Safety Analysis of Millstone Fuel Rods Potentially Disposed in Either the Barnwell, South Carolina or Hanford, Washington Commercial LLRW Disposal Sites

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Background

During the recent Millstone Unit 1 fuel records reconciliation effort, workers found data, which indicated that two spent nuclear fuel rods, may be missing from the Unit 1 spent fuel pool (SFP). Northeast Nuclear Energy Company established a team to locate the spent fuel rods and investigate this loss of accountability. The team has reviewed and analyzed many scenarios regarding the present location of these two spent fuel rods.

Based on the information gathered, the investigation has revealed that the two fuel rods may have been mistaken for irradiated hardware and inadvertently shipped offsite to one or both of two commercial low-level radioactive waste (LLRW) facilities. These facilities are located in Barnwell, South Carolina (Barnwell) and the Hanford Reservation in Richland, Washington (Hanford). This report evaluates the public and worker health and safety aspects and environmental risks associated with the potential shipment to, and burial of, the spent fuel rods at the commercial LLRW disposal facilities at Barnwell and/or Hanford.

Although there is currently no evidence that the two fuel rods were actually shipped to Barnwell or Hanford, for the purposes of the following analysis, it is assumed that the two fuel rods were inadvertently included with other shipments of highly irradiated components. With that assumption, the purpose of this report is threefold:

A. To assess whether the transportation of radioactive waste shipments containing one or both of the spent fuel rods to either Barnwell or Hanford posed an increased risk to workers (at Millstone, Barnwell, or Hanford), the public, or the environment,

B. To assess the potential health and environmental risks associated with potential burial of the two spent fuel rods at Barnwell or Hanford, and

C. To assess the benefits of exhumation of the spent fuel rods from Barnwell or Hanford, versus the public and worker health and safety risks and the potential environmental detriment.

Summary of Conclusions

A. The transportation of the spent fuel rods from Millstone Unit 1 to either Barnwell or Hanford did not pose any increased risk to the health and safety of the public, the workers associated with shipping and burying the waste, or the environment.

- The casks that transported radioactive waste from Millstone to the Hanford site (IF-300) and the Barnwell site (TN-RAM, CNSI 3-55, and TN-8L) were approved for the shipment of high-activity irradiated hardware. Each cask provided substantial shielding and physical protection for the contents during shipment to either burial facility. If the two spent fuel rods were included in an irradiated hardware shipment, there would be no criticality risk.

- The cask shipments complied v ith the then applicable state and federal regulatory requirements associ ated with the packaging and transportation of highly radioactive components. This helped to ensure that there was no increased risk to the public or transport workers associated with any of these shipments. However, if the shipments to Barnwell and Hanford included the fuel rods, the shipments would not have complied with all transportation and notification requirements applicable to spent fuel.

- There are no reported unusual occurrences or incidents associated with the transport of any of the suspect shipments to the disposal facilities. Each cask was monitored and surveyed prior to leaving Millstone and upon arrival at each facility. All casks arrived safely at their destinations.

- Shipping records indicate that one of the IF-300 shipments to Hanford encountered a minor operational problem with the rigging equipment. This problem was rectified and was unrelated to the cask contents. Additionally, one of the TN-RAM shipments to Barnwell had water in the liner that resulted in a penalty and suspension of access to the Barnwell facility for 30 days. This problem with cask dewatering was unrelated to the cask contents.

B. If buried at either Hanford or Barnwell, the presence of the two fuel rods at either facility does not pose an increased risk to the public, the workers, or the environment.

- The fuel rods – even in the worse case configuration – do not pose any criticality risk in the disposal environment.

- The spent fuel rods are an insignificant addition to the existing inventories of radioactive materials at both Barnwell and Hanford. Radioactive material inventories at Hanford and Barnwell show that the radionuclides contained in the spent fuel rods are already present (and authorized to be present) in substantially greater quantities at each of those facilities.

- The facilities are subject to continuous state regulatory oversight and periodic license renewal approximately every 5 years. The license renewal process includes assessments of operations, environmental monitoring results, operational and closure plans, and regulatory inspections. Barnwell's license was first issued in 1971 and Hanford's license was first issued in 1964. Each site has been successfully re-licensed since the time of the first suspect shipments.

- The environmental monitoring programs at Barnwell and Hanford have been designed to assess the environmental effects of long-term disposal of the entire inventory of radioactive materials at the disposal facilities. These programs will be adequate to account for the small amounts of radioactive materials potentially added by the two fuel rods.

- Facility performance assessments to evaluate whether the sites are meeting license conditions and regulatory requirements, and state regulatory inspections since 1985 (for Hanford) and 1988 (for Barnwell) do not reveal any environmental or other problems that could be attributable to the potential burial of the two spent fuel rods.

C. The exhumation of the two spent fuel rods poses a far greater worker health and safety risk and potential environmental detriment than leaving them buried at either Barnwell or Hanford.

- LLRW packages and site operations were developed for disposal not exhumation. All of the engineering, operations, and disposal cell management methods do not anticipate, or account for, the exhumation of buried wastes.

- The risks and challenges associated with exhumation are substantial. The exact physical conditions of the disposed shipping containers are not known. Challenges would be faced in every phase of an exhumation including the areas of engineering, operations, radiation protection, package evaluation, waste evaluation, and ultimate waste disposition.

- Workers attempting to exhume the waste (including the fuel rods) from a suspect shipment at either disposal facility would likely encounter very high operational radiation exposure levels. In addition, such an

exhumation has the potential to disturb adjacent disposed wastes at a substantial risk to the site workers and, potentially, the environment for no net benefit.

- Exposing workers by exhuming buried waste that does not pose any increased risk to public health and safety is not consistent with the regulatory requirement that licensees use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses, and doses to members of the public, that are as low as is reasonably achievable (ALARA).

Analysis and Discussion

Because these rods were removed from the reactor in 1972, they are classified as Spent Nuclear Fuel under 10 CFR § 2.1105(b). An evaluation of the inventory of the two spent fuel rods corrected for decay through December 1, 2000 estimates that the rods contain approximately 518 Ci of total radioactive material, and 132 gm of ^{235}U, 27 gm of ^{239}Pu, 0.032 Ci of ^{99}Tc and 0.0001 Ci of ^{129}I (Hamawi 2001). These particular radionuclides are important for two reasons. First, they include radionuclides that are SNM. Second, they are the radionuclides whose behavior in the environment after site closure is likely to be determinative of the facility's health, safety and environmental performance.

The following Table provides the important radiological characteristics of the two fuel rods.

