Dominion Nuclear Connecticut, Inc.
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Dominion

OCT 5 2001

Docket No. 50-245
B18496

RE: 10 CFR 70

Director
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Millstone Power Station, Unit No. 1
Issuance of Final Report
Pertaining to Unaccounted for Spent Fuel Rods

Dominion Nuclear Connecticut, Inc. (DNC) hereby forwards a copy of the Fuel Rod Accountability Project (FRAP) Final Report (Attachment 1), generated by Northeast Utilities, pertaining to the investigation of two unaccounted for Millstone Unit No. 1 spent fuel rods.

The two fuel rods that are the subject of the investigation were determined to be unaccounted for by Northeast Nuclear Energy Company (NNECO) prior to the March 31, 2001, sale of Millstone Station to Dominion Nuclear Connecticut, Inc. (DNC). The final report is under review by DNC at this time.

There are no regulatory commitments contained within this letter.

If you have any questions regarding this matter, please contact Mr. David A. Smith, at (860) 437-5840.

Very truly yours,

DOMINION NUCLEAR CONNECTICUT, INC.

FOR: J. Alan Price, Vice President
Nuclear Technical Services - Millstone

BY: Stephen E. Scace
Stephen E. Scace
Master Process Owner - Manage the Asset

Attachment (1)

cc: See next page

A001

cc: H. J. Miller, Region I Administrator
J. B. Hickman, NRC Project Manager, Millstone Unit No. 1
T. J. Jackson, NRC Inspector, Region I, Millstone Unit No. 1

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Director
Bureau of Air Management
Monitoring and Radiation Division
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127

Docket No. 50-245
B18496

Attachment 1

Millstone Power Station, Unit No. 1

Fuel Rod Accountability Project (FRAP) Final Report

Northeast
Utilities System

Millstone Unit 1

Fuel Rod Accountability Project

Project Number M10063

FINAL REPORT

Northeast Utilities System

107 Seldon Street, Berlin, CT 06037

Northeast Utilities Service Company
P.O. Box 270
Hartford, CT 06141-0270
(860) 442-7747
Fax (860) 444-5466

Frank C. Rothen
Vice President - Nuclear Services

October 1, 2001

VIA HAND DELIVERY

William R. Matthews
Vice President and Senior Nuclear Executive
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Re: Final Report of the Millstone Unit 1 Fuel Rod Accountability Project

Dear Bill:

On behalf of Northeast Utilities, I have enclosed the Final Report of the Millstone Unit 1 Fuel Rod Accountability Project.

Please extend my appreciation to the employees of Dominion Nuclear Connecticut, Inc. for their cooperation and support throughout the Project and my best wishes for their continued success.

Sincerely,

Frank C. Rothen

Millstone Unit 1

Fuel Rod Accountability Project

Project Number M10063

FINAL REPORT

Prepared: *Robert V. Fairbank* Date: *10/1/01*
Robert V. Fairbank
Project Manager

Approved: *[signature]* Date: *10/1/01*
Frank C. Rothen
Executive Sponsor

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1.0 EXECUTIVE SUMMARY

BACKGROUND

On September 1, 1972, Millstone Unit 1 condenser tubes failed and seawater entered the reactor coolant system. Station management requested that General Electric ("GE") help determine the effect of chlorides in the seawater on nuclear fuel components. In October 1972, GE personnel disassembled fuel assembly MS-557 in the Unit 1 spent fuel pool ("SFP" or "pool"), stored all of the 49 fuel rods in seven specially designed eight-rod containers, and shipped the non-fuel irradiated hardware to GE's Vallecitos Nuclear Center in Pleasanton, CA ("VNC" or "Vallecitos"). GE personnel recorded the placement of the rods into the eight-rod storage containers and also noted that one of the fuel rods (a tie rod) had been damaged in handling. Millstone personnel did not record the location of the eight-rod containers within the pool.

In April 1974, GE returned to re-assemble MS-557. They did not, however, return the damaged tie rod or the center spacer capture rod to the reconstituted assembly. GE personnel used a dummy center spacer rod to support the assembly and left a vacancy where the damaged tie rod would have gone. GE records of this work do not reflect what became of the two rods that had been stored separately in an eight-pin storage container in the spent fuel pool since 1972. Likewise, the Unit 1 Reactor Engineer prepared a record of the reconstitution of assembly MS-557, but made no mention of the center spacer capture rod or the tie rod.

In May 1979, the Unit 1 Reactor Engineer asked on-site GE personnel to read the serial numbers inscribed on the end plug of two rods in an eight-rod container to determine their origin. Using the partially legible serial numbers, the Reactor Engineer and GE personnel concluded that the rods were the two rods removed from the MS-557 seven years earlier.

The Reactor Engineer documented this work and created a data card in the Kardex file to document the location of these two rods in the eight-rod storage container. Later maps of the spent fuel pool drawn in February and April 1980, show the two fuel rods from MS-557 in the northwest corner of the pool. A third map, drawn in September 1980, and initialed by the same Reactor Engineer, omits the two MS-557 fuel rods. The team has not found any record prepared after April 1980, that refers to these two rods in any way.

In late-1980, the Reactor Engineer left Millstone and another engineer assumed the Reactor Engineer's responsibilities. Neither the new Reactor Engineer, nor any other individual interviewed by the team (except for the first Reactor Engineer and the Special Nuclear Material ("SNM") accountant at that time), indicated that they had any knowledge of the presence of two separate fuel rods in the spent fuel pool after 1980.

DISCOVERY

During document reviews conducted in connection with the decommissioning of Millstone Unit 1 in 2000, engineers found records from 1979 and 1980, indicating that during those years two fuel rods from MS-557 were being stored separately, i.e., not with their parent fuel assembly. Because these two rods did not appear to be accounted for in current records, the engineers looked for additional information about the disposition of those fuel rods. The most recent records that they found which reflected the location of the fuel rods in the Millstone Unit 1 spent fuel pool were created in 1979 and early 1980.

INVESTIGATION

When the engineers reported to management that their records review and preliminary investigation did not resolve the issue, Northeast Nuclear Energy Company ("NNECO") promptly initiated an internal Condition Report, reported the matter to the Nuclear Regulatory Commission ("NRC"), and initiated an investigation under the direction of Unit 1 management. In December 2000, NNECO retained the support of five industry experts, including engineering and nuclear fuels experts, as well as former senior executives from the NRC. NNECO expanded the search effort in January 2001 by forming a dedicated project team, the Fuel Rod Accountability Project ("FRAP" or "Project"), including over 20 individuals with diverse backgrounds and expertise to conduct the investigation. From January through September 2001, the team conducted an investigation to determine the location of the two fuel rods.

CONCLUSIONS

The Project team reviewed thousands of documents, interviewed almost two hundred knowledgeable individuals, and performed many hours of videotaped underwater inspections of the Unit 1 spent fuel pool. Despite these efforts, the investigation did not yield clear and convincing evidence of the precise location of the two fuel rods. Nevertheless, the investigation has established that the fuel rods are safely located in a facility that is licensed to store or dispose of radioactive material. Specifically, the investigation has determined that the rods are: (a) in an undetermined location in the Unit 1 spent fuel pool; (b) at GE's Vallecitos nuclear fuel facility; or (c) at one or both of the low-level radioactive waste ("LLRW") disposal facilities in Barnwell, South Carolina ("Barnwell") or the Hanford reservation in Richland, Washington ("Hanford"). Even if inadvertently shipped to a LLRW facility, the presence of the rods does not pose a danger to the health and safety of workers, the public, or the environment.

Although the evidence developed in the investigation was not sufficiently clear and convincing to conclude that the fuel rods are in one specific location, the evidence was substantial enough to permit some qualitative assessment of opportunities for inadvertent shipments. In this regard, the likelihood that the rods remain in the Unit 1 spent fuel pool is low. A detailed inspection of the accessible areas of spent fuel pool did not locate the rods. But the best reasonable efforts of the inspection team were not able to examine all areas of the pool or all areas where smaller sections of the rods might have been placed if they were segmented. Moreover, for safety reasons, the team did not disassemble each of the 2884 fuel assemblies in the pool to conduct a rod-by-rod inspection.

Similarly, the likelihood that the fuel rods are at GE's Vallecitos nuclear facility is low. The official records and inspection procedures implemented for SNM at that facility provide confidence that, if shipped, the records would reflect the presence of the rods. Nevertheless, there remain several important – and unanswered -- questions about a 1980 shipment to that facility that prevent the investigation from removing this location as a possible location of the rods.

One of the three shielded shipments from Unit 1 to the Hanford LLRW facility in 1985 provided some small opportunity to inadvertently ship the fuel rods. But there is no direct evidence and little circumstantial evidence available to support a conclusion that the rods were actually shipped.

Of the four possible locations, the LLRW facility at Barnwell, SC had the most significant opportunity to receive the rods. In particular, three shipments in 1988 contained the segments of about 90 Local Power Range Monitors ("LPRMs") that had been cut into pieces many years earlier and stored in containers in the spent fuel pool. These items, which are very similar in appearance to the fuel rods, were most likely cut in late 1979, shortly before the fuel rods disappeared from later spent fuel pool maps. Because the workers cutting the LPRMs lacked experience with reactor components, the workers may have mistakenly cut the fuel rods believing them to be LPRMs, and placed them in a container with the LPRMs. Many, if not all, of the LPRMs in that container were shipped to Barnwell in 1988.

Having concluded that the LLRW facility at Barnwell had a significant opportunity to receive the fuel rods does not mean that there is clear and convincing evidence that the rods are there. The evidence simply does not support that conclusion. In fact, there is <u>no</u> evidence, either in the form of documents or from interviews, that actually places the fuel rods in any of the off-site shipments to Barnwell or any other facility. The identification of the 1988 shipments to Barnwell as a potential explanation for the disposition of the fuel rods must be read in that context and not regarded as an established fact.

THE UNIT 1 SPENT FUEL POOL

The team performed focused, as well as comprehensive, inspections of the spent fuel pool. Fuel specialists used video cameras and radiation monitors to inspect thousands of fuel assemblies and other items in the pool. Inspectors used these devices remotely from the refuel deck floor or a refuel bridge that travels over the length of the pool. A crawler-mounted camera inspected the entire pool floor.

The results of the inspections revealed that there is a low likelihood that the fuel rods remain in the spent fuel pool. Indeed, the comprehensiveness and quality of the inspections strongly suggests that the fuel rods are not in the pool. The inspections addressed both the most likely places that the rods would be stored, as well as the places that full-length rods (or large segments of fuel rods) could be stored. But the best reasonable efforts of the inspection team were not able to examine all areas of the pool or all areas where segments of rods might have been placed. Indeed, if the fuel rods were cut – and there is evidence that they could have been – there remain many areas in the pool where smaller segments could be housed that could not have been seen during the inspections. Additionally, safety considerations, pragmatism, and prudence precluded a rod-by-rod inspection of the more than 167,000 fuel rods in the pool. Only after all of the spent fuel assemblies and other material have been inventoried and removed from the spent fuel pool can the question of the two rods' presence in the pool be finally determined.

THE GE FACILITY AT VALLECITOS

So too, the fuel rods are very likely not at the GE Vallecitos facility. Nevertheless, one shipment of spent fuel rods from Unit 1 in April 1980 contains discrepancies in the GE shipping and receipt documents, as well as in certain NRC documents. Additionally, after this shipment occurred, there are no known records that refer to the fuel rods.

To be sure, the shipping and receipt records for that April 1980 shipment, as well as the established GE procedures and practices, provide strong evidence that the rods are not at GE Vallecitos. Indeed, the contents of the shipping container were examined at Vallecitos and there is no indication that the examination revealed the presence of the two fuel rods from MS-557. Moreover, the official record of this SNM shipment, the DOE/NRC Form 741, does not indicate that the rods were shipped. The GE receipt records for certain non-fuel items in that shipment, however, are inconsistent with the shipping records. The inconsistency does not establish that the rods were shipped, but multiple discrepancies in the shipping records preclude unconditional reliance on the documents. More important, an unexplained difference exists between the weight of the SNM shipped (2.4 kg), and the entries on two NRC records that indicate that GE received 8.8 kg of spent fuel. The difference between these amounts is slightly less than the weight of the SNM in the two fuel rods.

These facts are sufficient to maintain the Vallecitos facility as a possible location of the rods. The loading of the segmented test rods in this shipment on May 5, 1979, and the unexplained movement of MS-557, the parent assembly of the two fuel rods, on that same day, creates another potential link between this shipment and the two fuel rods. The disappearance of the two fuel rods from all known documents immediately after the April 1980 shipment, and the disappearance of the two rods from the memories of those who should have seen or remembered the rods, adds to the uncertainty about this shipment. Again, the compilation of these matters does not establish that the rods are at Vallecitos. The possibility that they are, however, cannot be dismissed.

THE LLRW FACILITY AT HANFORD

There is no credible evidence, and certainly no clear and convincing evidence, proving that the fuel rods were shipped to the U.S. Ecology LLRW facility at Hanford. An opportunity for the inadvertent shipment of the rods, however, existed to some small degree in three shipments in 1985. The likelihood of an inadvertent loading of the rods in the first two shipments, however, is not significant. The loading of the first shipment by experienced GE personnel and the relative certainty regarding the identity of items bearing any resemblance to fuel rods in the second shipment, reduce considerably the opportunities for either of these shipments to have contained the fuel rods. And for the third shipment, only the inclusion of the hot sections of eight local power range monitors ("LPRMs") of uncertain origin causes this shipment to stand apart somewhat from the other two shipments to Hanford. Mistaking a fuel rod for an LPRM hot section is possible because of the similarities in appearance between an LPRM and a fuel rod. The identity of the items described as segments of LPRM hot sections in the third shipment cannot be established with certainty because the source of these items cannot be determined. A possibility exists that workers who were unfamiliar with reactor hardware may have cut the fuel rods by mistake in late-1979, when cutting a large build-up of LPRMs stored on the walls of the spent fuel pool. If the workers made such a mistake and stored the cut rods with cut LPRMs, and if the LPRM sections chosen for this shipment included cut rods, there is a chance that the rods, or a piece of the rods, could have been inadvertently included in this shipment. Given the relatively small quantity of LPRM sections in this shipment, however, the opportunity is not substantial.

THE LLRW FACILITY AT BARNWELL

There is no clear and convincing evidence that the fuel rods were shipped to the Chem-Nuclear facility at Barnwell, but the evidence available indicates that the opportunities for the inadvertent shipment of the rods to Barnwell are higher at this facility than any of the other three possible locations. Of the 16 shielded shipments to Barnwell that were investigated by the Project, two TN-8L cask shipments and the one CNSI 3-55 cask shipment to Barnwell in May 1988, stand out as having the most significant opportunity to contain the fuel rods.

In these three shipments, records indicate that WasteChem workers loaded the segments of somewhere between 90 and 98 items, described as LPRM hot sections. Other records establish, however, that there were less than 90 LPRMs in the spent fuel pool available for shipment. Thus, the shipments included a substantial quantity of LPRM-like material presumed to be LPRMs, but which were probably not LPRMs, given the total number of LPRMs that had been removed from the core and stored in the spent fuel pool. That disparity suggests the possibility that the fuel rods – or other LPRM-like items – were inadvertently included among the LPRM hot sections.

