "surprises" during the decommissioning process. Write the decommissioning plan with as much flexibility as possible to allow for change in the decommissioning approaches as the characterization results become clearer.

Seemingly, low impact items like floor drains or other small diameter (<4”) piping that might have been contaminated required a large portion of the schedule to disposition. The piping was field routed and available drawings were essentially process diagrams. As-built drawings of the presumed clean floor drain system were unavailable. Piping was first tested for continuity. It flunked. This piping had separated at some joints presumably from differential movement of the pool and the rest of the facility.
Chasing the piping that was contaminated was very labor intensive. The piping as field routed contained many sharp bends that the monitoring device could not pass through. A fiber-optic camera was used to inspect the lines. Obstructions that could be removed by high pressure water cleaning were removed. When the obstruction was a pipe fitting or elbow, access was cored in the concrete floor slab, the soil around the piping was hand excavated and the obstruction removed using plasma arc cutting. The detector was then inserted into the newly accessible piping run. If an obstruction was encountered before the end of the piping run, this process was repeated.

Lesson: Expect small bore piping to present difficulties in the disposal pathway determination if it has been even slightly contaminated. Evaluations of cost, schedule and performance constraints for “piping removal” versus “leave clean and survey” should be performed as new information becomes available.

While some articles are uncovered by the removal of other known components, some are just there. Present for many years they are realized to be part of the decommissioning. "The block" is an example. It was a 60" x 58" x 43" concrete block with two bent #12 size pieces of steel re-inforcing rod protruding 12 inches from two opposite sides of the block.

Fig. 4 "The block" sits off by itself awaiting determination of its fate.

The concrete cracking pattern had a white adhesive crust that probably was $CaCO_3$ (calcite) leaching out of the concrete from acid rainwater percolation (initially we thought it might be something from inside the concrete leaching out). It looked like a really big shield plug but would not fit in any known UVA facility experimental configuration.

No one contacted could remember or knew what the block was for or if it was used at the reactor. The last hypothesis proposed was that it was intended to be a shield/beam stop for the vertical beam tube when the beam was in operation. The belief was that the re-inforcing rods bent on the first attempt to lift it and it was abandoned in place. When we lifted the block with a crane into the parking area so we could survey it, the ground under it was covered with plastic sheeting, possibly from when it was originally poured.

The block weighed a calculated 13,000 pounds, which exceeded the lifting capacity of any on-site lifting equipment, and made movement difficult. We checked for chemical products, activation products, and contamination. It was clean. It was given by the University to the local breakwater company for the cost of transporting it offsite after survey for unrestricted release.

Lesson: Be prepared both contractually and technically to investigate unknowns. Sometimes you don't know what something was designed or used for, and/or just how to dispose of it. It is important to have the ability to perform real time investigations of unknown items.

CONCLUSIONS

Even a relatively small project can yield significant lessons-learned. Overall, the project was well executed and License Termination has been requested. This project has led to the identification of the following conditions that are significantly different from the usual design and build project.

- It is important to realize that decommissioning consists of "reverse construction" and the facility usually was not designed to enable reverse construction.
- Conditions (both industrial hazards and radiological hazards) change every day and require a large effort to keep all personnel informed of the changes.
- The project must establish a business method that allows the project the flexibility to deal with those changes.
- The impact of really good communication between the Owner and the Decommissioning Contractor cannot be over estimated.
- The use of divers for dose minimization should be seriously evaluated.

REFERENCES

1 Decommissioning Plan for the University of Virginia 100 W CAVALIER Reactor and Application for the Termination of the Cavalier Operating License, NRC License No. R-123, Docket 50-396, Reactor Facility, University of Virginia, February 1990.

2 Order Authorizing Dismantling of Facility and Disposition of Component Parts – University of Virginia CAVALIER Research Reactor, letter from NRC (A. Adams, Jr.) to University of Virginia (R. Mulder), February 3, 1992.

3 3. Amendment No. 26 to Amended Facility Operating License No. R-66 for the University of Virginia Research Reactor, Docket 50-62, TAC NO. MA8186, NRC, March 26, 2002.