Table-1 Radiological Characteristics of the Fuel Rods (Hamawi 2001)

Total Uranium in the 2 Fuel Rods	8210 gm
Total ^{235}U in the 2 Fuel Rods	132 gm
Total ^{239}Pu in the 2 Fuel Rods	27 gm
Total ^{129}I in the 2 Fuel Rods	0.0001 Ci
Total ^{99}Tc in the 2 Fuel Rods	0.032 Ci
Total Radioactivity in the 2 Fuel Rods	518 Ci

Both sites have conducted performance assessments to predict future behavior to assure that continued operations and post closure performance will conform to all applicable

license conditions and regulatory requirements. In these assessments, which are part of the license renewal process, the radionuclides listed in Table 1 are the most important radionuclides that are contained in the spent fuel rods.

The two rods were part of a larger inventory of spent fuel rods stored at Millstone. Millstone operates three reactors and, currently, there is a total inventory of over 450,000 spent fuel rods on site. The Unit 1 spent fuel pool alone contains approximately 167,000 spent fuel rods. The nuclear industry as a whole has millions of spent fuel rods in spent fuel pools and in dry cask storage at reactor locations across the country.

The U.S. Department of Energy's current plan for the disposal of spent nuclear fuel calls for the development of a disposal facility at Yucca Mountain. Although it is appropriate that large quantities of spent nuclear fuel be disposed in such a facility, it is not true that two rods disposed in a LLRW disposal facility necessarily creates an increased hazard to worker health and safety, public health and safety or to the environment. The particular radionuclides contained in the spent fuel rods are already present, and in far greater quantities, at these LLRW sites.

Although, the incremental risks associated with the burial of these two rods is small, this does not mean that, if shipped, the disposal was appropriate or excusable. It would not be. LLRW facilities are simply not authorized to receive spent fuel. Additionally, given the rods' radioactive material content, if these two fuel rods were contained in suspect shipments, these shipments would have been classified as containing greater than Class C LLRW. Commercial LLRW sites are not authorized to dispose of greater than Class C LLRW per 10 CFR 61.55.[1]

This analysis addresses the following three questions.

- Were the rods safely transported if sent to either the Barnwell or the Hanford commercial LLRW disposal sites?
- Are the fuel rods safe if buried in either the Barnwell or the Hanford commercial LLRW disposal sites?
- If the fuel rods are buried at one of the LLRW facilities, do the risks associated with exhumation outweigh the benefits such that it is prudent to leave the rods where they are?

[1] It is important to note that the various definitions and classifications of radioactive materials and radioactive wastes originated with the Atomic Energy Act of 1946. Although public health and safety were important considerations when these terms were originally defined, they are not based on health and safety factors, but on security and control of nuclear materials. (McMahon Act of 1946)

I. Were the rods safely transported if sent to either the Barnwell or the Hanford commercial LLRW disposal sites?

At the outset of the investigation, the Project identified various shipments to Barnwell and Hanford that had the potential to contain the two rods. Those shipments are listed in Appendix A to this report. The results of the investigation are described in the Project's Final Report.

All of the radioactive material shipments listed in Appendix A were prepared and shipped according to the Department of Transportation (DOT) regulations in force at the time, as they pertain to irradiated hardware. These regulations are found in 49 CFR 173 - 189 and specify the radiation protection and qualification parameters for the vehicle operator and for radiation levels in contact with the cask and at various distances from the transport unit. These criteria must be met regardless of the particular material in a given shipment. These shipments met the applicable DOT criteria at departure of the shipments from Millstone and they met applicable DOT and disposal facility criteria for irradiated hardware upon arrival at Hanford and Barnwell. All of the shipments arrived at their destinations (either Barnwell or Hanford) safely.

Each of the radioactive material shipments was comprised of a steel liner containing the radioactive waste that was ultimately disposed, a shielded shipping cask that is reusable, and a trailer or rail car on which the cask was secured for transport. Casks used for irradiated hardware shipments from Millstone, including the TN-RAM, TN-8L, CNS 3-55, and the IF-300 casks, are qualified to the safety performance criteria in 49 CFR 173-189 and 10 CFR 71. These casks are designed to safely transport their contents during both normal operation and specified accident conditions in order to protect public health and safety.

The unloading and burial of all irradiated hardware shipments at both Hanford and Barnwell are routine, but highly controlled evolutions, that are designed to minimize dose to the workers and public. These controls were adequate to ensure that the burial of any waste packages potentially containing the fuel rods did not pose any undue or increased risk to the workers at the site above those associated with routine burial operations. At both sites, shipment documentation does not indicate any unusual circumstances, unexpected radiation levels, or operational difficulties associated with any of the suspect shipments, with two minor exceptions. The April 1, 1985 shipment to Hanford involved a minor rigging difficulty that was identified, evaluated, and accommodated. This problem was unrelated to the cask contents. Additionally, a May 1990 shipment of one of the TN-RAM casks to Barnwell had water in the liner that resulted in a penalty and suspension of access to the Barnwell facility for 30 days. This cask-dewatering problem was unrelated to the contents of the cask.

Conclusion

If shipped, the transportation of the spent fuel rods, in an otherwise compliant shipment of irradiated hardware, to either Barnwell or Hanford did not pose a significantly increased risk to the health and safety of the public, the workers, or the environment. As noted above, the transport casks provided sufficient protection for transport operators and members of the general public during transport from Millstone to the disposal facilities.

II. Are the fuel rods safe if buried in either the Barnwell or the Hanford commercial LLRW disposal sites?

If buried at either Hanford or Barnwell, the two fuel rods do not pose an increased risk to the public, the workers, or the environment. Two principal reasons support this conclusion.

First, the radionuclides that exist in the fuel rods are already present in far greater quantities at both the Hanford and Barnwell LLRW facilities. In other words, the fuel rods would not significantly increase the existing radioactive material inventories at the facilities. Moreover, no new radionuclides would be added to the sites' inventories if a shipment contained the fuel rods. All the radionuclides in the fuel rods are already contained in other types of LLRW at these facilities.

Second, the facilities' programs and processes, which are overseen by state and federal regulators, are designed to protect the public and the environment from problems associated with any buried wastes. In fact, there are no known problems or anomalies potentially attributable to the presence of the two spent fuel rods at either facility.

A. If shipped, the spent fuel rods would not significantly add to the total radionuclide inventories or add any new radionuclides to either facility.

Duke Engineering and Services Inc. performed an analysis of the composition of the two fuel rods and identified all the radionuclides and the quantities of each contained in the two fuel rods (Hamawi 2001). This analysis shows that if the two fuel rods were sent to either the Barnwell or Hanford commercial LLRW facilities, the rods did not add any new radionuclides to the inventories of the facilities. This analysis also shows that the two fuel rods did not add significant quantities of the several radionuclides that are important to assessing the site's long-term performance. The most abundant of these significant radionuclides in the two spent fuel rods and their quantities are: 8210 gm of total uranium, 132 gm of ^{235}U, 27 gm of ^{239}Pu and of 0.032 Ci of ^{99}Tc, 0.0001 Ci of ^{129}I and approximately 518 total Ci radioactivity. This data is included in Table 1 of this report.