The evidence is clear that, regardless of the precise number of LPRMs included in those shipments, the vast majority of these LPRMs were from the 1979 LPRM cutting campaign discussed previously. The records also show clearly that neither NNECO nor WasteChem knew precisely the identity or characteristics of the items they considered to be LPRMs, which they had retrieved from old containers that had been stored in the pool. If the contractors from 1979 mistakenly cut the fuel rods, believing them to be LPRMs, and placed them in containers with LPRMs, it is likely that those cut rods were included in one or more of the May 1988 shipments. As discussed earlier, however, this evidence is not sufficiently clear and convincing to support a conclusion that the fuel rods were included in these, or any other shipments.

THEFT OR DIVERSION

The investigation found no evidence or data of any sort suggesting that the rods had been stolen or diverted. Not a single interview or document provided any indication of theft or diversion. Nevertheless, the team conducted an investigation to search for any indication of the failure of the multiple physical, technical, and administrative barriers, which protect the fuel from this possibility. The investigation found no such failure.

The barriers to theft and diversion are many and interlocking. First, the nature of the rods themselves makes theft inherently risky. They cannot be handled without the person taking special precautions to guard against receiving a high and potentially lethal dose of radiation. This means that if a person tried to remove the rods from the spent fuel pool without placing the rods in a properly shielded cask, the person would receive a very substantial, and potentially lethal, dose of radiation.

Second, if someone were to try to steal the rods without the necessary shielding, multiple radiation alarms on the refuel floor and various other radiation alarms throughout the reactor building would sound, signaling the presence of radiation and triggering various systems' responses, as well as a response from Control Room, Site Security, and Health Physics personnel.

Third, if a thief were to try to use a cask of some sort to hold the spent fuel rods, the task of bringing the cask into the reactor building and loading the cask on the refuel floor would be cumbersome and obvious. Among other things, this activity would require the use of heavy equipment and a crane, the acquiescence of supervision, and the breach of multiple security barriers and Health Physics checkpoints. Additionally, various security barriers and work procedures exist that restrict access only to persons authorized to be in the locations and trained to perform specific work in those locations.

Fourth, any unauthorized work around the spent fuel pool would be subject to discovery by workers, Health Physics technicians, supervisors, operators, and contractors in the area, all of whom are trained to report suspicious activity, particularly unusual activity associated with nuclear fuel. Health Physics personnel, in particular, carefully monitored the placement in, and removal of any item from, the spent fuel pool.

Fifth, security barriers, security alarms, Health Physics checkpoints, and other measures exist to ensure that unauthorized material does not leave the refuel floor, the reactor building, or the site.

Wholly apart from the various radiation, security, and personal barriers that exist to prevent theft, there would be little or no reason for someone to incur the expense, the extraordinary risk, and potential consequences associated with stealing two spent nuclear fuel rods. The fissile material contained in those rods is far less than that needed to achieve criticality or to create a nuclear device or weapon.

Additionally, the two spent fuel rods have no economic value. In fact, the radioisotopes found in the fuel rods are largely available in numerous commercial applications around the world and exist in businesses and locations far less secure than a nuclear power plant.

Finally, persons in the plant would have no motive to divert or improperly dispose of the rods in some unauthorized manner or in some unauthorized location, even if they could overcome the barriers. The presence of two fuel rods in a spent fuel pool has essentially no impact on the unit, its operations, or the costs of conducting business, either in the short or long-term. Moreover, the barriers and difficulties associated with an unauthorized disposal do not differ in substance from the barriers that prevent theft.

In short, a person attempting the theft or diversion of these rods would be risking almost certain detection and life-threatening health effects for items of virtually no value. Moreover, there is simply no evidence that the two fuel rods were stolen.

HEALTH AND SAFETY CONSIDERATIONS

Because the only possible locations for the fuel are facilities designed and licensed to store or dispose of nuclear material, the two fuel rods pose no identifiable risk to public health or safety. Although the Hanford and Barnwell low-level waste facilities are not authorized to accept spent nuclear fuel, they are licensed to receive and dispose of all of the radionuclides contained within that fuel. In fact, both facilities have significantly higher quantities of these radionuclides in their current inventories.

Wastes shipped to LLRW facilities are stored in liners transported by specially designed and licensed shipping casks. These low-level waste shipments are surveyed at the shipper's location before departure to ensure that radiation levels meet federal Department of Transportation and NRC standards designed to ensure the protection of public health and safety during shipment. The radiation levels of the fuel rods, if shipped, would fall well below those safety thresholds. Indeed, if shipped, the radiation levels of the fuel rods would have been lower than the radiation level of some of the other irradiated material authorized to be included in the shipment.

Upon arrival at the low-level waste disposal facilities, the liners were removed from the shipping cask and quickly deposited in burial trenches and covered with earth to shield workers and the public from radiation.

The presence of the two fuel rods does not introduce any different radioactive element than already exists in significantly greater quantities at either facility. The analysis supporting the scientific evaluation of each facility assumes that the sites will dispose of these same radionuclides in higher quantities than both rods contain. Accordingly, the two rods do not present a challenge to the effectiveness of these facilities' ability to protect public health and safety, worker safety, or the environment.

2.0 INTRODUCTION

During reconciliation and verification of the Millstone Unit 1 spent nuclear fuel records in connection with decommissioning activities at Millstone Unit 1 in 2000, engineers uncovered records calling into question the precise location of two irradiated fuel rods. These fuel rods, filled with ceramic pellets containing uranium, measure approximately 13 feet in length, one-half inch in diameter, and are clad in a zirconium alloy tube. A picture of a fuel rod appears in Section 1 of the Appendix. The records indicated that the two irradiated fuel rods had been separated from a fuel assembly that had been disassembled for inspection by GE in 1972. A 1979 memorandum indicated that in May 1979, personnel from Northeast Nuclear Energy Company ("NNECO"), the operator of Millstone Unit 1, and GE physically verified the identity of the displaced rods. The records also indicated that the rods would be stored in the northwest corner of the Unit 1 spent fuel pool until they could be moved to another fuel assembly.

By mid-November 2000, the engineers at Unit 1 who discovered the 1979 records determined that they could not identify the location of the two fuel rods. Accordingly, on November 16, 2000, they prepared a Condition Report (CR M1-00-0548), thereby entering the issue into the site's Corrective Action Program. NNECO made timely notifications to the Nuclear Regulatory Commission ("NRC") and other stakeholders. Also, in accordance with NRC reporting requirements, on December 14, 2000, NNECO submitted a formal telephonic report to the NRC describing the information then available about the fuel rod accountability issue. NNECO submitted a Licensee Event Report, LER 2000-002, and a Supplement to that report on January 11, 2001, and March 30, 2001, respectively.

2.1 Background

On September 1, 1972, Millstone Unit 1, a nominal 652 MW (electric) GE boiling water reactor ("BWR"), experienced condenser tube failures that resulted in an introduction of seawater into the condensate system.[1] Chlorides in the seawater caused a breakdown of the condensate demineralizers and a subsequent chloride intrusion into the reactor coolant system. Part of GE's effort to determine the effects of the chloride intrusion on nuclear fuel components included the October 1972 disassembly and inspection of fuel assembly MS-557.[2] Following disassembly, GE placed all forty-nine fuel rods from MS-557 in GE eight-rod containers and stored them in the Unit 1 SFP.[3] During handling in 1972, a tie rod (serial number BP0406) received damage to its upper end plug.[4] Neither it, nor the original center spacer rod (serial number BK0136) were re-used when, in May 1974, GE re-assembled MS-557.[5] GE records indicate that, after disassembly in 1972, workers stored both the damaged tie rod and the center spacer rod in the spent fuel pool in one eight-rod container with no other fuel rods.[6] A cross-sectional view of a GE BWR fuel assembly appears in Section 1 of the Appendix.

On May 12, 1979, GE examined the two fuel rods in an eight-rod container and attempted to identify their serial numbers.[7] Because of limited visibility, they were not able to read accurately all of the serial numbers inscribed on the circumference of the end plug of each rod.[8] GE later verbally indicated that the serial numbers, as read, were very similar to those of the two fuel rods orphaned during the 1974 re-assembly of MS-557.[9] Based on this information, NNECO concluded that the two fuel rods were from MS-557.[10] A NNECO memorandum of May 15, 1979, also indicates that the rods would be stored in a fuel rod storage rack in the northwest corner of the SFP until they could be "incorporated in a scavaged (sic) fuel assembly."[11] The Unit 1 Reactor Engineer documented the location of the rods in the fuel history card file and in the memorandum of May 15, 1979.[12] Spent fuel pool maps of February and April 1980 show the rods in the northwest corner of the pool. Later spent fuel maps and documents do not identify the location of the two fuel rods or refer to them in any way.

2.2 NNECO's Initial Investigation

After learning of the fuel rod issue in mid-November 2000, Unit 1 management promptly established a team to locate the rods and initiated an assessment of the expected radiation levels of the two fuel rods. NNECO also conducted a review of records related to Unit 2 and Unit 3 and confirmed the presence of all spent nuclear fuel for those units.

Radiation levels, on contact, for each of the two missing rods were about 2000R/hr in the early 1980's, and approximately 1000R/hr in 2000. Based upon these radiation levels, NNECO concluded that the attempted removal of the rods from the SFP, in anything other than in a shielded cask, would have triggered multiple plant alarms and would have resulted in incapacitating, if not lethal, radiation doses to the individuals involved. Alternatively, introduction or removal of a cask of sufficient size and shielding would require the knowledge and involvement of numerous individuals, including plant managers. NNECO concluded, therefore, that theft or diversion of the two fuel rods was highly unlikely.

Accordingly, Unit 1 management developed a plan to locate the rods that focused on the Unit 1 spent fuel pool and at facilities licensed to accept radioactive material. The action plan addressed likely scenarios that either assumed the fuel rods remained in the spent fuel pool, or assumed that the fuel rods left the site inadvertently as part of a low-level waste shipment, or left the site with authorization as part of an authorized shipment of other fuel. NNECO formed two teams, a spent fuel pool inspection team and a records inspection team.

The spent fuel pool inspection team began their physical inspection tasks looking first in the areas that they thought would have the highest potential for locating the fuel rods or areas that could be inspected promptly. The spent fuel pool inspection team conducted visual inspections of the SFP designed around four possible scenarios: (1) the rods were still in their original GE eight-rod container; (2) the rods had been removed from the original container and placed in a different container; (3) the rods had been placed into a fuel assembly; or (4) the rods were stored in another pool location (e.g., empty fuel storage locations, control rod storage tubes, etc.).

GE supported the pool inspection effort by inspecting fuel assembly MS-557 and confirming that the center spacer rod and tie rod were not in the assembly. GE also inspected SRP-2D, an assembly that was used to house the rods removed from the segmented test rod assembly. NNECO inspectors also inspected a damaged fuel assembly (MS-508), a fuel storage canister, the pool floor, and other SFP locations. The inspections did not locate the two fuel rods.

A description of the key pre-FRAP spent fuel pool inspections appears in Section 2 of the Appendix.

The records inspection team focused on finding and reviewing those documents that might provide information on the disposition of the missing rods. The records review team searched NNECO records at Millstone and off-site, and records from other off-site sources, including GE. Types of records searched included Material Transfer Forms ("MTFs"), shipping records, DOE/NRC Form 741 SNM material transfer forms, SNM inventory records, SFP maps, records of the 1988-89 Unit 1 SFP Re-Rack Project, and other related records. The records review did not identify the location of the two fuel rods.

2.3 Formation of the Fuel Rod Accountability Project

In mid-December 2000, when discovery of the location of the missing rods did not appear imminent, NNECO executives augmented the already substantial search effort. First, NNECO formed an Independent Review Team ("IRT") to explore additional possibilities and provide oversight for the ongoing search effort. The IRT included industry experts with significant special knowledge in subject areas relevant to the search, including BWR fuels and fuel handling, nuclear plant operations and maintenance, nuclear engineering, and state and federal regulatory requirements. A summary of the backgrounds of the members of the IRT appears in Section 3 of the Appendix.

In January 2001, NNECO formed the Fuel Rod Accountability Project, retaining an experienced Project Manager to lead the investigation. Not including the IRT, the FRAP team included over 20 individuals retained to focus exclusively on locating the two fuel rods. These individuals averaged 28 years of professional experience gained at over 84 nuclear facilities, with diverse backgrounds, including nuclear fuel specialists, engineering, management, regulatory affairs, project management, and independent assessment.

In addition to the IRT and the FRAP Investigation Team, NNECO also formed a Root Cause Assessment Team, made up of individuals with substantial experience in root cause determinations and led by a recognized expert in the field. Finally, to oversee and coordinate the effort, NNECO also dedicated an experienced Vice President to serve as executive sponsor for the project. From the outset of the Project, senior management at Northeast Utilities, the corporate parent of NNECO, has provided all necessary resources and funding to staff and successfully complete the Project.

2.4 Final Report

This Final Report provides a summary of the Project, a description of the efforts taken to locate the missing fuel rods, and the results of the investigation. The report is presented in two parts. Section 3.0 contains a description of the investigation and the methodology applied to the investigation efforts. Section 4.0 provides the specific findings and conclusions. The Root Cause Assessment Team is preparing a separate report addressing the causes for the loss of accountability of the fuel rods, the reasons why the loss was not detected earlier, an evaluation of the extent of condition, and recommendations for corrective actions.

3.0 CONDUCT OF THE INVESTIGATION

3.1 Mission Statement, Principles, and Guidelines

NNECO assigned the Project the mission to determine the disposition of two missing spent fuel rods. Specifically, NNECO assigned the Project to:

- Conduct a comprehensive investigation, including physical inspections of the Unit 1 SFP, research and review documents and records, and conduct interviews of potentially knowledgeable individuals;
- Conduct an independent assessment of Project activities; and
- Use appropriate Project support to facilitate communications and interactions with internal and external stakeholders.

The fundamental principles underlying and guiding the Project work included:

- Protection of public health and safety;
- Purpose and commitment consistent with the seriousness of the mission;

- Objectivity in the investigatory process;
- Openness and forthrightness in communications with federal and state regulators, the public, and other stakeholders; and
- Cooperation with potentially affected entities

These principles guided the Project team in completion of all assigned tasks.

This Project and all work under it were organized and governed by a set of approved guideline documents. A high level description of the organization, the responsibilities of various individuals, and purpose of the FRAP is contained in the Project Description. The Project Plan describes the investigation methodology and the roles of the different Project participants. Ten Project Guidelines describe the processes used in different phases and aspects of the Project, including administration and records retention, scenario development, conduct of physical inspections, document investigation, conduct of interviews, and training. A listing of the Project Guidelines appears in Section 4 of the Appendix.

3.2 Summary of Investigative Method

The Project's investigation followed two parallel paths, similar to those initially used by Unit 1 management. One team collected and reviewed documents and conducted interviews. Another team performed detailed physical inspections in the SFP. Section 5 of the Appendix contains a flow chart depicting the investigatory process used by the two FRAP teams.

3.2.1 Collection of Documents

The Project executed a process designed to identify, retrieve, and review all available documentation containing information that might help determine the location of the two spent fuel rods. The search included both electronic document database searches and hard copy document storage locations, on and off-site. With the support of the Nuclear Document Services organization at Millstone, the Project performed electronic searches on the nuclear records databases. This document retrieval system includes the capability to search on key words, dates, functions, organizations and other parameters.

In addition to the database searches, the investigation team sought and collected hard copy documents from various locations. Because Unit 1 was already well into the decommissioning process, some historical records related to fuel handling at that unit had been moved, or in some cases discarded. Possible temporary storage locations were included in the search. Documents were collected from various on-site and off-site sources.

In some cases, these records were official departmental records. In other cases, the team recovered records maintained by individuals in local collections.

Through interviews and record searches, the team attempted to recover all existing, available relevant documentation.

Despite the comprehensive search and retrieval process, many important documents could not be found. For example, the FRAP was unable to find many older editions of maps of the Unit 1 spent fuel pool. Additionally, record keeping requirements and practices at Millstone Unit 1, like the rest of the industry, improved over time. Information that might have been helpful in this investigation, especially information related to movements of the two fuel rods in the 1970s or early 1980s, may never have been recorded.

In addition to Millstone locations and parts of the NU nuclear organization in Berlin, CT and elsewhere, Project members also sought and obtained records from other organizations that performed work at the Unit 1 SFP. These sources included the GE facilities in Wilmington, NC, Morris, IL, San Jose, CA and the Vallecitos Nuclear Center. The Project also received records from contractors who supported clean-up projects in the Unit 1 SFP between 1988 and 2000. Additionally, the FRAP collected waste shipping documents from the operators of the LLRW storage facilities in Barnwell, SC and Richland, WA..

Through an approved guideline, the FRAP established a process to review documents collected for information potentially relevant to the disposition of the two fuel rods, and to disseminate that information to the investigators. The guideline also established a mechanism to identify, collate, file, and maintain the documentation in a form suitable for audit. The guideline established formal requirements for reviewers to document the results of "applicability" reviews of each document. After the broad scope "applicability" review, Project members also performed another review for "relevance" to particular issues. Relevant information was extracted and included in an event timeline, as appropriate.

Later, during the course of scenario development when key questions and dates were identified and better understood, the Project performed another round of applicability and relevance reviews in light of the new information and the more mature scenario descriptions. Relevant information was subsequently linked with the one or more scenarios to which it applied. Scenario investigators then reviewed the documents applicable to their scenarios to support their investigations.

3.2.2 Scenario Development

In March and April 2001, the Project conducted a process designed to use the information gathered to develop the universe of plausible scenarios to be investigated. With the assistance of the IRT, Project team members met to identify and discuss various ideas about possible dispositions of the fuel rods based upon their experience and the information contained in the initial document reviews. The Project Manager established a low threshold for scenario plausibility in light of the very early stage of the Project.

In Project meetings, observed by the IRT, team members suggested and discussed a wide range of ideas for possible scenarios. The ideas also included questions and suggestions about the potential disposition of the rods raised by members of the public at periodic Unit 1 decommissioning meetings. The ideas were collected and placed into different categories by location (e.g., Unit 1 SFP, Hanford, etc.), with each scenario assigned a unique identifying number. A complete list of the scenarios considered by the FRAP appears in Section 6 of the Appendix.

Once initial scenario ideas had been identified, the Project Manager assigned a pair of Project team members to more rigorously develop each scenario. Each of these pairs followed a standardized scenario description format designed to identify scenario "attributes" – those facts and assumptions supporting or refuting its plausibility. Upon completion of the detailed scenario descriptions, the pairs brought the scenarios again before the larger Project group and the IRT for discussion of those scenario attributes.

The assigned investigators developed an initial scenario assessment and considered whether the scenario should or should not be regarded as plausible. The team members, again following a standardized format, then identified all known information supporting the scenarios, what conditions needed to be true for the scenario to be plausible, and what assumptions were necessary. They also identified the information, conditions and assumptions that tended to disprove the scenario or make it unlikely to have occurred. After analyzing each scenario, the pairs assessed the plausibility of the scenario and articulated the basis for that assessment. They also recommended any additional actions (e.g., action plan, confirmatory inspections, etc.) that were warranted. The Project Manager and IRT reviewed the scenario descriptions and assessments.

Based upon these plausibility reviews, the FRAP assigned follow-up actions commensurate with the scenario's likelihood or potential significance. Of the seventy-five scenarios assessed by the FRAP, eight required fully developed action plans, ten required one or more confirmatory actions, twelve were determined to be implausible. The thirty-five scenarios that identified locations within the Unit 1 SFP were not subjected to the scenario assessment process. Rather, Project management determined that all in-pool scenarios deemed plausible by the group would be investigated by physical inspection. Six additional Millstone site locations were also investigated by physical inspection. Finally, although considered implausible, because of the significance of the potential consequences, the Project Manager decided to investigate four scenarios involving the possibility of theft or diversion of the fuel rods through an investigation.

The Project prepared detailed action plans and descriptions of confirmatory actions. The Project added additional scenarios as the investigation proceeded. During the course of the investigation, one scenario initially considered implausible (a shipment to Vallecitos in 1980) was upgraded to a full investigation and action plan. The table below presents a summary of the results of the scenario development and assessment process.

FRAP Scenarios by Disposition Method

Location	Action Plan	Confirmatory Actions	Implausible	Physical Inspection	TOTAL
Barnwell	4		1		5
Hanford	3		1		4
Millstone Site	1	3	7	6	17
Morris			1		1
Other			2		2
Unit 1 SFP		3		35	38
Theft/Diversion	3				3
Vallecitos	1	4			5
TOTAL	**12**	**10**	**12**	**41**	**75**

The investigation action plans identify possible measures to prove or disprove the attributes, information, conditions, and assumptions identified in the scenario assessments. Many of the actions in these action plans involved areas for discussion in the interviews conducted by the Project team and Root Cause Assessment team. In some cases, the action plans suggest sample questions designed to help probe the topic. All action plans were reviewed by the IRT and approved by the Project Manager.

Completion of every action in the investigation action plans was not necessary to fully investigate the scenario. Rather, the action plans served as guides to assist the investigators and to inform the interviewers of significant issues. Upon completion of the scenario investigations, the FRAP and IRT reviewed actions relative to each each action plan to ensure that necessary steps had been taken.

3.2.3 Implausible Scenario Analysis

As discussed above, the investigative process led the team to consider a wide variety of potential scenarios, many of which had no factual basis in the documents gathered. Nevertheless, to ensure consideration of even these most unlikely explanations, the team analyzed their plausibility. Although that effort did not directly aid in identifying the precise location of the fuel rods, it assisted the investigation by ensuring that the team did not overlook less obvious possibilities. In so doing, this process provided added assurance that the four locations identified as possible repositories of the rods are, indeed, the only four possible locations.

Given that these scenarios are implausible, there is no need to discuss in detail the scenarios or the basis for the determination of implausibility. For completeness of the report, however, some discussion of this work is warranted.

The team explored a number of scenarios associated with the movement of the fuel rods to another location on or near the Millstone site. For example, it considered whether the rods could have been transferred to another unit's spent fuel pool, or to a radwaste storage facility on-site. In looking at these possibilities, the team not only examined the barriers inherent in such a move, it also conducted a number of confirmatory inspections of the site locations, interviewed appropriate personnel, and reviewed documents associated with the operation and inventory of these facilities.

The team also examined whether the rods could have been removed from the site in something other than a shielded cask and shipped as low specific activity waste ("LSA") to some appropriate facility. Again, the team reviewed relevant processes, procedures, and practices, as well as the radiation levels of the rods and the other items shipped and confirmed that rods could not have been included in such a shipment without detection.

Additionally, the team considered whether the rods could have been shipped to the GE facility in Morris, IL. Knowing that Connecticut Yankee had properly shipped spent fuel to that facility in the past, team members and an IRT member conducted a review of the relevant documents and visited the GE facility to determine whether these rods had been included in any of those shipments. The visit and other analysis confirmed that the rods had not been shipped to GE Morris.

This brief discussion is, by no means, a comprehensive list of the implausible scenarios considered, but it provides some understanding of the scope, objectivity, and level of effort expended to assess even the most unlikely scenarios.

3.2.4 Global Search Plan

During the early weeks of the FRAP, the Project team followed NNECO's prior physical inspections with searches estimated to have a high-likelihood of success in finding the two fuel rods. These physical inspections focused on the gaps between spent fuel assemblies and their storage racks in unchanneled fuel assemblies. The space between an unchanneled fuel assembly and the spent fuel storage rack is sufficiently wide to permit storage of a spent fuel rod. An unchanneled fuel assembly in the spent fuel storage rack in shown in Section 1 of the Appendix. The physical inspection team inspected greater than 350 unchanneled fuel assembly locations by lifting the fuel assembly and inserting a light and a camera into the empty spent fuel rack position.

In addition to the unchanneled fuel assemblies, the FRAP examined a number of raised fuel assemblies – assemblies that did not appear fully seated in the bottom of the fuel racks. Using the same inspection method as used for the unchanneled assemblies, the investigators looked for evidence that the fuel assemblies might be resting on the missing fuel rods. Overall, more than 400 of the 2884 fuel assemblies in the Unit 1 SFP were pulled and inspected during this effort. Again, these inspections involved looking in and around the fuel racks. They did not involve the disassembly of the fuel assemblies or the inspection of the individual fuel rods.

During the course of this inspection of the unchanneled and raised fuel assemblies, the FRAP began developing a detailed and comprehensive inspection plan intended to inspect all likely and accessible areas in the Unit 1 SFP and reactor cavity where full-length rods or rods cut into several foot segments could be stored. With the assistance of personnel from Unit 1 Reactor Engineering, guidance from experts on the IRT, and suggestions and insights from GE, the Project established a comprehensive list of locations capable of physically accommodating the two rods.

This Global Search Plan listed the specific locations to be searched, unique characteristics of that location, and the planned inspection method. As with the non-pool scenarios, when additional information or insights suggested other locations not previously considered, the Project amended the Global Search Plan to incorporate those additional locations. The table below lists the thirty-eight scenarios addressed by inspection or other confirmatory action under the Global Search Plan.

Physical Inspection Scenario Descriptions

Scenario	Description
5.1.1	Inspection of MS-508 storage container.
5.1.2	Inspection of the gap between MS-508 storage container and the gun barrel (control rod rack storage cylinder).
5.1.3	Look for rods on the SFP floor in segments with or without pellets.
5.1.4	Look for fuel pellets separated from fuel rods.
5.1.5	Inspect the SRP-2D fuel bundle.
5.1.6	Examine water rod sites in the 8X8 fuel bundles. (A 7x7 fuel rod can fit into an 8x8 bundle water rod site.)
5.1.7	Inspect fuel assembly MS-557, the host assembly for the orphaned fuel rods.
5.1.8	Inspect unchanneled fuel bundles to see if the missing rods were placed in the gap between fuel bundle and storage rack.
5.1.9	Investigate whether or not a rod could be placed in the gap between a channeled fuel assembly and its storage rack.

Scenario	Description
5.1.10	Examine the area inside control rod blade guides.
5.1.11	Examine the rack cell area occupied by a control rod blade guide.
5.1.12	Inspect the contents, if any, of two square cans located in the SFP.
5.1.13	Inspect boxes of stored LPRMs and verify that no fuel rods are stored there.
5.1.14	Inspect the filter baskets hanging from the SFP wall and video tape.
5.1.15	Examine the Segmented Test Rod (STR) fuel assembly, MSB-125.
5.1.16	Inspect the empty storage racks.
5.1.17	Examine two cells containing debris.
5.1.18	Examine the channel storage racks containing fuel channels.
5.1.19	Inspect the control rod storage racks on the south end of the SFP for any evidence of fuel rods.
5.1.20	Inspect 1 ½" pipe on the north side of the SFP for fuel rods.
5.1.21	Inspect a cask liner used for instrument tubes.
5.1.22	Inspect the internal areas of the fuel preparation machine.
5.1.23	Inspect the fuel preparation machine external areas.
5.1.24	Inspect the two (2) dummy assemblies for possible rework and insertion of the orphan fuel rods.
5.1.25	Free space inspection of areas between fuel racks.
5.1.26	Examine areas between fuel racks and the SFP wall/liner.
5.1.27	Examine the two (2) boraflex coupon containers.
5.1.28	Examine the area between the fuel pool to Reactor cavity gates.
5.1.29	Examine scavenged fuel bundles.
5.1.30	Inspect the new fuel vault area.
5.1.31	Inspect the northwest wall area of the SFP for any objects which may have been placed there.
5.1.32	Examine areas on the top of the fuel racks.
5.1.33	Examine the raised fuel assemblies to determine why they will not seat and to look for the orphaned fuel rods.
5.1.34	Inspect the free space under the fuel racks.
5.1.35	Examine fuel assemblies for signs of disassembly and rework.
5.1.36	Examine miscellaneous items around and in pool. Stellite ball container, box of dry tubes, instrument tube, PVC filter, pump, control rod handle, cask liner.
5.1.37	Inspect the sump near the center of the spent fuel pool floor.
5.1.38	Examine free spaces between the cylinders of the control rod storage rack.

Execution of the searches and inspections identified in the Global Search Plan required coordination among the FRAP, Dominion Nuclear Connecticut, Inc. ("Dominion") personnel from Unit 1 Reactor Engineering, Operations, Site Health Physics, GE, and ROV Technologies, Inc. The vast majority of the inspections were performed using underwater cameras. Other visual inspections used underwater binoculars, fuel inspection equipment, or other devices. Areas beneath the spent fuel storage racks were inspected using a remotely operated, camera-mounted crawler, in conjunction with other cameras. The crawler used installed grippers to grasp and move items and to compare items to known references. These inspections also required expert use of various pieces of underwater lighting equipment to enhance visibility in the pool. Many inspections also involved use of radiation survey meters to measure the radiation levels of objects in the pool.

The Project Manager and IRT closely monitored the progress and results of physical inspections in the pool and reactor cavity. The FRAP provided regulators and Dominion weekly progress reports on the progress of the investigation in scheduled teleconferences with NRC headquarters, Region I, and state regulators in Washington, South Carolina, and Connecticut. The FRAP completed all planned inspections in the Unit 1 SFP and reactor cavity in August 2001, and dispositioned the results of the searches.

3.2.5 Interviews

Investigation of each action plan required interviews with knowledgeable individuals. The Project conducted over 200 interviews of current and former NNECO employees, NNECO retirees, current employees of Dominion, current and former contractor workers at Millstone, and personnel at GE, Hanford, and Barnwell. Members of the FRAP began the process by identifying key individuals responsible for, or directly involved with, various aspects of each of the scenarios. They also compiled a collection of documents relevant to the significant events and memory aids such as photographs of different shipping casks and the SFP at different times, sketches and diagrams of reactor hardware, and other relevant documents. Gathered as a group, members of the Project discussed potential interviewees and their expected areas of knowledge. They then prioritized the list for conducting the interviews.

The team identified over 100 individuals for formal, in-person interviews. These interviews were conducted by a limited number of FRAP and Root Cause Assessment team members to ensure consistency and continuity. The interviewers prepared formal written summaries of each interview. The formal summaries were then distributed to all members of the FRAP, Root Cause Assessment Team, and IRT, and discussed during weekly debriefing sessions.

In addition to the primary interviews, FRAP members conducted less formal telephone interviews of almost another 100 individuals, using a common questionnaire probing a wide range of topics. Based on their responses to these questions, the Project invited some of these individuals for more detailed interviews. As the investigation moved forward and more information surfaced, Project members also re-interviewed some individuals. A few key people were interviewed four or more times. FRAP members formally documented each interview.

On July 27, 2001, after a substantial majority of the available information had been collected and digested, and specific information holes had been identified, the FRAP conducted a one-day, facilitated panel discussion involving approximately two dozen of the most knowledgeable individuals.

Overall, the FRAP experienced good cooperation in the interview process. However, not everyone was available. Some individuals were deceased. Some could not be found. Others declined to cooperate, despite repeated attempts to persuade the individuals to assist the investigation.