Also, the two fuel rods would not have added significantly to the total radionuclide inventories at either facility. A 1980 NRC report entitled "Data Base for Radioactive Waste Management – Review of Low-Level Radioactive Waste Disposal History," reports that for the Hanford facility that "[t]hrough 1980 over 323,560 m^3 (11,424,900 ft^3) of waste containing 1,655,100 Ci of byproduct radioactivity, 5,467,000 lb of source material and 1121 kg of special nuclear material had been disposed through 1980." More recent information from an August 2000 Draft Environmental Impact Statement (Appendix III page 7) for Hanford identifies that 61.9 Ci of ^{99}Tc and 5.66 Ci of ^{129}I have been disposed at Hanford.

Radioactive material inventory data for the Barnwell facility is reported in its Interim Site Stabilization and Closure Plan for the Barnwell Low-Level Radioactive Waste Disposal Facility (September 2000, Chem Nuclear Systems Inc.). Site inventory data for shipments received from January 1, 1983 through December 21, 1999 indicate that Barnwell received approximately 7.1 million total Ci of radioactive material and approximately 3.2 million grams of fissile material of which 212 gm is ^{239}Pu and the remainder is ^{235}U (Still, 2001a, Still 2001b). Additionally, the Barnwell Interim Site Stabilization and Closure plan reports that the Barnwell site has received 88.75 Ci of ^{99}Tc and 9.1 Ci of ^{129}I. These results are summarized in Table 2 below for easy comparison.

It is clear that the two fuel rods would not significantly increase the total inventory or the inventory of key radionuclides at either the Hanford or Barnwell facility.

Comparing the amount of the radioactive material in the fuel rods that is important to site performance to the amount presently at the Barnwell and Hanford sites, demonstrates that the burial of the rods would not add significantly to the sites' current inventories of these materials. The insignificant addition attributable to the rods will, therefore, pose no increased risk to the health and safety of the public or the environment not already anticipated for the long-term management of these facilities.

Table 2 – Radionuclide Inventory Comparison

Radionuclide	Two Fuel Rods	Barnwell [2]	Hanford
Total Uranium	8210 gm	1,942 Ci (^{238}U) 5,830,000,000 gm	27,518,181 gm (reported as lbs. depleted uranium1965-1980) [3]
^{235}U	132 gm	3,200,000 gm (reported as total fissile material)	101,915 gm [3]
^{239}Pu	27 gm	212 gm	25,060 gm (reported as $^{239}Pu/^{241}Pu$) [3]
^{129}I	0.0001 Ci	9.1 Ci	5.66 Ci [5]
^{99}Tc	0.032 Ci	88.75 Ci	61.9 Ci [5]
Total Radioactive Material Inventory	518 Ci	7,100,000 Ci	1,655,100 Ci [4]

B. The LLRW Facilities' Existing Monitoring Programs Were Designed to Protect the Health and Safety of the Public and the Environment

Having demonstrated that the fuel rods, if shipped to Barnwell or Hanford, would not have any significant effect on the facilities' radionuclide inventories, it follows that the facilities' existing environmental monitoring and oversight programs are adequate to protect the health and safety of the public and the environment during continued operations and post closure.

Regulatory oversight

The Barnwell and Hanford facilities are under routine and continuous review from their respective State agencies. These agencies provide an overarching process of checks and balances to ensure that site operations, eventual closure, and long-term performance meet all applicable regulatory requirements pertaining to public health and safety and environmental protection. The following sections describe the processes and

[2] Interim Site Stabilization and Closure Plan for the Barnwell Low-Level Radioactive Waste Disposal Facility, September 2000, Chem Nuclear Systems Inc.

[3] Letter, from Gary Robertson, Head Waste Management Section, State of Washington, Department of Health, to Hugh Thompson Turner, Harper and Associates, Inc. documenting the source term for the Hanford LLRW Disposal Site through August 1980 dated 9/21/01.

[4] Data current through 1980 as reported in Vol. 1 of NUREG/CR 1759, Database for Radioactive Waste Management, US Nuclear Regulatory Commission, November 1981.

[5] Maxine Dunkelman, Groundwater Pathway Analysis for the Commercial Low-Level Radioactive Disposal Site in Richland Washington by the state of Washington Department of Health Division of Radiation Protection, July 19, 2000, included as Appendix 3 in Draft Environmental Impact Statement – Commercial Low Level Radioactive Waste Disposal Site, Richland Washington, August 2000.

requirements that are used by the state regulators and incorporated into the regulatory management of the Barnwell and Hanford facilities. At the outset, it is important to note that no information has been identified that would call into question the ability of either site to continue to operate safely and in conformance with all regulatory requirements.

Both South Carolina and Washington are Agreement States. The Nuclear Regulatory Commission has oversight responsibility for the conduct of each Agreement State's Program for managing licensed radioactive material. Agreement States' regulations are reviewed and approved by the NRC regarding their compatibility with the NRC's regulations. This helps to assure that whether the NRC or an Agreement State grants a license, uniform rules, regulations and requirements will apply. Periodically, the NRC conducts audits and oversight of the Agreement States' activities in licensing, inspection, and enforcement of licensees. This oversight includes direct participation by the NRC in state inspections of their licensees, as well as programmatic reviews. Both the Hanford site and the Barnwell site have been selected as licensees to be reviewed by NRC in these oversight activities.

Each facility is operated pursuant to a detailed license that is typically renewed every five years. The regulators routinely inspect the LLRW facilities with regard to conformance to specific license conditions, and make their inspection results part of the public record. Prior regulatory oversight at Barnwell and Hanford (as referenced in recent license renewal documents for both facilities) has not indicated any significant deficiencies regarding the ability of either site to operate safely and in conformance with the regulatory requirements over time.

Each facility's license has detailed and specific license conditions that must be met by the site operator. These license conditions address all aspects of site operations through closure, including institutional controls and monitoring for the long-term. These license conditions will help ensure that even if the spent fuel rods were buried at either facility, the site will be monitored and maintained to protect public health and safety and the environment. License conditions for both facilities can be grouped into the following categories.

<u>Environmental monitoring during site operation and closure activities</u>

Both the Barnwell and Hanford sites have provisions for environmental monitoring to assure that site operations conform to all license and regulatory requirements. Additionally, there are provisions for environmental monitoring after waste receipt operations cease and for an ensuing period of time, typically called the institutional control period. Currently, samples are collected and analyzed from ground water, surface water, surface soils, vegetation, and the air. This sampling will continue into the institutional control period. By analyzing these data, LLRW site performance can be monitored and trended. If the results indicate that disposed waste is behaving as planned, normal monitoring and site maintenance can continue. If the results indicate that changes may be occurring with disposed wastes, additional data can be collected to make further

assessments of this behavior. If further analyses indicate that corrective measures are needed, the data can be used to assess and plan corrective measures. This program, which adapts and responds to environmental monitoring data, will help ensure that public health and safety and the environment are protected in the long-term from any potential environmental consequences associated with all buried wastes (including a small quantity of spent fuel).

Waste placement operations

The Barnwell and Hanford disposal sites are different from one another in terms of the natural environment and the engineering and construction of their disposal cells. However, for each facility, waste shipment placement and disposal operations are carefully planned and conducted according to written plans and procedures. Records are kept regarding the placement of each waste shipment. If any anomalies are noted during operational or environmental monitoring, the facilities are able to determine which waste shipments are adjacent to or near the monitoring point in question. As a result, both sites are capable of analyzing and responding to any environmental anomalies in monitored data that could be caused by the spent fuel rods or other radioactive wastes.

Site closure

Both the Barnwell and Hanford sites have closure plans that are routinely updated – typically at the time of license renewal. (Dunkelman, 2000 DHEC, CNS Closure plan, 2000). The closure plans include detailed assessments of the facilities' histories, operations, long-term performance, and radionuclide inventories. By assessing systematically the performance of the sites over ever-increasing periods of time, the certainty with which long-term behavior can be predicted increases. This kind of assessment adds to the body of evidence that these sites will perform as expected to protect the public health and safety from any potential environmental consequences associated with all buried wastes.

Permanent capping of each disposal cell (trench), at the Barnwell facility is being accomplished in segments as the various areas of the facility are completed. Details regarding closure have been reported in the Barnwell Closure plan. The Closure Plan states that:

> "As of 2000, CNS had completed approximately 80 acres of enhanced cap, covering 65 trenches (locations shown on CNS Drawing #B-500-D-300). All construction phases to date have involved older closed trenches (previously covered with compacted clay and soil materials). Data for each capping phase including date of completion, covered area, construction cost, and number of trenches involved are included in Table 6-9 and summarized below."

Table 6-9 HISTORICAL ENHANCED CAPPING SUMMARY				
Phase	Date of Completion	Acres	# of Trenches Covered	Approximate Cost ($ in Millions)
1	1/92	12.5	20	1.7
2	2/94	9	10	1.4
3	7/95	26	12	4.1
4	5/97	22	14	3.0
5	9/98	10	9	1.65
Total		**79.5**	**65**	**11.85**

Capping at the Hanford facility, which is located in a much dryer environment, is not planned until final closure of the facility currently scheduled for 2056. As noted in the draft Environmental Impact Statement (EIS) prepared for the Hanford site as part of the license renewal process, site closure and five alternatives for permanent cover designs are being evaluated. The site is also considering early partial closures. Details of these options and schedules are provided in the draft EIS.

The closure plans described above for both Barnwell and Hanford will help ensure that as the sites transition from operating facilities to facilities that are closed, they will be monitored for long-term post closure performance and that all wastes buried at the facilities do not pose a threat to public health and safety and the environment.

Financial assurance for long-term monitoring and maintenance

Both sites have state controlled funds to assure that sufficient financial resources will be available to successfully carry out closure and long-term monitoring programs. These dedicated and regulated funds will help ensure that proper monitoring (and early corrective actions if necessary) will occur for all disposed waste. The Hanford fund held by the State of Washington in a special account has $28.6 million in the fall of 2000 as reported in the Fall 2000 "The US Ecology Monitor." The Barnwell Atomic Waste Burial Escrow Account (long-term care fund) had approximately $67.9 million as of July 31, 2001, and the Decommissioning Trust Fund (site closure fund) had approximately $18.4 million as of June 30, 2001.

C. Other Safety Considerations

A criticality assessment for the two fuel rods was performed and documented in a report by R.J. Weader II, Duke Engineering and Services, " Spent Fuel Rod Criticality Calculation," NUC-203. These calculations and analyses show that, even under the most limiting conditions and configuration (zero burnup with a water reflector), there is no risk of criticality associated with the two fuel rods.

Conclusions

If buried at either Hanford or Barnwell, the presence of the two fuel rods does not pose an increased risk to the public, worker health and safety, or the environment for the following reasons.

- The two spent fuel rods do not introduce any new radionuclides to the radioactive inventory of the Barnwell or Hanford commercial LLRW disposal facilities.

- The total amount of specific radioactive materials and the total amount of radioactive materials in the rods do not add significantly to the radioactive inventory of the Barnwell or Hanford commercial LLRW disposal facilities.

- Programs and plans are in place to continue monitoring during operations, after closure, and through the institutional control period as defined for each of the disposal facilities. These programs will help identify any site performance anomalies arising from any disposed wastes should they occur.

- There are plans in place, as there have been since the sites were first opened, for regulatory oversight and review. This regulatory oversight is ongoing and is central to the renewal of site licenses, which occur approximately every five years. Plans and financial resources are in place to provide for continued monitoring, maintenance, and corrective measures should they be needed.

- There is no criticality risk associated with the two fuel rods.

III. If the fuel rods are buried at one of the LLRW facilities, do the risks associated with exhumation outweigh the benefits such that it is prudent to leave the rods disposed?

Because the fuel rods would not pose an significant incremental risk to the safety and health of the public or the environment over those associated with normal LLRW facility operations, there is no sound reason to exhume the fuel rods. In fact, there are compelling reasons not to exhume the rods. Assuming that a specific shipment or shipments could be identified as containing the spent fuel rods, exhumation would involve first-of-a-kind operations at commercial LLRW burial facilities to retrieve the permanently buried wastes. Additionally, exhumation would create very high radiation levels from which workers and the public would need to be protected, making the operations all the more complex.

A. Operational and Engineering Challenges Associated with Exhumation

The investigation has determined that there is no clear and convincing evidence to demonstrate that the fuel rods were shipped, much less that they were included in a particular shipment. Therefore, it is not a simple matter of identifying one shipment for consideration of exhumation.

As noted earlier, both LLRW facilities bury waste permanently and the facilities, equipment, and procedures are not intended for waste retrieval. As a result, there would be many engineering difficulties and operational problems that make retrieval of any buried shipment a high-risk activity. These problems are associated with developing approaches, procedures, and precautions to exhume materials for which exhumation was never anticipated, and for obtaining regulatory approvals for many individual activities that have not previously been licensed or approved.