3.2.6 GE Support

Supplementing NNECO's efforts, GE provided additional support to the investigation. In June 2000, a GE team, comprised of personnel from the GE facilities in Wilmington, NC and San Jose, CA met with the Project team. GE personnel provided suggestions for enhancements of the physical inspection plan and conducted interviews of GE personnel involved with Millstone Unit 1 and with the segmented test rod ("STR") program – a program run by GE at Millstone Unit 1 and elsewhere in the 1970s and 1980s to improve fuel quality. The GE team also reviewed available documents at GE facilities in Vallecitos and San Jose, CA, and in Wilmington, NC. Later in the investigation, GE invited individuals from the FRAP to visit GE locations to review additional documentation. Additionally, former GE workers participated in the July 27, 2001, panel discussion.

3.3 The Standard of Proof

To determine whether the evidence developed in the investigation established a fact or a conclusion, the team required that there be clear and convincing evidence of that fact or conclusion. As discussed in FRAP Guideline For Weighing Evidence, M10063-10, this means that the evidence must be sufficiently convincing that it leaves no substantial doubt in the mind of a reasonable person that the finding or conclusion is true. In other words, the finding must be far more than theoretically possible or even likely; it must be highly probable.

Using this standard, it is possible that the weight of the evidence available on a certain matter may suggest the existence or non-existence of a particular fact. But if the evidence available was based on documents that were unclear, on records that were incomplete, or on memories that were clouded, that evidence would not be sufficient to support the finding.

The investigation used this standard, rather than a lower "preponderance of the evidence" standard, because the purpose of the investigation was to render an objective determination about the actual location of the fuel rods – not simply to weigh the available evidence. Indeed, this investigation involved many matters that occurred over twenty years ago. Not surprisingly, the body of evidence is imperfect. In fact, four persons who may have had relevant information are deceased. Two others, including one person who was very active on the spent fuel pool floor in 1978 and 1979, refused to cooperate with the investigation. Twenty-nine others identified for interviews could not be located. And, many people interviewed had considerable difficulty recalling key events. So too, document collection efforts were not perfect. Among the documents that could not be located were a number of old spent fuel maps, GE field notes of fuel movements, Unit 1 Maintenance Department photographs and logs, and the personal files of many former employees, one of whom was the Reactor Engineer who first identified the rods in May 1979.

These circumstances make it clear that it would be unwise to simply take the available evidence, weigh it, and render a determination without considering whether the quality of the evidence is such that the finding or conclusion is highly probable. Accordingly, the findings and conclusions contained in this report are based upon the accumulation (or absence) of clear and convincing evidence.

4.0 RESULTS AND CONCLUSIONS

The investigation did not produce clear and convincing evidence of the specific location of the two fuel rods from MS-557. The investigation found no credible evidence to believe, however, that the fuel rods are in any location other than a facility licensed to possess, and protect the public from, radioactive material. Consequently, there is no undue threat to the health and safety of the public, the workers, or the environment.

4.1 Findings and Results of Key Scenario Investigations

4.1.1 Background

4.1.1.1 Early History of the Fuel Rods

Early fuel records show conclusively that fuel assembly MS-557 consisted of 49 fuel rods when Millstone received it on June 13, 1969.[13] Those records also show that the assembly included a center spacer capture rod with serial number BK 0136 and a tie rod with serial number BP 0406.[14] MS-557 was one of the 580 assemblies placed in the core when the Unit 1 reactor first achieved criticality in October 1970.[15]

On September 1, 1972, seawater entered the primary coolant system through the condenser on Unit 1.[16] Because of the intrusion of the seawater, management conducted an orderly shutdown of the unit, removed the assemblies from the core, and placed them in the Unit 1 pool.[17] On October 8, 1972, workers from GE disassembled MS-557 and placed the 49 individual rods in seven GE eight-rod containers.[18] During the disassembly, one tie rod dropped, breaking part of the upper end plug shank on that rod.[19] As a result, GE workers placed that tie rod and the center spacer capture rod in a single eight-rod container.[20] Available records do not disclose the location of the container in the SFP. GE then shipped various non-fuel structural components of MS-557 to its Vallecitos laboratory to study the potential effect of the seawater intrusion.[21] Shipping records do not suggest that the two separate fuel rods from MS-557 accompanied the non-fuel components. Contemporaneous notes indicate that all 49 rods were left in the Unit 1 SFP.

In May 1974, GE workers reassembled MS-557 with 47 of the 49 original fuel rods.[22] The handwritten notes of the Unit 1 Reactor Engineer reflect the re-assembly of MS-557, but they make no mention whatsoever of the original missing center spacer capture rod and the damaged tie rod.[23] Neither those notes, nor any other document, indicate whether the two rods were included in the reassembled bundle, left in the eight-rod container, or treated otherwise. The notes are simply silent.

The investigation found no SFP maps, fuel records, or SNM records that mention the two fuel rods between disassembly in October 1972, and March 1979. Moreover, no one interviewed recalled seeing the rods during this period.

4.1.1.2 Key Records of the Fuel Rods in 1979

On March 13, 1979, engineers prepared two SFP maps, both of which include a notation of an unspecified number of "fuel rods" from an unidentified assembly located in the southeast corner of the SFP.[24] No other records describe the circumstances surrounding this entry. The Reactor Engineer who initialed the maps does not recall how that entry came to be or what that entry represents.[25] Although not conclusive, the evidence suggests that this entry represents the two rods from MS-557.

On May 15, 1979, the same Reactor Engineer prepared a memorandum that indicates that on May 12, 1979, workers from GE read the serial numbers on two fuel rods and concluded that the rods were the center spacer capture rod and tie rod from MS-557.[26] Two weeks later, the Unit 1 Superintendent wrote to GE expressing his appreciation for their support in identifying these rods.[27]

The reliability of this May 15, 1979 memorandum is key to this investigation. If it is reliable, a host of pre-May 1979 activities that could have affected, or that could explain the disposition of, the rods become moot. If it is not accurate or reliable, almost seven years of SFP activities and a host of off-site shipments become possible explanations for the current status of the rods. Because of the existence of considerable circumstantial evidence corroborating various aspects of the May 15, 1979 memorandum, the investigation concluded that there is clear and convincing evidence that the memorandum is reliable and that workers actually saw the two rods from MS-557 on or about May 12, 1979.

Although the investigation has reached this conclusion based on the evidence available, the passage of time, the absence of confirmatory records, and the existence of some contradictory evidence counsel against placing absolute confidence in this conclusion. In other words, the investigation cannot conclude with absolute certainty that the rods were in the pool on May 12, 1979. But the evidence reviewed was sufficiently compelling to remove any substantial doubt about the reliability of the memorandum of May 15, 1979.

GE's identification of the two fuel rods enabled the Unit 1 Reactor Engineer to prepare a SNM Kardex file card on or about May 12, 1979, for the two rods identifying the location of the rods, the weight of uranium contained in the rods, and their condition.[28] Except for the entries made on May 12, 1979, however, the card file contains no other information about the fuel rods, their location, or disposition.

We cannot presume that the rods remained in the location where they were placed after their identification. In fact, in the May 15, 1979 memorandum, the Reactor Engineer expressed his intent to move the rods.[29] Specifically, he noted that the rods "will be stored in the fuel rod storage rack in the North-West corner of the spent fuel pool until they can be incorporated in a scavaged [sic] fuel assembly."[30] The investigation did not find any evidence, however, that he followed through and placed the rods in another bundle.

4.1.1.3 The Status of the Rods After the May 1979 Serial Number Reading

When GE read the serial numbers on the rods in May 1979, Unit 1 was in the midst of a refueling outage.[31] That outage ended on June 27, 1979.[32] At some point between the end of the outage and the beginning of an audit on November 8, 1979, audit documents indicate that unit personnel prepared a map of the spent fuel pool.[33] The investigation, however, has not discovered any SFP map prepared during that period. Thus, we cannot conclude – one way or the other – whether the fuel rods appeared on that map, and if they were on the map, where the map depicts the rods.

That map may be significant because in September and October, 1979, contract workers from Crouse Nuclear Services cut LPRMs that were stored in the Unit 1 SFP and placed them in liners in the pool.[34] If the missing SFP map includes a depiction of the rods, and if the engineers prepared the map after Crouse completed its work, the missing map would be evidence that the rods survived the cutting campaign and were not cut by mistake.

Although there is no direct evidence that Crouse workers inadvertently cut the rods, that possibility cannot be ignored. Because LPRM hot sections are similar in length and diameter to a fuel rod, a person who is unfamiliar with boiling water reactor components would have difficulty distinguishing between the two.[35]

Adding to that difficulty, the Crouse workers did not have visual aids, such as borescopes or reverse periscopes, to help identify the underwater objects. Moreover, if the fuel rods were being stored in the corner of the spent fuel pool, as the memorandum of May 15, 1979 indicates, those workers would not have expected to find fuel being stored outside the fuel racks, with non-fuel items. Indeed, after the SFP re-racking in March 1979, the fuel racks containing the spent fuel were between 22 and 90 inches from the walls of the pool.[36] Encountering an item that looks like an LPRM, in a place where non-fuel items were stored, underwater and under conditions of limited visibility, could well explain how fuel rods could have been inadvertently cut. Nevertheless, the evidence is simply insufficient to determine to any reasonable degree of certainty that the Crouse workers actually cut the rods in the Fall of 1979.

4.1.1.4 The Removal of the Rods from SFP Maps in 1980

A SFP map prepared on February 26, 1980 – four months after Crouse finished the LPRM cutting operations – potentially resolves the question of the inadvertent cutting of the fuel rods.[37] That map depicts the two fuel rods in a square in the northwest corner of the SFP with the caption "2 Fuel Rods MS-557."[38] A later SFP map dated April 30, 1980, also contains the same entry and same notation about the fuel rods.[39] By all appearances, that April map is a copy of the February map, with one item about certain segmented test rods deleted. The April 1980 SFP map is the last known document that mentions the two fuel rods.

If accurate, these maps prove that the rods were in the SFP after the Fall 1979 LPRM cutting campaign. The practice used to prepare SFP maps during that period, however, does not necessarily assure their accuracy. Specifically, the engineers did not always draw new maps each time they issued a SFP map.[40] Nor did they always perform a visual inventory of each item in the pool before issuance of the map.[41] Often, they updated a prior map to reflect changes in the pool since the last map.[42] Based upon interviews, it is possible that engineers placed the rods on either the missing SFP map or the February 1980 map without the benefit of personal observation at the time of the map's preparation. In fact, the engineer who prepared much of the map said that the notation of the "2 Fuel Rods MS-557" on the February 1980 map is not in his handwriting as the remainder of the entries on that map.

If no personal observation of the rods occurred in February 1980, it is also possible that the engineer(s) responsible for the preparation of later SFP maps might not have known about an inadvertent cutting of the rods and, as a result, would not have changed earlier entries reflecting the rods. That practice could explain how cut rods could go undetected, but still appear on later SFP maps. The investigation did not uncover sufficient evidence to conclude, however, that the rods were, in fact, cut by mistake.

Of course, the converse is also true. In other words, the maps could well be accurate representations of the pool at the time of their preparation. Consistent with the Reactor Engineer's memorandum of May 15, 1979, the February and April 1980 SFP maps (and possibly on the earlier missing map) show the two fuel rods to be in the northwest corner of the SFP.[43] Other than the SFP map preparation methodology, i.e., preparation by exception, there is no reason to believe that the maps erroneously depict the fuel rods. That methodology and the ultimate inability to locate the fuel rods, however, raise too many questions about the accuracy of those maps to reach a definitive conclusion about the rods' condition or location after the Fall 1979 LPRM cutting campaign.

A September 1980 SFP map complicates the analysis further and, indeed, shows that engineers did not always prepare SFP maps by replicating, and then updating, earlier versions. In September 1980, reactor engineers prepared a SFP map that is not simply a copy of an earlier map.[44] Among other differences, this map contains no reference of any sort to the fuel rods. The existence of a freshly drafted SFP map at least suggests some additional increment of accuracy, and may support the notion that the rods were cut, placed in a "scavenged" bundle, or disposed of in some other unknown way. But the Reactor Engineer who identified the fuel rods in May 1979 believes that the omission of the fuel rods from that map was simply an inadvertent oversight in drafting.[45] If he is correct, the practice of generating maps based upon changes in SFP composition could explain how engineers could perpetuate the error in maps drafted after September 1980. And, in fact, not one SFP map prepared after September 1980 – or any other document of any sort – mentions the two fuel rods.

This inconsistent evidence precludes reaching a conclusion about the location of the rods in 1980, and thereafter. The loss of fuel rod accountability does not mean that the rods were not in the SFP, but the absence of any record of the fuel rods for the next 20 years makes the identification of their precise location or disposition challenging at best.

4.1.2 Results of Scenario Investigations

4.1.2.1 The 1980 Shipment To Vallecitos

As previously discussed, the absence of any reference to the individual fuel rods in any records after April 1980 could be attributable to: (a) the rods having been inadvertently cut during the Fall 1979 LPRM cutting campaign; (b) the placement of the rods in another assembly or their undocumented movement to some other unidentified location in the pool; or (c) a simple oversight in the creation of the September 1980 SFP and the perpetuation of that mistake in later maps. Another possibility arose in April 1980, when Unit 1 shipped a shielded cask to GE's Vallecitos facility.

On May 5, 1979, GE personnel removed a segmented test rod from fuel assembly MSB-125, unscrewed its four segments, and placed the segments in a GE–1600 shipping rack.[46] Ironically, on that same date, GE and NNECO workers also took MS-557 and MS-330 from their respective locations in the SFP and moved them to the fuel prep machine in the SFP. Both of these assemblies were in the core during the 1972 seawater intrusion and GE tested the fuel rods from both after that event. MS-557 and MS-330 remained in the fuel prep machine for about 24 hours, until they were returned to their storage locations. The documents do not indicate the reason for the movement of these assemblies to the fuel prep machine or what work, if any, occurred there. As discussed earlier, one week later, on or about May 12, 1979, workers from a GE channel measurement crew read the serial numbers on the two fuel rods and, based upon the similarity between the numbers read, and those in records, concluded that the rods were from fuel assembly MS-557.[47]

In July 1979, a GE fuel handling crew arrived at Millstone to reconstitute another assembly, GEB-20. On July 20, 1979, GE removed some non-fuel hardware from that assembly and placed it in the same shipping rack that housed the segmented test rods, which an earlier GE crew placed there in May 1979.[48] The shipping rack remained in the SFP.

On December 28, 1979, GE notified the NRC that it intended to ship the GE-1600 cask, with the previously loaded shipping rack, from Unit 1 to GE Vallecitos.[49] The individual in the NRC responsible for preparing NUREG-0725 also prepared a "Spent Fuel Shipment Data" form that contained information about the shipment.[50] Two entries may be important to the question of the content of the shipment. First, the NRC employee entered the number "4" next to the line asking for the "Number of fuel segments."[51] But beneath a typed entry for "Number of fuel rods," he wrote "8.8 kgs."[52] Both entries are handwritten.

The shipment left Millstone on April 30, 1980.[53] The DOE/NRC Form 741 for this shipment – the official record of the transfer of special nuclear material – indicates that the shipment contained 2.4 kg of uranium when it left Millstone.[54] GE signed the Form 741 on May 7, 1980, acknowledging receipt of the shipment and "accepting shipper's weights."[55] The actual weight of the uranium contained in the four STR segments was only about 2.4 kg, which is consistent with the 2.4 kg entry on the Form 741. The 2.4 kg entry is also very close to the 2.5 kg amount reported by the NRC in the initial NUREG-0725 report, an NRC document that reports shipments of spent fuel and the amount of spent fuel shipped.[56] NRC officials informed the Project that the NRC employee who prepared the "Spent Fuel Shipment Data" form would have done so based upon letters and/or telephonic information provided by GE.[57] The NRC employee who actually prepared this form informed the NRC and Project Team members that he did not recall Millstone Station at all or the 8.8 kg entry, much less the basis for this entry.[58]

In 1990, a different NRC staff person changed the NUREG-0725 shipment amount from Millstone – for the first time since 1980 – to reflect a shipment that is generally consistent with the 1980 entry on the NRC "Spent Fuel Shipment Data," but inconsistent with the signed DOE/NRC Form 741.[59] The NRC employee responsible for the NUREG 0725 change is deceased.[60] The NNECO official who signed the DOE/NRC Form 741, which reflects 2.4 kg of uranium in the shipment, is also deceased.

The evidence cited above does not establish that the two fuel rods are at GE Vallecitos. In fact, the majority of the evidence indicates the rods are not at that facility. In particular, the official record of the shipment, the DOE/NRC Form 741, is consistent with the weight of the four segmented test rods and consistent with the inventory. The NUREG 0725 issued after the 1980 shipment reflects that amount as well. Additionally, a review of the GE Vallecitos "Material Balance Status" forms did not reveal an amount of SNM attributable to the SNM contained in the two fuel rods. Moreover, GE inspection processes at Vallecitos required that the container be opened and the contents inspected.[61] There is no indication that the receipt inspection led to the discovery of the two rods from MS-557. Had the rods been there, the receiving inspector almost certainly would have provided some indication of his discovery.

Although this evidence is quite strong, and may even be compelling, there are discrepancies that have not been resolved. For example, GE receipt records do not precisely match the GE shipping inventory for the irradiated hardware contained in the April 30, 1980 shipment. Specifically, a GE representative signed a GE Fuel Operations Procedure on April 10, 1980, which included a list of the items placed in the shipping rack.[62] The handwritten "Inventory of Rec'd Reactor Hardware" indicates that on May 8, 1980, GE received two additional lock tab washers and eight nuts that were not on the signed shipping inventory.[63] And, two expansion springs that were on the shipping inventory do not appear on the receipt inventory or in the receipt photograph.[64] These discrepancies certainly do not establish that two fuel rods were included in the shipment, but they preclude reliance on the inventory documents as categorical proof of the contents of the shipment.

Additionally, as noted earlier, two NRC records (the Spent Fuel Shipment Data and 1990 version of NUREG 0725) indicate that GE received 8.8 kg of SNM in the shipment of April 30, 1980. That amount of SNM exceeds the amount contained in the four, segmented rods by about 6.4 kg – an amount slightly less than the 7.5 kg of SNM contained in the two fuel rods from MS-557. The NRC has investigated this discrepancy but cannot identify the basis for this entry.[65] Likewise, GE has reviewed its records and it, too, cannot reconcile these documents. The two NRC employees who would be most likely able to resolve the issue are either deceased or unable to recall any relevant information.[66] Although the GE receipt records and processes described above seem to preclude the inclusion of the rods, the inability of anyone to explain the 8.8 kg entry compels the investigation to conclude that – although very unlikely – GE Vallecitos must be included as a possible repository.

Additionally, GE loaded the segmented test rods on May 5, 1979 – the same day that the parent assembly of the two unaccounted for rods (MS-557) suddenly appeared for unexplained reasons in the fuel prep machine.[67] That "scrap" assembly had not been worked on since GE reassembled it in 1974, and yet, on the day the shipping rack was loaded, MS-557 was moved to the fuel prep machine. Perhaps related, seven days later, GE identified the two stray rods from that assembly.[68] The convergence in time of this movement of MS-557, the identification of the two fuel rods, and the loading of the segmented rods in this shipping rack may be coincidental, but, at a minimum, the timing raises unanswered questions about a possible relationship between this shipment and the two fuel rods.

The shipping rack containing the segmented rods and the irradiated hardware could have easily accommodated two cut fuel rods. Moreover, the shipping rack remained in the Unit 1 SFP for almost <u>one year</u> before being shipped to Vallecitos. Indeed, after receiving the four segmented rods in May 1979, the rack remained in the pool. Again, in July 1979, it received the irradiated hardware from assembly GEB-020.[69] But even then, the rack remained in the pool until its shipment in late April 1980 – over 11 months after the segmented rods were loaded. Clearly, ample opportunity existed to load the rods in the rack.

Finally, the shipment of the rods on April 30, 1980, could well explain the inability of anyone to recall seeing the rods after GE's identification of the rods in May 1979. And, if the SFP map of April 30, 1980 was not the product of a visual confirmation, but was prepared to reflect only those known changes, the map could well have been prepared without reflecting the shipment on April 30, 1980.[70] The absence of the rods from the September 1980 SFP map – a map that is <u>not</u> merely an amended copy of a prior map – could, in fact, accurately reflect the shipment of the rods.[71]

Again, these considerations do <u>not</u> warrant a conclusion that the two fuel rods are at Vallecitos. To the contrary, the clear weight of the evidence favors a finding that the rods are not at Vallecitos. The record discrepancies and open questions, however, do not permit the investigation to exclude the possibility that the rods were shipped to Vallecitos.

4.1.2.2 The 1985 Shipments to Hanford

In late 1984 and early 1985, Millstone implemented a program to reduce the amount of irradiated waste in the Unit 1 SFP. NNECO hired GE to perform "consolidation and densification services" for control rod blades ("CRBs") and LPRMs, and to provide assistance in loading activities.[72] Initially, the contract envisioned only one shipment of an IF-300 cask to the commercial LLRW facility on the Hanford reservation in Richland, WA. GE and NNECO amended the contract, however, and three IF-300 shipments occurred.[73]

The investigation did not produce clear and convincing evidence that the two fuel rods from MS-557 were shipped to Hanford. In fact, there is no direct evidence that they were included in any of these three shipments. Nevertheless, the evidence is not sufficiently compelling to exclude the possibility that the fuel rods were inadvertently included.

The March 20, 1985 Shipment

As noted earlier, the evidence does not establish either the location or condition of the fuel rods after May 1979. This uncertainty creates at least the possibility that workers could have unintentionally loaded cut fuel rods into the liner before shipping the first IF-300 cask on March 20, 1985. The inventories and related documents, however, do not provide any evidence to support a conclusion that the rods were shipped. Rather, the only items reflected in the shipping documents that could have been confused with the fuel rods were 38 LPRMs that GE cut in early 1985.[74] But the detailed procedures that GE followed, the related documentary evidence of procedural compliance, and interviews clearly establish that those items were, in fact, LPRMs and not fuel rods.[75] Moreover, the evidence clearly establishes that GE loaded the 38 LPRMs that they cut, not other LPRMs that had been previously cut and were stored in the SFP – and not inadvertently cut fuel rods.[76]

Although that conclusion is sound, there was an opportunity for the loading of additional items that precludes the categorical exclusion of this shipment. Specifically, one of the GE workers recalled that the IF-300 liner lid was not closed when GE finished its cutting and loading work on February 9, 1985.[77] Reports in 1985 indicating that the Hanford and Barnwell LLRW repositories might be closing, provided a possible incentive for NNECO to want to load additional material in the shipment.[78] But having the motive and opportunity to load additional material does not make it so. Moreover, workers would have had no reason to violate procedures and regulatory requirements by loading additional material and not recording it on shipping records.

Additionally, the physical dimensions of the liner effectively precluded the shipment of full-length fuel rods. Simply stated, the liner was five inches too short to hold a full-length fuel rod or an eight-rod container loaded with a fuel rod.[79] The insertion of a full-length rod would have required a nearly empty liner and a pronounced bow in the fuel rod.[80] The documents establish that the liner was not empty when GE workers loaded the LPRMs and no one interviewed recalled any manipulation of the items being loaded.[81] There were, however, no significant physical restrictions on the loading of cut fuel rods. Indeed, the liner had more than enough space to accept two cut rods.[82] But the investigation found no evidence that cut rods were actually placed in the liner or shipped.

The May 29, 1985 Shipment

Similarly, there is no direct evidence that the fuel rods were included in the second shipment to Hanford. In this shipment, the only items on the inventory that bore any resemblance at all to fuel rods were 38 cold ends of LPRMs.[83] Unlike hot ends, however, an LPRM cold end is more than one inch in diameter, notably larger than that of a fuel rod.[84] And the radiation levels of the cold ends in this shipment were considerably less than that of an irradiated fuel rod.[85] Moreover, the evidence indicated that the cold ends shipped in this cask were the cold ends from the LPRMs cut by GE workers in early 1985.[86] As noted earlier, the procedures used by GE, and the documentation associated with that cutting operation, provide clear and convincing evidence that GE did not inadvertently cut the two fuel rods.

As in the case of the first shipment, however, there was also an opportunity for the loading of additional items into the liner of the second shipment. In particular, workers removed CRB handles from three old containers that were in the pool and loaded them into the IF-300 liner for shipment.[87] The containers that housed the CRB handles may have also contained other, unidentified irradiated items. Although there is virtually no possibility that a worker could mistake a fuel rod, or fuel rod segment, for a CRB handle, the investigation could not rule out the possibility that some other items in the three old containers were also transferred to the IF-300 liner. Again, however, there is no evidence that such a transfer occurred, much less that the fuel rods were transferred from an old container to the IF-300 for shipment.

Similarly, while workers were loading the IF-300 liner, old PB-1 and AP-101/ANEFCO liners were transferred to the cask laydown area for identification of the contents of those liners.[88] The workers were not instructed to load the contents of the old liners into the IF-300.[89] The IF-300 loading was a separate activity, but the presence of these old liners provided an opportunity to transfer items from those liners to the IF-300 liner. But again, there is no direct evidence that the fuel rods were in any of those liners and there is no evidence of any sort that they were transferred to the IF-300 liner.

The July 31, 1985 Shipment

NNECO conducted the third IF-300 shipment in essentially the same manner as it did the second shipment. Once again, there is no evidence that the shipment included the two fuel rods or segments of the rods. There were, however, two aspects of this shipment that created the opportunity for the inadvertent inclusion of the rods.

First, workers loaded 40 segments of LPRM hot ends, which the final inventory describes as coming from 8 LPRM hot ends.[90] As previously noted, LPRM hot ends are similar in appearance to fuel rods. The evidence indicates that the workers loaded all of the LPRM segments that were in a particular container on the west wall of the SFP.[91] The investigation was unable, however, to trace the specific history of these LPRM segments to determine whether they contained, or may have contained, cut fuel rods. Nevertheless, for this shipment, the Project Manager and Project Engineer required that workers confirm the identity, volume, mass, composition, number of cycles of core exposure, year discharged from the core, location in the core, and major dimensions of inventoried items before loading.[92] Those requirements also necessitated concurrence of Radiological Assessments personnel and Reactor Plant Systems before loading items into the liner.[93] Although the investigation did not find documentation specifically providing this data for the LPRM hot ends included in this shipment, the investigation did find that the Project Engineer submitted the required waste classification information and curie calculations - information that would have required that he have that data.[94]

The second opportunity to inadvertently place cut fuel rods in this shipment arose when workers unloaded items from an old PB-1 liner. As discussed in the second shipment, the old PB-1 liners contained unidentified irradiated material. In this shipment, the Project Manager specifically instructed the workers to unload one PB-1 liner that was in the cask laydown area, "in conjunction with" the loading of the IF-300 liner.[95] He limited the loading of items from the PB-1, however, to the types of items designated for shipment, i.e., velocity limiters and CRB handles.[96] The workers were not instructed to transfer all items in the PB-1 to the IF-300.[97] And there is no evidence that workers ignored these instructions. In fact, the notes of one worker indicate that when he unexpectedly encountered two LPRMs in a liner with poison curtain handles, he did not load the LPRMs or other items that he found, but instead called them to management's attention.[98]

As in the case of the two earlier shipments to Hanford, the evidence does not establish that the rods were shipped to Hanford in 1985.

4.1.2.3 The 1988 - 2000 Shipments to Barnwell

In the late-1980s, NNECO conducted a number of significant activities to improve operations in the Unit 1 SFP. Those activities included a substantial re-racking of the SFP in 1989 to increase the pool's storage capacity. The Unit also made multiple shielded shipments of waste between 1988 to 2000, to the LLRW facility in Barnwell, South Carolina. The evidence is not sufficient to establish that the fuel rods were included in any of the shipments to Barnwell.

The May 1988 Shipments

In anticipation of the 1989 re-rack, Northeast Utilities Service Company ("NUSCO") hired WasteChem in January 1988, to perform a major clean up of irradiated hardware, contaminated materials, and filters in the Unit 1 SFP.[99] Documents associated with this work reveal that WasteChem submitted its proposal and, in fact, began work without having been provided a precise list or characterization of the various irradiated hardware and contaminated items in the pool to be processed and shipped.[100] This clean up effort included three shipments of TN 8L shipping casks and one CNSI 3-55 cask. Each TN-8L cask included three rectangular liners, each one large enough to accommodate full length rods and the eight-rod container. The CNSI 3-55 liner was not large enough to hold full length rods or the eight-rod container.

The uncertainty about the non-fuel contents of the SFP – particularly the number and location of LPRMs – is potentially significant. WasteChem reported that it shipped 15 full-length LPRMs, consistent with the bid specification.[101] The report of 15 full-length LPRMs is, in fact, consistent with the Unit's operating history.[102] During the late-1985 refueling outage, workers removed eight LPRMs from the core and, during the 1987 outage, they removed seven more LPRMs.[103] The fact that these LPRMs still had their hot and cold ends joined when WasteChem arrived to process and ship them precludes any serious consideration that the two fuel rods from MS-557 could have been mistakenly included for shipment with these LPRMs.[104]

The accounting of the previously cut LPRMs, however, is a different matter. For example, NUSCO's 1987 bid specification indicates that the pool contained five containers of hot ends from 96 LPRMs.[105] WasteChem reported, however, that it shipped, in addition to the 15 full-length LPRMs, hot ends from 98 LPRMs, which it found in nine "baskets" and three "inserts."[106] Moreover, the identity and source of the cut LPRMs in these baskets and inserts could not be determined with certainty.[107] Given the limited number of LPRMs shipped in the 1985 shipments to Hanford (38 in the first shipment and 8 in the third shipment), and the fact that 38 of these were cut by GE in 1985,[108] the 98 (or 96) segmented LPRMs shipped in 1988 were most likely cut during the 1979 or 1984 LPRM cutting operations. As discussed earlier, a relatively inexperienced contractor work force performed the September to October 1979 LPRM cutting operations. (The 1984 LPRM cuttings occurred on only two days in August 1984, and were performed by NNECO operators.)[109] Thus, if in 1979 or 1984, workers cut the fuel rods by mistake and placed them in any of the twelve baskets and inserts found by WasteChem, the rods could have been inadvertently shipped to Barnwell in 1988.