It is important to note that there are numerous technical and regulatory problems that would have to be resolved prior to, and during, such an evolution. For example:

- Prior to lifting, the liner must be verified to be in a retrievable and shippable condition with intact lifting devices and rigging points. If the liner was deformed or damaged during burial, it may require a specially designed cask for shipping, or the liner may even need to be replaced (or placed within another liner). If the lifting devices were not operable or damaged, special rigging devices and equipment would be required. Each one of these possibilities would require detailed regulatory review by appropriate State agencies and the NRC.

- Liner and cask loading is normally conducted underwater in fuel pools at power plants for irradiated hardware shipments. The disposal facility would have to ensure that an open-air lift and loading of the liner into the cask is allowed by applicable regulations and LLRW facility specific procedures. This would likely require formal review and approval by the State and the NRC.

- The facility would have to ensure that the liner lift could be accomplished given the crane size and the ability of the surface soil (and possibly an engineered trench cap) to withstand the heavy equipment necessary for the activity. This would complicate equipment arrangements and could complicate personnel access to excavated areas to perform other work.

- Exhumation of any buried liner involves substantial radiation risks. To ensure worker and public health and safety, extensive shielding must be available to support all phases of the exhumation and an open-air lift of the liner into an appropriate cask. Even with substantial local shielding near the work, radiation that travels directly upward would be scattered back to the ground by the

atmosphere. This "sky shine" would create potential areas of exposure to members of the public. The particulars of any lift would depend on the specific disposal location, the specific disposal facility, and the detailed physical arrangements for the shipment in question.

Because liners are normally buried horizontally at a depth of about 15 – 45 feet (depending on the facility), and the lid is on the side of the liner, it would be virtually impossible to extract the fuel rods from an in-place or partially exposed liner. Therefore the entire liner would have to be uncovered, upended, and removed from the ground to access the liner lid. And, because removing the lid in the open air could result in unacceptable radiation fields, the liner would have to be placed in a cask, and the cask shipped from the disposal facility to a location licensed to receive a liner that has been in a disposal site for as much as 20 years. This is because processing of waste is typically not allowed by a LLRW disposal facility license. The operational and engineering issues that would have to be addressed to make such a retrieval and shipment are discussed below. The significant occupational radiation exposure issues involved with such retrieval are discussed more fully in section B below. While there are differences in the Hanford and Barnwell facilities, exhumation would present significant challenges at both facilities.

Excavation of the soils near a suspect shipment may be difficult as some disposal cells (waste trenches) are placed near one another. Additionally, waste packages are buried closely (side-by-side) in a disposal cell to efficiently use air space and to help maintain cell integrity. The packages are not stored to allow later access or exhumation of an individual package. Excavation, therefore, would need to occur directly from on top of the buried waste packages. Eventually, the top of a waste package would be exposed, creating high radiation fields long before making the actual lift. As the condition of the liner would not be known prior to exhumation, there is no assurance that exhumation could be successfully completed once begun. As a result, contingency plans would need to be ready to assure that, if necessary, the evolution could be halted and the liner placed in a safe condition.

A lift to exhume a waste liner would have to be made vertically and to such a height above the ground as to maneuver the liner over and finally into a receiving cask. This might be done at grade or in an excavated area within a disposal cell if possible. Operational control of a lift of a previously buried waste package would have to be exact, specific and expedient due to the high radiation levels (several hundred to several thousand R/hr) that would exist in the work area. (It is important to note that off loads of waste packagers at the commercial burial facilities are performed with appropriately designed equipment to minimize occupational radiation exposure.)

Prior to placement in the cask, the liner may have to be cleaned and prepared in ways that could only be determined after detailed inspection and based on the ability of the receiving facility to handle soiled liners. Such cleaning itself, if it is performed in an open-air environment, would create substantial radiation hazards, contamination control

hazards, and secondary wastes. If these difficulties could be mitigated or overcome and the liner loaded into a cask, the liner and cask combination would then have to be certified per NRC and DOT regulations for shipment to a licensed facility prepared to receive and process the shipment.

The receiving facility would then have to be prepared to open the used liner, retrieve any fuel rods or segments that might be present, and repackage the remaining materials in the existing or new liner and ship them for disposal as LLRW. The subsequent management of the fuel rods would have to be resolved separately.

B. Radiation Exposure Associated With Exhumation

In addition to the technical difficulties associated with exhumation, workers performing the exhumation would be exposed to very high radiation fields. Based on the dose rates near an exposed waste package of the type that might contain the two fuel rods, these exposures would be significant and in the order of several hundred to several thousand R/hr.

All licensees are required to maintain radiation exposures to workers As Low As Reasonable Achievable (ALARA). ALARA is defined in 10 CFR 20.1003 as:

> ALARA (acronym for ``as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

The specific requirements to implement ALARA are specified in 10 CFR 20.1101 (b):

> The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).

In short, this principle instructs all licensees to keep workers' exposure as low as possible taking into account the benefit of an activity. Simple compliance with an exposure limit is not enough. The net benefit of an activity must be weighed against the risks associated with it, and the radiation exposures to workers that might result. In the case of the two spent fuel rods, if there is no significant increase in the inventory of disposed waste, then there is no radiological benefit or improvement in public health and safety, and certainly no worker protection, from retrieving the rods. It is likely that significant worker doses would be present during exhumation, without a net benefit from the activity.

The dose rates that would be encountered in close proximity to the waste packages would be on the order of hundreds to thousands of R/hr. These are potentially lethal radiation levels for workers that would require strict, very careful, and detailed engineering management and operational controls. Exhuming such high activity shipments would result in much higher than normal dose rates and, therefore, increased risk in areas of public access outside the facility. All of the operational and engineering issues developed for exhumation would have to be reviewed not only for their inherent operational and engineering difficulties, but also for the health, safety and environmental risks to the public and to workers.

In summary, when the significant engineering and technical challenges of waste exhumation are considered, along with the lack of demonstrated benefit to exhumation, exhumation is not needed or prudent.

Conclusion

Given the absence of an increased risk to the public, it would be unwise and unnecessary to undertake the exhumation of any shipment potentially containing the two spent fuel rods. LLRW packages were buried permanently. There are currently no approved engineering, operations, and disposal methods for exhumation of buried wastes at commercial LLRW facilities. Exhumation and the safe management of an exhumed liner and its contents would involve complex and untested engineering and operational activities. Such an exhumation has the potential to create substantial radiation exposure risks to the site workers and the environment for no net benefit. Exposing workers to such significant doses with no net safety benefit is not consistent with the ALARA principle.