The loading procedures used by WasteChem would probably not have led to the identification of the fuel rods, if they were in the containers of cut LPRMs. WasteChem did not attempt to verify the identity of the LPRM segments or perform a radiological survey of each piece. Rather, they surveyed each of the twelve containers as a whole, and then placed the contents of each container into a shipping liner.[110] Specifically, WasteChem loaded the contents of six of the twelve baskets and inserts of LPRMs in the CNSI 3-55 liner, and the remaining six baskets and inserts into four of the six TN-8L liners.[111] Records show that approximately two-thirds of the old LPRM segments were placed in the CNSI 3-55 liner. The remaining one-third were dispersed in four of the TN-8L liners.[112]

WasteChem did, however, measure the total length of LPRM hot end material in each container before loading it into a liner. They performed this measurement to determine the number of fission chambers being shipped. The total number of feet of LPRM hot sections measured and shipped by WasteChem is the equivalent of 90 LPRMs.[113] Analysis Unit 1's LPRM history indicates, however, that there were less than 90 LPRMs actually available for shipment. Indeed, GE records indicate that between four and six LPRMs, or segments of LPRMs, had been previously shipped to GE Vallecitos in 1972 for testing, unbeknownst to NNECO reactor engineers in 1988.[114] NNECO records do not reflect this shipment. Additionally, after the 1988 shipments, NNECO found three additional LPRMs in the pool that it believed had been shipped in 1988.[115] Also, at some point after the 1988 shipment, WasteChem unexpectedly found an unidentified quantity of LPRMs sections in a container with fission chambers.[116] Thus, if WasteChem accurately measured an amount of material equal to the length of 90 LPRMs before the May 1988 shipments, or if it shipped 98 LPRMs as it indicated in its final report, a substantial portion of that material must have been something other than LPRMs.

The investigation revealed no direct evidence that the fuel rods account for the additional material shipped. But, the discrepancy at least suggests the possibility that the fuel rods could have been inadvertently included in the shipment. More important, the inclusion of the contents of the old baskets and inserts with somewhere between 90 and 98 LPRM's worth of segmented material identified as LPRMs created a substantial opportunity to have inadvertently shipped the fuel rods if they were cut previously. Again, however, the evidence is not sufficiently convincing to support a conclusion that the rods were included in this shipment.

The 1989 and 1990 Shipments

After the May 1988 shipments, NNECO conducted the planned re-racking of the Unit 1 SFP. Soon after the re-rack was completed, NNECO performed another clean-up of the pool beginning in the Fall of 1989. That clean-up effort culminated in Unit 1 shipping four shielded casks to Barnwell in late 1989 and 1990. The investigation did not produce clear and convincing evidence that any of these shipments included the two fuel rods. One principal discrepancy in the

May 7, 1990 shipment (the third shipment), however, causes that shipment to be a potential explanation for the disposition of the fuel rods.

At the conclusion of the 1988 clean-up campaign, NNECO managers believed that all LPRMs had been shipped off-site, with the exception of the fission chambers cut from 46 LPRMs in 1985 (and possibly 1984).[117] However, what was believed to be an LPRM segment 8 to 12 feet long was noted during the 1988 re-rack project.[118] Accordingly, data provided to vendors bidding on the 1989 clean-up effort indicated that the contractor would be required to ship, among other things, 184 (4x46) fission chambers and one 12 foot LPRM segment.[119] As noted above, a November 1, 1988 radiation survey indicated that three LPRMs remained in the pool after the 1988 shipments. WasteChem's proposal reflected the intent to ship three LPRMs. Additionally, an unsigned, undated letter from WasteChem indicates that WasteChem experienced delays in its performance under the contract because "extra LPRM sections in the container with 184 fission chambers required processing, and additional handling."[120] The evidence indicates that WasteChem did not ship the three LPRM segments.[121] Nor does the evidence indicate whether the "extra LPRM sections" were, in fact, confirmed to be LPRMs, whether WasteChem assumed them to be LPRMs because they were in a container with fission chambers, or whether they were actually shipped. The absence of any other information clearly precludes reaching any conclusion about the identity of these items or a conclusion about the likelihood that the shipment contained the fuel rods.

Of course, the presence of LPRMs after the 1988 shipments is not necessarily suspicious. But, their presence in the pool after NNECO believed that it had shipped all LPRMs adds additional evidence that the objects shipped in 1988 were not LPRMs, as workers believed at the time. Regardless, the uncertainty of the true identity of these items contained in the box of fission chambers in the third shipment precludes a conclusion that there is clear and convincing evidence, one way or the other, about the contents of that shipment.

The 1992 Shipments

In 1992, Unit 1 again hired WasteChem to make three shielded shipments from the Unit 1 SFP to the LLRW facility at Barnwell. WasteChem used the TN-RAM cask for all three shipments.[122] Because of its limited size, this cask and, thus, these shipments could not include full-length fuel rods.[123]

Of the three shipments, only the shipment of December 8, 1992 (the second shipment) provided a reasonable opportunity for segments of the two fuel rods to have been included. And, even for that shipment, the possibility does not appear to be great, but it cannot be discounted completely.

The opportunity for workers to have inadvertently loaded the fuel rods in that shipment arises because that shipment included the contents of a 12"x12"x 42" stainless steel box, which according to the bid specification and a SFP Inventory Log, contained "miscellaneous trash [measuring] 150R/hr."[124] The Radiological Engineering Section Supervisor indicated in an interview, however, that the container actually included old LPRM pieces.[125] The waste characterization for this shipment, prepared by the Radiological Engineering Section Supervisor, indicates that LPRM pieces, the equivalent of three LPRMs, were included in this shipment.[126] He based this conclusion on the word of the then Reactor Engineer, who informed him that the items were cut-up LPRMs.[127] The actual identity of the items in the box is uncertain because individual pieces were not radiologically surveyed.[128] Rather, workers surveyed only the external surface of the box.[129] If the Reactor Engineer was correct, those LPRMs would have been older LPRMs that were not disposed of in earlier shipments.[130] This provides additional evidence that the segments shipped in 1988 may not have been all LPRMs.

Indeed, the evidence is clear that the box did not include LPRMs recently removed from the core during the immediately preceding outage. The six LPRMs that were removed from the core, during the 1991 outage, were processed in accordance with station procedure, and then tied to the side of the pool in approximately 26-foot long segments that still had the hot and cold sections joined.[131] The waste characterizations for the second and third TN-RAM shipments account for each of the six full-length LPRMs removed during the 1991 outage.[132]

But, because of the possibility that workers in the late 1970s may have inadvertently cut the fuel rods believing them to be LPRMs, and because the contents of the box of old LPRM pieces were not verified before shipment, the investigation could not exclude the possibility that segments of the fuel rods were included in the TN-RAM shipment of December 8, 1992.

The 2000 Shipments

In anticipation of decommissioning, Unit 1 hired NUKEM, the successor of WasteChem, to conduct a series of shipments to the LLRW facility at Barnwell in 2000.[133] Specifically, Unit 1 made six shielded shipments, five in a TN-RAM cask, and one in a CNSI 8-120B cask.[134]

The investigation concluded that the fuel rods were not included in the first three TN-RAM shipments or in the CNSI 8-120B shipment. Additionally, given the size of the TN-RAM[135] and CNSI 8-120B[136] casks, full-length rods, either alone or in an 8-rod container, could not be loaded.[137]

The final two TN-RAM shipments probably do not include the two fuel rods, either, but the evidence is not sufficiently clear and convincing to reach that conclusion. For example, the October 1999 bid specification soliciting proposals for these shipments identified a single 72-inch section of an instrument dry tube for shipment.[138] That same bid specification also indicated that there were two boxes containing cut-up segments of 12 instrument dry tubes in the pool to be surveyed and considered for shipment. (Ultimately, the radiation levels of these tubes precluded their shipment.) What is potentially significant, however, is the fact that, by 2000, Unit 1 had discharged only 12 dry tubes from the reactor vessel.[139] Thus, if the bid specification is accurate in saying that the two boxes in the SFP contain the segments of 12 instrument tubes, the 72-inch "instrument dry tube" also identified for shipment cannot be an instrument dry tube. This does not mean that the item was a fuel rod. It may have been one of the source holders removed in 1978.[140] Because dry tubes and source holders have similar diameters of about 0.7 inch,[141] which is also similar to the 0.57 inch diameter of a fuel rod, the possibility exists that the "dry tube" is one of the source holders. Other than the physical similarity between an instrument dry tube and a fuel rod, and the potentially erroneous identification of the 72-inch item, however, there is no evidence that suggests that this item was, in fact, part of one of the MS-557 fuel rods. Moreover, the shipping records do not clearly indicate that this 72-inch item, whatever it was, was actually shipped. In fact, none of the items listed in any inventory identify this 72-inch object as having been shipped.

The final TN-RAM shipment contained an additional anomaly. That shipment included an unidentified "bucket of debris."[142] Having no description of the contents of the bucket, the size of the bucket, or the length of time the bucket was in the SFP makes any pronouncement about its contents little more than speculation. Some evidence suggests that the bucket contains pieces of boron tubes, but this evidence is not conclusive. Additionally, a radiological survey of the bucket indicates that the contents were 125 R/hr,[143] which does nothing to either confirm or exclude the presence of cut fuel rods. Regardless, the survey results are suspect because the survey is dated one week <u>after</u> the shipment left Millstone.[144] This evidence is far too unreliable to support any conclusion about the presence of the fuel rods in this final shipment.

4.1.2.4 The Spent Fuel Pool

Concurrent with the investigation of the scenarios described above, the team conducted an inspection of the Unit 1 spent fuel pool and the control rod blade guides in the reactor vessel cavity to determine whether the fuel rods remained in some undocumented location. To conduct this inspection, qualified team members prepared and implemented a Global Search Plan.

The Global Search Plan established a comprehensive list of locations capable of physically accommodating the two rods. After identifying these areas, the team developed appropriate inspection plans and, using underwater cameras, a robot, and various other forms of equipment, the team examined the accessible locations of the spent fuel pool, including the free space in the pool.

Although that plan required the inspection of many areas in the spent fuel pool, it did not contemplate the physical inspection of every fuel assembly or item in the pool. Indeed, inspectors checked the vast majority of the assemblies by observing the upper tie plates to determine if there was any evidence that the assembly had been disassembled after it left the core for the last time. That inspection searched for, among other things, assemblies with new or missing lock tab washers or new nuts. If an assembly did not have such hardware, the team concluded that the two fuel rods could not have been inserted in that assembly because of the absence of evidence of disassembly. On the other hand, if an assembly exhibited signs of disassembly, the team conducted additional work to determine if the assembly contained the correct number of fuel rods.

In addition to searching for signs of disassembled fuel assemblies, the team identified certain locations in the pool as potentially having a greater likelihood of containing one or both of the two fuel rods. For example:

- GE conducted an inspection of the parent assembly, MS-557, and confirmed that the center spacer capture rod and a tie rod were actually missing from that assembly.

- The team considered SRP 2D, the assembly that GE used to house the spent segmented test rods, as a likely place to store two separate fuel rods. GE inspected that assembly and concluded that all of the rods present were part of the segmented test rod program, not the rods from MS-557.

- The team also considered it possible that the two fuel rods could be stored in MS-508, a damaged fuel assembly that rests in a container in a control rod storage rack in the spent fuel pool. The team used a camera to examine the assembly, its container, and the space around the container. That inspection showed all 49 fuel rods from that assembly to be in place.

- The team conducted a visual inspection of MSB-125, the fuel assembly that housed segmented test rods when in the core. The assembly contains the expected number of full-length fuel rods and dummy rods. The observation of the upper tie plate revealed that the assembly had not been disassembled since it was last in the core. Accordingly, it could not contain the two rods from MS-557.

- The team inspected those assemblies in the spent fuel pool that are "raised," i.e., they are not fully seated in the storage rack, to see if a fuel rod or fuel rod segment caused the assembly to be raised. The inspectors lifted the assemblies and inspected the vacated space in the storage rack, but did not find the rods.

- The team conducted an inspection of the free space in the pool, including the areas under and between the fuel storage racks.

The inspections of the specific locations, the fuel assemblies, and the free space in the spent fuel pool did not locate the two fuel rods.

Although comprehensive, the execution of the Global Search Plan does not permit a conclusion that the two fuel rods, or segments of the rods, are not in the reactor cavity or spent fuel pool. That final determination will not be possible until all 2884 fuel assemblies and obstructions are inspected and ultimately removed from the pool. As noted, the Global Search Plan addressed the areas that the team considered capable of accommodating full-length or large segments of fuel rods. It did not address every possible place that the rods, or smaller rod segments could be. Nor did it address some less likely places because of the perceived low likelihood of locating the rods and/or because the inspection could result in a significant radiation exposure for the inspectors. For example:

- The team did not take apart the eight-by-eight fuel assemblies to inspect the water rods in those assemblies to see whether a fuel rod had been inserted in that space. A fuel rod can physically fit in that space and one GE employee recalled storing single fuel rods in water rods at another site. The visual inspection of the assemblies looking for some sign of post-irradiation work on the assemblies, however, provides some assurance that the rods were not placed in a water rod.

- Likewise, the team did not physically disassemble and inspect the rods of each of the 2884 fuel assemblies in the pool. To disassemble each of these assemblies would require about five years to complete and would involve an exposure of about 2,200 man-rem. Moreover, a rod-by-rod inspection of over 167,000 fuel rods would have an associated risk of a fuel handling accident. To conduct such an inspection, each assembly would have to be lifted from its storage rack location, moved to a fuel prep machine, disassembled, inspected rod-by-rod, reassembled, and returned to its storage rack. Even if safely performed, the effectiveness of the inspection is questionable because it would require the underwater reading of small serial numbers etched around the circumference of the fuel rod's end plug. Difficult under the best of circumstances, years of corrosion product build-up on the fuel rods make accurate readings of the serial numbers even more challenging.

- The team did not inspect the entire length of the channeled fuel assemblies to see whether a segment of a rod was lodged between the channel and the assembly. In thirteen instances, the team raised the assembly somewhat, but not to a height that would permit an inspection of the entire channel. For the remainder of the channeled assemblies, the team used a camera to inspect to a depth of about five feet from the top of the assembly. This depth would have detected a full length rod.

In conclusion, the spent fuel pool inspection was both focused and comprehensive. Its focused inspections targeted MS-508, MSB-125, and SRP-2D, and other likely fuel rod storage locations. Its comprehensive inspections searched the free space in the pool, the floor beneath the fuel storage racks, and other potential storage locations. The results of these inspections establish that, subject to the limitations of each search, the fuel rods are not in locations searched. But given the limitations and conditions discussed earlier, the inspections cannot rule out the possibility that the fuel rods remain in the spent fuel pool. The final answer to that question will only be found when the pool is emptied and its contents transferred to another location or repository.

4.1.2.5 An Examination of the Possibility of Theft or Diversion

Because the investigation did not find clear and convincing evidence that identifies the current location of the fuel rods, some may ask whether the rods were stolen. Certainly, the terrorist attack of September 11, 2001, and the heightened awareness of security matters have the potential to color this discussion in ways that it would not have been had the attack not occurred. But neither the sudden recognition of the vulnerability of our country to terrorism nor the magnitude of the tragedy can be allowed to alter the truth. There is simply no evidence of any sort that suggests that the fuel rods were stolen or diverted.

Soon after the investigation began, the team recognized that regardless of the ultimate outcome of the other scenarios, it should look for any sign of theft. It based this decision solely on the need to safeguard the public. There was no evidence, no suggestion, and no implication of any sort that prompted the inquiry into this topic. Nevertheless, the team created a scenario to examine this issue. Consistent with the process, the team considered the scenario implausible, but, again, because of the importance of this issue from a public health and safety perspective, it began a confirmatory investigation. Unlike other scenario investigations, however, this investigation did not have a shipment, a transfer, a location, or a particular event to investigate. Rather, its task was to determine whether an unknown, unreported theft occurred at an unknown time over a twenty-year period.

Simply stated, the investigation did not reveal a single piece of evidence that even remotely supports an inference, much less a conclusion, that the rods were stolen or diverted. Not one document or interview contains any indication of theft. Indeed, no one interviewed even offered an opinion that the rods might have been stolen.

The investigation, however, did not simply accept the absence of any evidence as proof that theft or diversion did not occur. Rather, the team conducted an assessment of the circumstances and conditions that would affect the Unit's vulnerability, or lack of vulnerability, to a theft of the rods from the spent fuel pool.

A successful theft or diversion of the fuel rods would require the breakdown of multiple, interlocking barriers. An examination of those barriers from May 1979, when GE verified the presence of the rods in the pool, through November 2000, when the Company began its initial investigation, confirms that the barriers were effective. Indeed, there was no time when a failure or weakness existed in all of the barriers against theft or diversion.

To understand the nature of the barriers, and the difficulty inherent in overcoming them, consider how some of the barriers would mutually support each other in preventing the theft of the rods.

First, the nature of the rods themselves makes theft or any unshielded handling inherently risky. As discussed earlier, spent fuel rods are highly radioactive, which means that they cannot be handled without the person taking special precautions to guard against receiving a high (potentially lethal) dose of radiation. This means that if a person tried to remove the rods without placing the rods in a properly shielded cask, the person would receive a very substantial, and potentially lethal, dose of radiation.

Second, because the spent fuel rods are highly radioactive, if someone were to try to steal the rods without the necessary shielding, not only would that person jeopardize his health, multiple radiation alarms on the refuel floor and various other radiation alarms throughout the reactor building would sound, signaling the presence of radiation and triggering a response from the Control Room, Site Security, and Health Physics, and others. Activation of certain alarms on the refuel floor would also trigger other reactions in the operation of various plant systems, such as standby gas treatment and isolation of reactor building ventilation.

Third, if the person were to recognize the need for shielding and try to use a cask of some sort to hold the spent fuel rods, the person would have to obtain a cask of sufficient size, weight, and shielding – not an easy, innocuous, or inexpensive task. Even if such a cask could be somehow obtained without notice, the task of bringing the cask into the reactor building and loading the cask on the refuel floor would be both cumbersome and obvious. Among other things, this activity would require the use of heavy equipment and a crane, and the breach of multiple security barriers and Health Physics checkpoints, as well as the participation of multiple persons, making the clandestine taking all the more risky and all the more unlikely. Additionally, various security barriers and work procedures exist that restrict access only to persons authorized to be in the locations and trained to perform specific work in those locations.

Fourth, any unauthorized work around the spent fuel pool would be subject to discovery by workers, Health Physics technicians, supervisors, operators, and contractors in the area, all of whom are trained to report suspicious activity, particularly unusual activity associated with nuclear fuel. Health Physics personnel in particular, carefully monitored the placement in, and removal of any item from, the spent fuel pool. Moreover, the presence on the refuel floor of an unauthorized cask, the unauthorized removal of material from the spent fuel pool, and the unauthorized loading of the material in the cask would not go unnoticed or unreported. Indeed, the fuel movements and loading operations alone would almost certainly require the assistance of multiple workers. Additionally, Control Room operators have the ability to monitor a television camera that observes activity on the refuel floor. And, operators make periodic rounds of the refuel floor to check on operations, activities, and the equipment in the plant. Security personnel also patrol the area, looking specifically for activities or conditions that are out of the ordinary or that otherwise could affect the security of the plant.

Fifth, security barriers, security alarms, and other measures exist to ensure that unauthorized material does not leave the refuel floor, the reactor building, or the site. Again, the unauthorized removal of a cask or unshielded fuel rods from the refuel floor and the reactor building would require the avoidance of multiple alarms and inspections. Site exit points also contain security measures and radiation alarms.

In short, there are multiple barriers, built to create a defense-in-depth, that would prevent the theft or diversion of the fuel rods.

Two additional reasons support the conclusion that the rods were not stolen or diverted. First, wholly apart from the various radiation, security, and personal barriers that exist to prevent theft, there would be little or no reason for someone to incur the effort and the extraordinary consequences associated with taking two spent nuclear fuel rods. The uranium contained in those rods is far less than that needed to achieve criticality and far insufficient to create a nuclear device or weapon. The rods are simply insufficient in quality and quantity. Moreover, the loss of accountability of these fuel rods occurred over twenty years ago. If a person took the rods when the loss of accountability occurred, it is very likely that the person would have made the taking known in some way by now. Indeed, as mentioned earlier, the highly radioactive nature of spent nuclear fuel makes its retention and actual use extraordinarily difficult, and in fact dangerous, from a practical perspective.

Second, the two spent fuel rods have no economic value. In fact, the radioisotopes found in the fuel rods are largely available in numerous commercial applications around the world and exist in businesses and locations far less secure than a nuclear power plant.

Consistent with this conclusion, since the late 1960s, the NRC (or its predecessor) has collected information about nuclear events involving potential breaches of nuclear security. Of the 1,944 "safeguards" events identified between 1976 and 2000, only thirteen occurred at a U.S. commercial nuclear power facility. Not one of those events involved the theft or attempted theft of nuclear fuel.

Finally, persons in the plant would have no motive to divert or improperly dispose of the rods in some unauthorized manner or in some unauthorized location, even if they could overcome the barriers. The presence of two fuel rods in a spent fuel pool has essentially no impact on the unit, its operations, or the cost of conducting business, either in the short or long-term. Moreover, the barriers and difficulties associated with an unauthorized disposal do not differ in substance from the barriers that prevent theft.

In short, a person attempting the theft or diversion of these rods would be risking almost certain detection and life-threatening health effects for items of virtually no value. There is simply no evidence that the two fuel rods were stolen or diverted.

4.2 Conclusions of the Investigation

The investigation did not produce clear and convincing evidence of the specific location of the two fuel rods from MS-557. The investigation found no credible evidence to believe, however, that the fuel rods are in any place other than the four locations discussed above. Specifically, the two fuel rods are in the Unit 1 spent fuel pool, the GE Vallecitos facility, the U.S. Ecology LLRW facility at Richland, Washington, or the Chem-Nuclear LLRW facility at Barnwell, South Carolina.

The imperfect nature of the body of evidence precludes any attempt to assign reasonable or meaningful probabilities to the four locations. Such an assignment would be highly subjective, and of questionable value. Nevertheless, some better understanding of the evidence is possible.

The likelihood that the fuel rods remain in the spent fuel pool is low. Indeed, the comprehensiveness and quality of the inspections strongly suggests that the fuel rods are not in the pool. The inspections addressed both the most likely places that the rods would be stored, as well as the places that full-length rods (or large segments of fuel rods) could be stored. But the best reasonable efforts of the inspection team were not able to examine all areas of the pool or all areas where smaller segments of cut rods might have been placed. Additionally, safety considerations, pragmatism, and prudence precluded a rod-by-rod inspection of all fuel rods in the pool.

So too, the fuel rods are probably not at the GE Vallecitos facility. Nevertheless, the lack of any confirmed sighting of the rods in 1980, the timing of the April 1980 shipment, and the appearance of many unanswered questions about the April 1980 shipment prevent a categorical finding that the rods were not shipped. To be sure, the consistency of DOE/NRC Form 741 with the known weights of the segmented test rods being shipped, the GE receipt inspection of the arriving cask, as well as the GE testing of the contents of the shipment, provide strong evidence that the rods are not at GE Vallecitos. The GE receipt records for the non-fuel hardware, however, are not fully consistent with the shipping records. The inconsistency does not establish that the rods were shipped, but the appearance of discrepancies in the record of the shipment's contents precludes unconditional reliance on the documents. Perhaps most important is the difference between the weight of the SNM shipped (2.4 kg) and the entries on two NRC documents that indicate that GE received a greater quantity of SNM.

These facts, standing alone, require that the Vallecitos facility remain as a possible – albeit unlikely – location of the rods. The loading of the segmented test rods in this shipment on May 5, 1979, and the unexplained movement of MS-557, the parent assembly of the two fuel rods, to the fuel prep machine on that same day, creates another potential link between this shipment and the two fuel rods. The disappearance of the two fuel rods from all known documents later that year, and the disappearance of the two rods from the memories of those who should have seen or remembered the rods, adds to the uncertainties associated with this shipment. Again, the compilation of these matters does not establish that the rods are at Vallecitos. The possibility that they are, however, cannot be dismissed.

There is no clear and convincing evidence, and in fact, no substantial credible evidence, proving that the fuel rods were shipped to the U.S. Ecology LLRW facility at Hanford. An opportunity for the inadvertent shipment of the rods, however, existed to some small degree in three 1985 shipments. The likelihood of an inadvertent loading of the rods in the first two shipments, however, is not significant. GE's loading of the first shipment and the relative certainty regarding the identity of items bearing any resemblance to fuel rods in the second shipment, reduce considerably the likelihood that either of these shipments contained the fuel rods. For the third shipment, only the inclusion of the hot sections of eight LPRMs of uncertain origin causes this shipment to rise modestly above the others in likelihood. The identity of those LPRM hot sections cannot be established with certainty because, as noted, the source of these items could not be determined. Given the relatively small quantity of LPRM sections included in this shipment, however, the likelihood of inclusion of the fuel rods is not substantial.

So too, there is no clear and convincing evidence that the fuel rods were shipped to the Chem-Nuclear LLRW facility at Barnwell. Of the many shielded shipments to Barnwell, and the three shipments to Hanford, however, the two TN-8L shipments and the one CNSI 3-55 shipment to Barnwell in May 1988 stand out as having a significant opportunity to contain the fuel rods.

In those shipments, WasteChem workers loaded the segments of somewhere between 90 and 98 items described as LPRM hot ends. A review of the total length of LPRM hot ends measured by WasteChem, however, reveals that the shipments included items that could not be LPRMs, given the total number of LPRMs that had been removed from the core and were available for shipment and the number of LPRMs that remained in the pool after the 1988 shipments. That disparity provides the greatest opportunity for the fuel rods to have been included inadvertently among the LPRM hot end sections.

The evidence is clear that, regardless of the precise number of LPRMs included in those shipments, the vast majority of these LPRMs were from the 1979 cutting campaign discussed previously. The records also show clearly that neither NNECO nor WasteChem knew precisely the identity or characteristics of the items being loaded as LPRMs, which they had retrieved from old containers that had been stored in the pool since at least 1979. If the contractors from 1979 mistakenly cut the fuel rods, believing them to be LPRMs, and placed them in containers with LPRMs, it is likely that those cut rods were included in one or all three of the May 1988 shipments.

When NNECO completed the 1988 shipments, engineers responsible for the spent fuel pool believed that they had shipped all LPRMs. The records from the shipments in late-1989 and 1990, however, indicate that LPRMs remained. In fact, WasteChem records show that they encountered "extra LPRMs" in performing work associated with the 1989 and 1990 shipments to Barnwell. The record of those shipments, however, does not disclose any significant opportunities to have mistakenly shipped the fuel rods, but the appearance of extra LPRMs could be an indication that the items previously shipped as LPRMs were not, in fact, LPRMs.

One of the three 1992 shipments to Barnwell provided another – but a significantly diminished – opportunity to ship the fuel rods. The December 8, 1992, shipment of a TN-RAM cask included the contents of a box that engineering personnel believed to be cut-up LPRMs. The actual identity of the contents, however, is uncertain. Again, there is no evidence that this box actually contained the fuel rods, but if they had been cut and were inadvertently placed in the box, they could have been mistakenly shipped. Compared to the 1988 shipments, this shipment is significantly less likely as a possible explanation for the disposition of the rods.

Two of the six shielded shipments to Barnwell in 2000 contain anomalies in the documentation or a lack of clarity in the identification of the items being shipped. For example, the final shipment included an unidentified "bucket of debris" in the inventory with a survey level that neither supports nor refutes the possibility that the bucket contained segments of the fuel rods. That sketchy evidence precludes the exclusion of this shipment from consideration, but the likelihood that this shipment inadvertently contained the fuel rods is slight.

As discussed at the outset, the identification of the 1988 shipments to Barnwell as a possible explanation for the disposition of the fuel rods does not mean that the rods are at Barnwell. Neither the documents nor the interviews provided any evidence actually placing the fuel rods in these – or any other – off-site shipments. The evidence is not sufficiently clear and convincing to establish that the fuel rods are at Barnwell and the conclusions of this report must be read in that context.

4.3 Health and Safety Considerations

Because the investigation was not able to exclude the LLRW waste facilities at Hanford and Barnwell as possible locations for the two fuel rods, it is necessary to consider the potential health and safety effects, if any, of the shipment and disposed of the rods.

Wastes shipped to LLRW facilities are stored in liners transported by specially designed and licensed shipping casks. These low-level waste shipments are surveyed at the shipper's location before departure to ensure that radiation levels meet federal Department of Transportation and NRC standards designed to ensure the protection of public health and safety during shipment. The radiation levels of the fuel rods, if shipped, would fall well below those safety thresholds. Indeed, if shipped, the radiation levels of the fuel rods would have been lower than the radiation level of some of the other irradiated material authorized to be included in the shipment.

Upon arrival at the low-level waste disposal facilities, the liners were removed from the shipping cask and quickly deposited in burial trenches and covered with earth to shield workers and the public from radiation.

The burial of the rods at either LLRW facility would not increase the risk to the health and safety of the public, site workers, or the environment. Both facilities are designed and licensed to safely dispose of all radionuclides contained in the fuel rods. Indeed, all of the radionuclides contained in the two fuel rods are already present in the inventories of those facilities. Moreover, the current inventories of these radionuclides at the facilities far exceed the amount of radionuclides contained in the fuel rods. Thus, even if shipped, the presence of the rods would add only a small amount to the present inventories at the facilities. Although not licensed to accept these materials in the form of spent nuclear fuel, the addition of the rods should not cause either facility to have radionuclides that would change the site's performance assessment for continued long-term disposal. For this reason, the facilities' environmental and safety programs, which assure the safety of the long-term disposal of these radioactive materials, are adequate to account for the relatively small amounts of radioactive material found in the two fuel rods. The sites' operations and programs are also subject to extensive state regulatory oversight, independent assessments, and periodic inspections, providing further assurance of ongoing environmental protection. Indeed, none of the numerous assessments and inspections at either facility have revealed any environmental or other problems that could be attributable to the possible burial of two spent fuel rods. The NRC also provides additional oversight by conducting independent program evaluations of the States' overall regulatory programs and the Low-Level Waste Programs for both South Carolina and Washington.

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137 Memorandum, from J.W. Heard, FRAP-01-012, Fuel Design Configurations for MP-1, April 9, 2001, (Reference 89).

138 Specification P-MI-ME-1004, MP-1 – Request for Services; Personnel, Equipment and Labor Services for Spent Fuel Pool Cleanup, Rev. 1, October 6, 1999, (Reference 90).

139 Automated Work Order AWO MI-91-06527, Remove and Replace SRM/IRM Dry Tubes IAW SP-91-1-037 and PDRC 1-126-91, May 7, 1991, (Reference 91).

140 Memorandum, from E. Biemiller, FRAP-01-083, Millstone Unit 1 Start-up Sources, September 12, 2001, (Reference 92).

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143 *Id.*

144 *Id.*

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Reference 15	Memorandum, from A.W. Cretella/C.D. Mandigo to R.T. Herbert, NEE-79-F-353, Audit of SNM Inventory and Control Procedure RE 1001, November 15, 1979.
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Reference 89 Memorandum, from J.W. Heard, FRAP-01-012, Fuel Design Configurations for MP-1, April 9, 2001.

Reference 90 Specification P-MI-ME-1004, MP-1 – Request for Services; Personnel, Equipment and Labor Services for Spent Fuel Pool Cleanup, Rev. 1, October 6, 1999.

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Reference 92 Memorandum, from E. Biemiller, FRAP-01-083, Millstone Unit 1 Start-up Sources, September 12, 2001.

Reference 93 General Electric Drawing, 886D424, Dry Tube, Rev. 5 (undated).