References

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Interim Site Stabilization and Closure Plan for the Barnwell Low-Level Radioactive Waste Disposal Facility September 2000, Chem Nuclear Systems Inc.
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(Dunkelman, 2000) Maxine Dunkelman, Groundwater Pathway Analysis for the Commercial Low-Level Radioactive Disposal Site in Richland Washington by the State of Washington Department of Health Division of Radiation Protection, September 5, 2000

(Hamawi, 2001) Report by J.N. Hamawi, Duke Engineering and Services, "MP1-Source Terms and Associated Radiation Fields" NUC-204 Rev. 1, Transmitted under a letter from Richard Cacciapouti to Bryan Ford, dated June 6, 2001

(State of Washington, 2000), Report by the Washington Department of Health, Division of Radiation Protection, "Draft Environmental Impact Statement, Commercial Low-Level Radioactive Waste Disposal Site, Richland, WA, August 2000

(Still, 2001) Letter from Jimmy Still (CNS) to Jerry Keto (NE Utilities) dated June 4, 2001 with attached information package regarding Chem-Nuclear's information regarding shipment of interest to Northeast Utilities and related site data.

(Still, 2001b) Email message from Jimmy Still (CNS) to Bill House (CNS) dated September 7, 2001 regarding details of CNS Barnwell site inventories

(USNRC 1980) "Data Base for Radioactive Waste Management – Review of Low-Level Radioactive Waste Disposal History" prepared by J.J. Clancy, D.F. Gray, O. I. Oztunali, U.S. Nuclear Regulatory Commission NUREG/CR-1759, November 1981

(Weader, II R.J., 2000) Report by R.J. Weader II, Duke Engineering and Services, " Spent Fuel Rod Criticality Calculation", NUC-203, Transmitted under a letter from Richard Cacciapouti to Bryan Ford dated December 22, 2000

(FRAP, 2001) Documentation regarding the Millstone Shipment to US Ecology, transmitted to Michael T. Ryan Ph.D.,C.H.P., February 15, 2001

Appendix A

Shipments to Barnwell South Carolina

Cask	Type of Package	Package Content	Volume (ft³)	Curies (Est)	Contact Exp. Rate	Date Shpd	Date Rcvd	Date Buried	Ship Method
TN-8L	Liner	Irradiated Hardware (3 TN-8L liners from Unit 1 SFP contents)	22.5	4.63E04	5900 R/hr	5/5/88	5/7/88	5/7/88	Truck
TN-8L	Liner	Irradiated Hardware (3 TN-8L liners from Unit 1 SFP contents)	22.5	4.23E04	7420 R/hr	5/16/88	5/18/88	5/18/88	Truck
CNS 3-55	Liner	Irradiated Hardware (1 CNS 3-55 steel liner from Unit 1)	57.4	5.13 E06	2100 R/hr	5/25/88	5/27/88	5/31/88	Truck
CNSI 8-120B	Foamed HIC	Velocity Limiters & Filters	120.3	4.47E04	—	8/4/88	8/6/88	8/6/88	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner from Unit 1 SFP contents)	57.5	18,100	15,000 R/hr	12/5/89	12/7/89	12/7/89	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner from Unit 1 SFP contents)	57.5	17,200	11,300 R/hr	1/16/90	1/18/90	1/18/90	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner from Unit 1 SFP contents)	57.4	1.62E04	10,050 R/hr	5/7/90	5/9/90	5/9/90	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner irradiated reactor components)	57.4	6,900	5,200 R/hr	10/13/92	10/15/92	10/15/92	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner irradiated reactor components)	57.4	8,520	6050 R/hr	12/8/92	12/10/92	12/10/92	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner irradiated reactor components)	57.4	7,510	5,140 R/hr	12/21/92	12/22/92	12/22/92	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner control rod blades, stellite rollers, LPRMs)	57.8	13,100	2940 R/hr	4/14/00	4/17/00	4/17/00	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner control rod blades. stellite rollers, LPRMs)	57.8	1.09E04	2840 R/hr	5/8/00	5/15/00	5/15/00	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner control rod blades, stellite rollers, LPRMs)	57.8	1.06E04	3,230 R/hr	5/19/00	5/19/00	5/20/00	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner control rod blades, stellite rollers, LPRMs)	57.8	4900	—	6/7/00	6/9/00	6/9/00	Truck
TN-RAM	Liner	Irradiated Hardware (1 TN-RAM liner control rod blades, stellite rollers, LPRMs)	57.8	4700	—	7/17/00	7/21/00	7/21/00	Truck
CNSI 8-120B	Liner	Velocity Limiters, Filters & DAW	120.3	11.7	—	7/28/00	8/1/00	8/2/00	Truck

Shipments to Hanford Washington

Cask	Type of Package	Package Content	Volume (ft^3) internal	Contact Exp. Rate	Curies (Est)	Date Shipped	Date Rcvd	Date Buried	Ship Method
IF-300	Carbon Steel (Coated) Liner	Metal Oxides Control rod blades, Beam bolts, channel clips, LPRMs	63.6	30, 000 R/hr	3.9E04	3/20/85	4/1/85	4/1/85	Rail
IF-300	Carbon Steel (Coated) Liner	Metal Oxides (Control Rod blades, Jet Pump Beam Bolts and LPRMs)	63.6	15,000 R/hr	5.33E04	5/29/85	6/6/85	6/11/85	Rail
IF-300	Carbon Steel (Coated) Liner	Metal Oxides (Velocity Limiters, CRB Handles, Poison Curtain Handles, LPRM Hot Sections and Jet Pump Beam Bolts)	93	20,000 R/hr	9290	7/31/85	8/6/85	8/9/85	Rail

MICHAEL T. RYAN, PH.D., C.H.P.

EDUCATION

1982	Ph.D., Health Physics, Georgia Institute of Technology, Atlanta, Georgia. Dissertation title: "The In Vitro Transport of $^{238}PuO_2$ and $^{239}PuO_2$ Through a Membrane Filter and its Importance in Radiation Dosimetry."
1976	M.S. in Radiological Sciences and Protection, University of Lowell, Lowell, Massachusetts. Thesis title: "An Evaluation of Aggregate Recoil Particle Transfer in Glass Fiber Filtration Media."
1975 - 1976	ERDA Traineeship
1974	B.S. in Radiological Health Physics, Lowell Technological Institute, Lowell, Massachusetts
September 1996	University of Virginia, "Service Excellence People Process and Technology," Darden School of Business, Charlottesville, Virginia
June 1995	University of Virginia, "Bargaining and Negotiating: A Learning Laboratory," Darden School of Business, Charlottesville, Virginia
April 1994	University of Pennsylvania, "Implementing Strategy," Wharton School of Executive Education, Philadelphia, Pennsylvania
April 1993	University of Virginia, "Financial Management for Non-Financial Managers," Darden School of Business, Charlottesville, Virginia
October 1992	Northwestern University, "Business-to-Business Marketing Strategy," J. L. Kellogg Graduate School of Management, Evanston, Illinois
April 1992	University of Michigan, "Management of Managers", School of Business Administration, Executive Training Program, Ann Arbor, Michigan

EMPLOYMENT AND EXPERIENCE

SUMMARY

Michael T. Ryan, Ph. D., C.H.P. is an independent consultant in radiological sciences and health physics. He is an Adjunct Associate Professor in the College of Health Professions at the Medical University of South Carolina. He was previously Associate Professor in the Department of Health Administration and Policy. He earned his B.S. in radiological health physics from Lowell Technological Institute in 1974. In 1976, he earned his M.S. in radiological sciences and protection from the University of Lowell under a U.S. Energy Research and Development Administration (ERDA) Scholarship. Dr. Ryan received the Ph.D. in 1982 from the Georgia Institute of Technology, where he was recently inducted into the Academy of Distinguished Alumni. He is a recipient of

the Francis Cabot Lowell Distinguished Alumni for Arts and Sciences Award for the University of Massachusetts Lowell.

Dr. Ryan is Editor In Chief of Health Physics Journal. In 1989, he received Health Physics Society's Elda E. Anderson Award, which is awarded each year to the one young member who has demonstrated excellence in research, discovery, and/or significant contribution to the field of health physics. Dr. Ryan has held numerous offices in the Health Physics Society, including President of the Environmental Section. Over the past ten years, Dr. Ryan has served on the Technical Advisory Radiation Control Council for the State of South Carolina. He is a member of the National Council of Radiation Protection and Measurements (NCRP), a national body chartered by Congress in 1964 to collect, analyze and disseminate information and make public policy recommendations about radiation protection. He is a Scientific Vice President for Radioactive and Mixed Waste Management and Chair of Scientific Committee 87 and a member of the Board of Directors. Dr. Ryan is certified in the comprehensive practice of health physics by the American Board of Health Physics. Dr. Ryan holds adjunct appointments at Texas A & M University, Georgia Institute of Technology, University of South Carolina, and the College of Charleston where has taught radiation protection courses on the graduate level. In addition, Dr. Ryan has authored many refereed articles and publications in the areas of environmental radiation assessment, radiation dosimetry, and regulatory compliance for radioactive materials.

Dr. Ryan's research, grants, and contracts are in the areas of regulatory compliance, compliance data management, occupational radiation dosimetry, environmental management, and radiation protection policy. He has been funded by grants from PHP Healthcare Corporation, Mitsubishi Materials Corporation and the National Council on Radiation Protection and Measurements. Dr. Ryan is active in his consultancy with a number of national corporations. This work generally involves radiological health and regulatory compliance for workplace and environmental issues. He is currently serving on the Scientific Review Group appointed by the Assistant Secretary of Energy to review the ongoing research in health effects at the former weapons complex at Mayak in the Southern Urals of the former Soviet Union and on two Committees of the National Academy of Sciences.

Prior to his appointment at MUSC, Dr. Ryan was most recently the Vice President of Barnwell Operations for Chem-Nuclear Systems, Inc., and had overall responsibility for operation of the low-level radioactive waste disposal and service facilities in Barnwell, South Carolina. Dr. Ryan's area of responsibility included financial management of a profit and loss budget exceeding $50 million; management of a over 200 scientific, technical, and support staff; implementation of the scientific programs that assure the safe and compliant operation of the company's low-level radioactive waste processing and disposal facilities. These programs include facility operations and implementation of policy and procedures for operation, environmental monitoring and regulatory compliance. Prior to this assignment Dr. Ryan served since 1988 as the Vice President of Regulatory Affairs, having responsibility for developing and implementing the Company's regulatory compliance policies and programs to comply with state and federal regulators. Before joining Chem-Nuclear Systems, Inc., as Director of the Environmental and Dosimetry Laboratory in 1983, Dr. Ryan spent seven years in environmental health physics at Oak Ridge National Laboratory.

PROFESSIONAL ASSIGNMENTS

July 2001 - Present	Radiological Sciences Consultant
February 1997 - Present	Medical University of South Carolina, Charleston South Carolina
September2001- Present	Adjunct Graduate Faculty, Texas A & M University
July 2001 – Present	Adjunct Associate Professor, College of Health Professions
Jan 1998 – June 2001	Associate Professor, Department of Health Administration and Policy Responsibilities included administrative, research, and teaching activities related to the mission of the Department and University. These duties include development of research proposals, the conduct of research, classroom instruction, and support of the departments ongoing masters and doctoral academic programs. Department Associate Chair, April1999 - April 2000 Faculty Affairs Committee 1997/1999 College Research Subcommittee 1997/1998 Faculty Assembly Chair-Elect 1998, Chair 1999 Academic Affairs, 1997-1999 Administrative Affairs, 1999-2000 MHA Admissions Committee, 1999-2000 Joint MUSC/Clemson Program Committee, 1999-2000 MHA Recruitment Task Force, Ad Hoc, 1999-2000 United Way Coordinator 1999/2000
February 1997 – January 1998	Associate Professor and Program Director, Environmental Health Sciences Department. Responsibilities included research and teaching activities related to the mission of the Department and University. These duties included development of research proposals, the conduct of research, classroom instruction, and support of the department's ongoing academic programs.
April 1996 - January 1997	Chem-Nuclear Systems, Inc., Columbia, South Carolina. Vice-President, Barnwell Operations Responsibilities included the safe and efficient operation of Chem-Nuclear facilities in Barnwell, South Carolina. These facilities include the low-level radioactive waste (LLRW) disposal facility site and the LLRW consolidation facilities along with related operational and support facilities. The responsibilities for this position included health, safety and environmental management, operational management, strategic planning and business development.

June 1991 - April 1996	Chem-Nuclear Systems, Inc., Columbia, South Carolina.
	Vice-President of Regulatory Affairs. Responsibilities included the implementation of programs that assure corporate compliance objectives were achieved. These programs included safety, environmental monitoring, licensing, quality assurance, occupational radiation exposure and control, health physics and document control. These programs encompassed the various business units of the company as well as low-level radioactive waste treatment disposal facilities being developed by CNSI. Management responsibilities also included Diversified Scientific Services, Inc. (DSSI), a mixed radioactive and hazardous waste thermal destruction facility, permitted by the State of Tennessee and the EPA, which specializes in the thermal destruction of RCRA and radioactive mixed waste liquids.
September 1987 - June 1991	Chem-Nuclear Systems, Inc., Columbia, South Carolina.
	Executive Director of Regulatory Affairs. Responsible for the overall management and direction of compliance programs within all areas of CNSI. These programs included safety, environmental monitoring, licensing, quality assurance, occupational radiation exposure and control, health physics and document control. These programs encompassed the various business units of the company as well as low-level radioactive waste disposal facilities being developed by CNSI.
March 1984 - September 1987	Chem-Nuclear Systems, Inc., Barnwell, South Carolina.
	Director of Regulatory Affairs. Responsible for the regulatory compliance areas of safety, environmental monitoring, occupational radiation exposure and control, health physics, and licensing for all CNSI activities. These responsibilities included the company's operating low-level radioactive waste facility at Barnwell, SC.
April 1983 - March, 1984	Chem-Nuclear Systems, Inc., Barnwell, South Carolina.
	Director of Environmental and Dosimetry Laboratory. Responsible for the direction of the environmental monitoring and occupational radiation exposure and control program for the Barnwell Disposal Facility.
January 1983 - April 1983	Industrial Safety and Applied Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN.
	Section Head, Radiation Dosimetry Dose Data and Radioassay. Supervised the analysis of bioassay samples.

	Supervised and performed data interpretation for all dosimetry related measurements. Supervised the data base management for all personnel dosimetry records.
February 1981 - January 1983	Industrial Safety and Applied Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
	Internal Radiation Dosimetrist. Responsible for the evaluation of all significant internal exposures by interpretation of bioassay and in vivo counting data
September 1976 - February 1981	Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
	Research Associate. Integrated radiological assessment of the phosphate industry. This assessment examined the non-occupational and environmental impacts of the phosphate industry in the United States.
	Radiological Survey Team Leader - FUSRAP Program. (Formerly Utilized Sites/Remedial Action Program), Planning, execution, and report writing of radiological assessment surveys of former Atomic Energy Commission (AEC) and Manhattan Engineer District (MED) industrial sites. Team consisted of up to ten scientific and technical personnel, depending upon the site.
	Division Safety Committee, Member, July 1, 1979 to July 1, 1980 Division Safety and Radiation Control Officer, July 1, 1980 to February 1981. Environmental Protection Officer, July 1, 1980 to February 1981
September 1977 - September 1978	Georgia Institute of Technology, Atlanta, Georgia. Educational leave of absence for work toward the degree of Doctor of Philosophy
	Reactor Operator - AGN-201 Licensed March 17, 1978, NRC #R-111 (Concurrent with academic program).
June, 1975 - September 1976	Division of Chemical Technology, Oak Ridge National Laboratory, Oak Ridge, Tennessee
	Research Associate. (Summer months only).
April 1975 - June 1975	Defense Civil Preparedness Agency (DCPA), University of Lowell, Lowell, Massachusetts
September 1973- June 1974	Consultant (Course Material Preparation) University of Lowell, Lowell, Massachusetts Research Assistant. (Academic months only.)
1990 - 1991	President, Savannah River Chapter of the Health Physics Society

CERTIFICATIONS AND AWARDS

2000	Nominated for the MUSC Health Sciences Foundation Award of Educator-Mentor of the Year
1982	Certified by the American Board of Health Physics in Comprehensive Practice (Re-certified in 1986, 1990, 1994, and 1998)
June1989	Recipient of Elda E. Anderson Award, Health Physics Society
November 1996	Elected to the Academy of Distinguished Alumni by the Georgia Institute of Technology, College of Engineering
September 1998	Recipient of the Francis Cabot Lowell Distinguished Alumni Award for Arts and Sciences

PROFESSIONAL EXPERIENCE

July 2000	Appointed Editor-in-Chief of the Health Physics Journal
May 1999 to present	Member of the Committee E-36 on TENORM Implementation Standards for the Conference of Radiation Control Program Directors
August 1999	Preceptor and Faculty Associate Department of Health Policy and Administration, University of North Carolina at Chapel Hill
April 1999	Elected to the Board of Directors of the National Council on Radiation Protection and Measurements
January 1999	Appointed to the University of Lowell Foundation Board of Advisors
February 1998 - present	Member of the Task Force on TENORM for the Conference of Radiation Control Program Directors
December 1998 - present	Senior Associate Editor, Operational Radiation Safety
1998-2001	Board of Visitors, Charleston Southern University
April 1998	Appointed as Chairman of Scientific Committee 87 and Scientific Vice President for the Program Area of Radioactive and Mixed Waste for the National Council on Radiation Protection and Measurements
July 1997	Appointed to the Scientific Review Group (SRG) for the Department of Energy (DOE) funded work group under the auspices of the Joint Coordinating Committee for Radiation Research Effects (JCCRER)
January 1996 - June 2000	Book Editor, Health Physics Journal.

September, 1995 -	Adjunct Professor, Health Physics, The George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia
August 1995 - present	National Council on Radiation Protection and Measurements' representative to the Conference of Radiation Control Program Directors' Committee on Naturally Occurring Radioactive Materials (NORM).
1995 - 1997	Member of the State and Federal Regulations Committee of the Health Physics Society
1995 - present	Member of the National Council on Radiation Protection and Measurements Scientific Committee 87
1993-1994	Radiation Control Research and Education Foundation, Frankfort, KY, Member of Board of Directors
March 1992 - 2004	Member of the National Council on Radiation Protection and Measurements (re-elected in 1998)
1990 – 1991	President of the Savannah River Chapter of the Health Physics Society
September 1988 - Present	Adjunct Associate Professor, Department of Environmental Health Sciences, University of South Carolina, Columbia, South Carolina.
March 1987 - July 2000	Associate Editor, Health Physics Journal
September 1986 - present	State of South Carolina Technical Advisory Radiation Control Council appointed by Governor Richard Riley; named Chairman in September 1991. Re-appointed by Governor Beasley in 1996.
1984 - 1996	Advisory Committee Member, Nuclear Engineering Technology Program, Aiken Technical College, Aiken, South Carolina, Chairman August, 1992 - November, 1995.
1984 - 1986	Health Physics Society, Member Health Physics Related Research Ad Hoc Committee
July 1986 - July 1992	Health Physics Society Representative (Alternate), Standards Committee N13 (Radiation Protection)
1985	President, Environmental Radiation Section of the Health Physics Society (3-year term on Board of Directors as President-Elect 1984, President 1985 and Past-President 1986.)
1985	Program Committee, Savannah River Chapter of the Health Physics Society

1984	American Board of Health Physics Member Panel of Examiners
1984 - 1991	National Council on Radiation Protection and Measurements Member Task Group 7 of Committee 64 (Radionuclides in the Environment).
1982	Member of the 1982 Marshall Islands Dosimetry and Medical Field Evaluation Team
1981	Member of the 1981 Marshall Islands Dosimetry and Medical Field Evaluation Team
1981	Member of the Governor's Hazardous Waste Policy Council, State of Florida.

PROFESSIONAL MEMBERSHIPS

Health Physics Society
Sigma Xi
American Industrial Hygiene Association
New York Academy of Science
American Public Health Association