APPENDIX

APPENDIX INDEX

SECTION 1

FIGURES

Figure 1

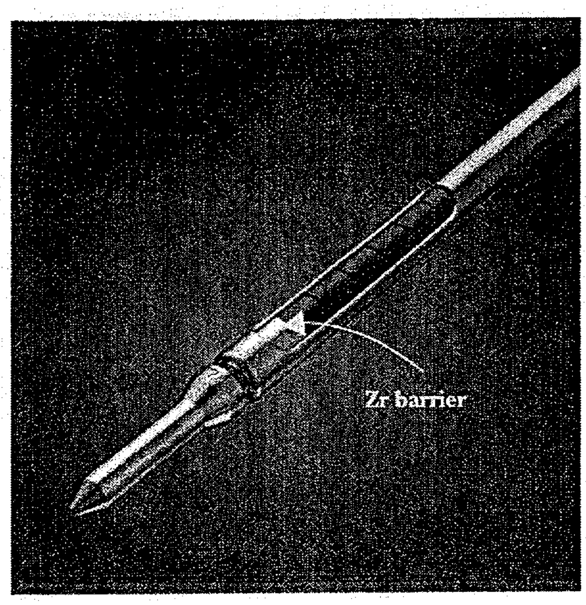
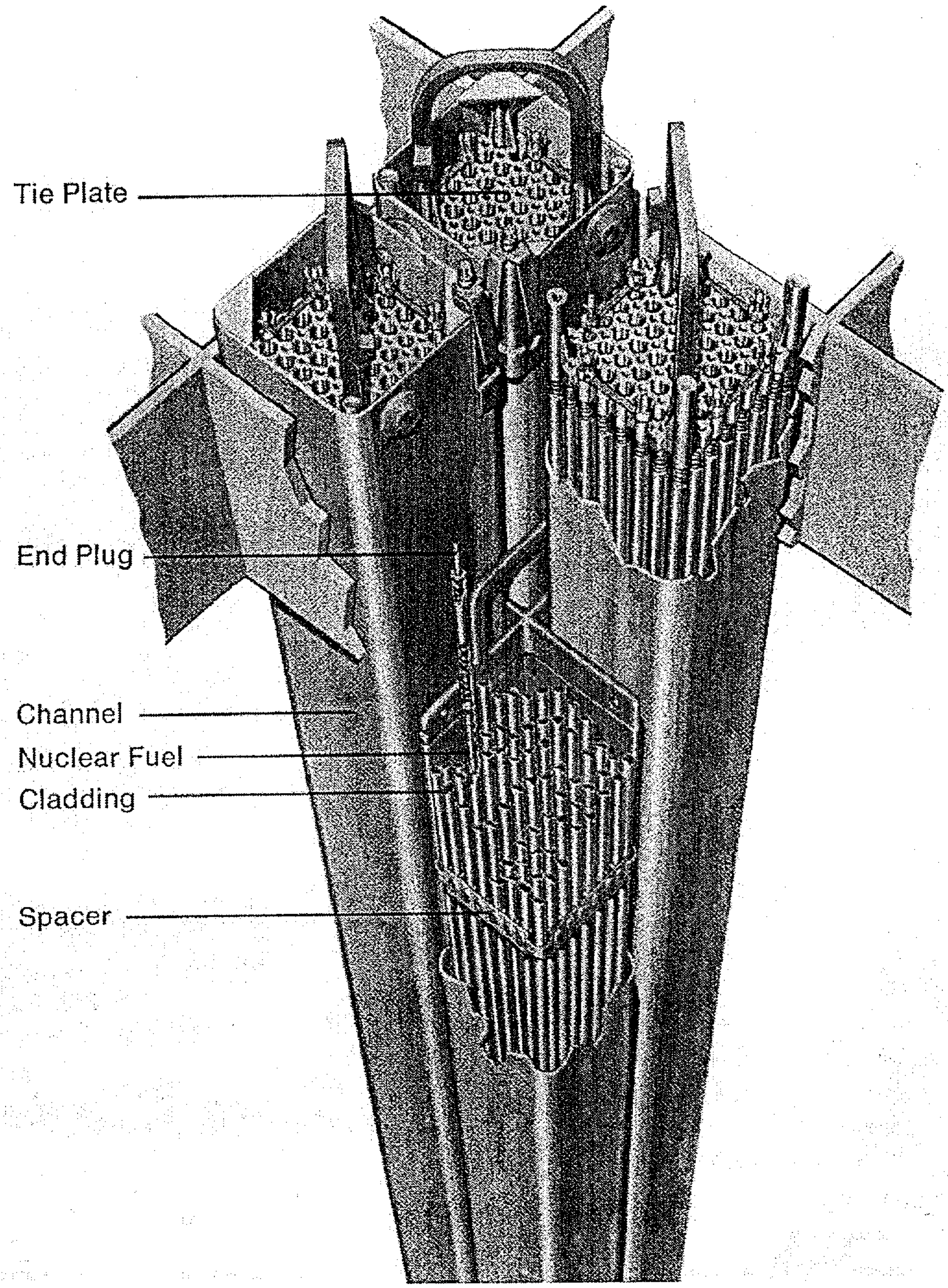


Figure 2



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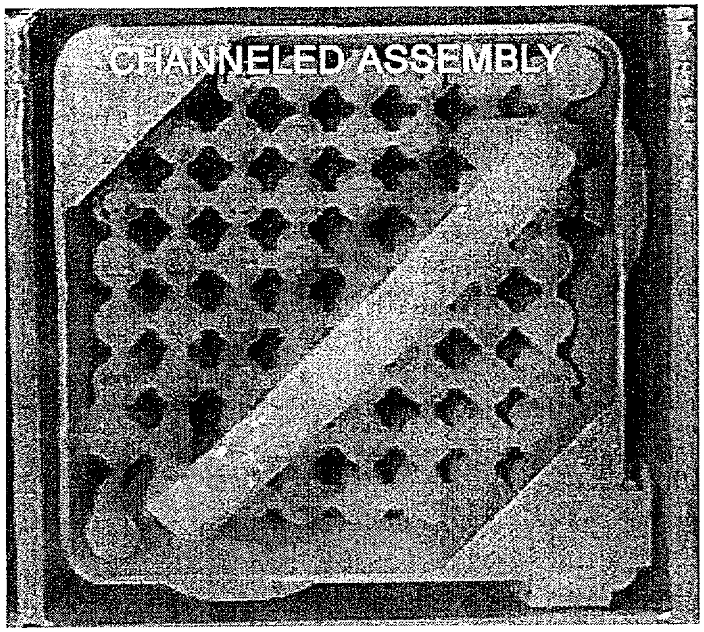


Figure 4

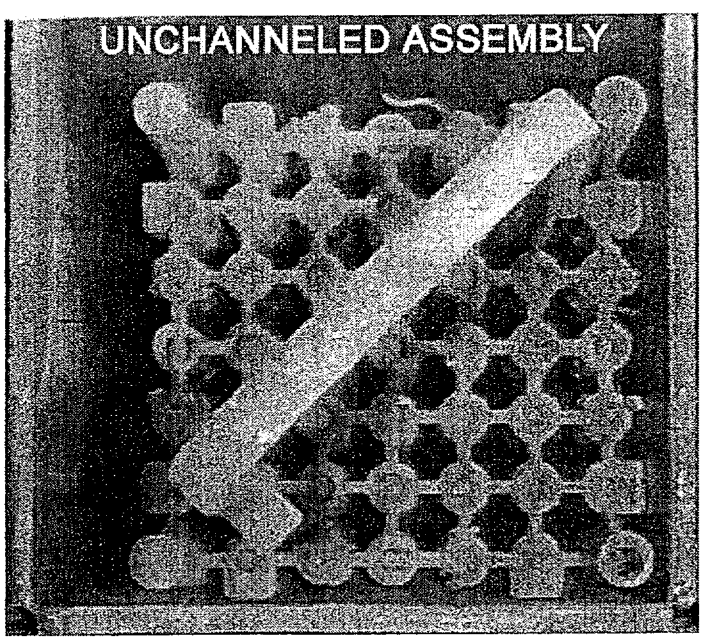
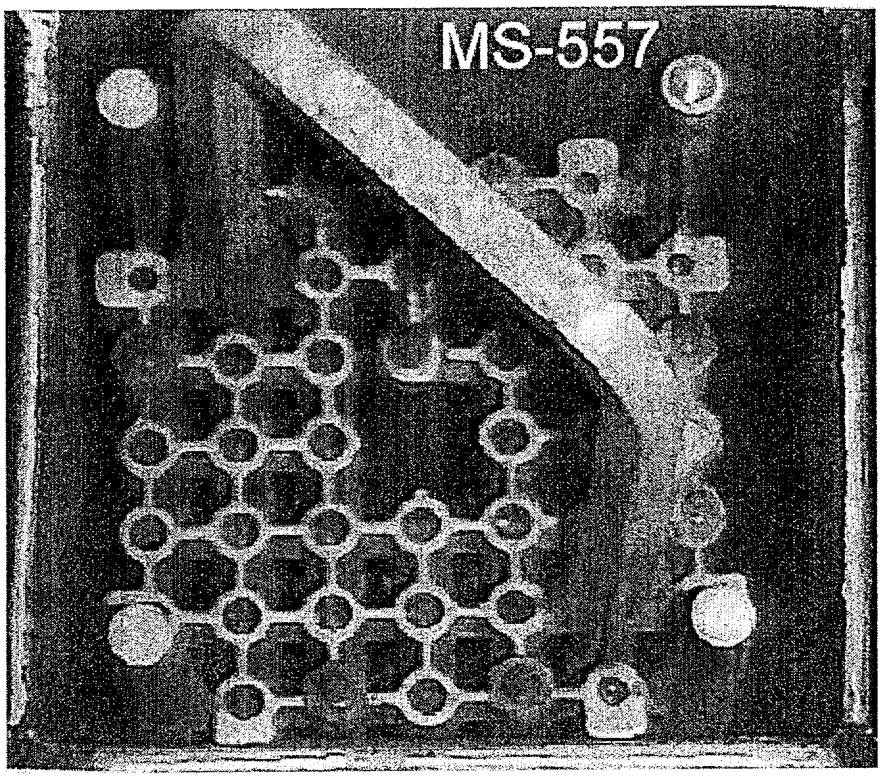


Figure 5



SECTION 2

PHYSICAL INSPECTIONS PERFORMED BEFORE FORMATION OF THE FRAP

Physical Inspections Performed Before Formation of the FRAP

The FRAP did not initiate this investigation. NNECO made substantial efforts and considerable progress in uncovering relevant information months before the formation of the Project.

Early NNECO Physical Inspections

NNECO's initial fuel assembly and spent fuel pool inspections focused on three areas. One area involved a broad search of the pool, including non-standard storage locations, such as behind and under spent fuel storage racks. To perform these spent fuel pool inspections, NNECO contracted ROV Technologies Inc., a group with significant experience in spent fuel pools and reactor video inspection. The second area involved inspections of fuel assemblies MS-557, MS-508 (a previously damaged fuel assembly), and storage assembly SRP-2D. GE performed the fuel assembly inspections under NNECO oversight. NNECO conducted the third set of inspections of other areas and miscellaneous locations.

MS-508

NNECO selected fuel assembly MS-508 for inspection as a potential location because it had been damaged when dropped during the refueling outage of 1974. The fuel assembly itself does not have sufficient extra space in its grid lattice to store a missing rod. However, it sits in a fuel canister designed to hold damaged fuel assemblies. The damaged fuel container is stored in an area of the pool away from the other spent fuel assemblies in a rack designed to hold control rod blades. The damaged fuel container in which MS-508 sits has space sufficient to store one or both of the missing fuel rods. On November 16, 2000, NNECO contractors visually inspected fuel assembly MS-508 with a color camera system without disturbing the damaged fuel assembly. However, the presence of rope and wire on the top of the damaged fuel assembly left over from rigging the damaged assembly into the secure storage location limited visibility.

MS-557

Assembly MS-557 is the original parent assembly of the two missing fuel rods. Prior to November 16, 2000, NNECO contractors visually inspected MS-557 with a color camera without disturbing the fuel assembly. The inspection showed that the fuel assembly's upper tie plate had been modified and that the center spacer capture rod protruded above the upper tie plate. The spacer capture rod appeared to be clean and free of the corrosion layer expected of an irradiated fuel rod. This suggested that it was not the original center spacer capture rod, but was a dummy rod. The inspection also revealed that the lattice location of the missing tie rod was empty. On December 5, 2000, a GE team began additional inspections of MS-557. The fuel assembly was moved to a fuel preparation machine where visual inspections confirmed that the missing tie rod was not located elsewhere in the assembly. To verify the identity of the center spacer capture rod, GE removed the assembly's upper tie plate and withdrew three fuel rods to allow visual inspection of the entire length of the center spacer capture rod. GE observed the rod over its full length; no indications of exposure to a reactor environment were observed. Additionally, the installed rod, which protruded above the upper tie plate, was observed to be measurably longer than the dimensions of the original, now missing, spacer capture rod. GE assembled MS-557 and it was returned to its storage location in the spent fuel storage racks.

SRP-2D

The Unit 1 SFP also contains a spent fuel storage assembly, similar to a spent fuel assembly, left behind as a result of GE's segmented test rod program. In the 1970s and 1980s, GE carried out a program of inserting segmented test rods ("STRs") in a specifically designated fuel assembly, MSB-125, subsequently removing the rods from that assembly, and shipping some of them to VNC for testing. GE placed those spent STRs not returned to VNC for testing in assembly SRP-2D for storage.

On December 5, 2000, assembly SRP-2D was also taken to the east fuel prep machine for inspection by GE. The inspections involved using a video system to observe the interior of the fuel assembly and to verify that the fuel rods present in the assembly matched those reflected in plant records. The fuel assembly was noted to have 15 segmented fuel rods and four full-length rods from the STR program. No other rods were observed in the fuel assembly.

SECTION 3

PERSONNEL INFORMATION AND ORGANIZATION STRUCTURE

Organization Structure and Personnel Information

Key Personnel

Frank C. Rothen
Mr. Rothen serves as the Executive Sponsor for the investigation on behalf of Northeast Utilities Service Company ("NUSCO"). As the Executive Sponsor, he is the senior manager on the project and primary point of contact to the Unit 1 licensee, Dominion Nuclear Connecticut ("DNC"). When named Executive Sponsor, Mr. Rothen was Vice President - Nuclear Work Services for Northeast Utilities Service Company.

Robert V. Fairbank
Mr. Fairbank is the Project Manager for the FRAP investigation. His responsibilities include management of the Investigation Team and its day-to-day operations. He possesses over 30 years of engineering and management experience in the nuclear power generation industry, with major experience in engineering, project management, and regulatory assurance.

Richard N. Swanson, P.E.
Mr. Swanson is the senior member of the Root Cause Assessment Team. He is a licensed Professional Engineer (mechanical) possessing 16 years experience with nuclear utilities (11 years in senior management positions) and 6 years as an independent consultant.

L. Joseph Callan
A member of the Independent Review Team ("IRT"), Mr. Callan has held several senior management positions within the U.S. Nuclear Regulatory Commission ("NRC") and has more than 30 years of nuclear experience. He has been a NRC Regional Administrator and the Executive Director of Operations. At present, he serves as a consultant to the nuclear industry and serves on several top-level oversight and advisory boards.

Bruce Hinkley
Mr. Hinkley is the lead member of the IRT. He has more than 25 years of nuclear industry experience and has held senior positions with nuclear utilities and engineering organizations. He is currently the Manager of Nuclear Projects with Stone and Webster.

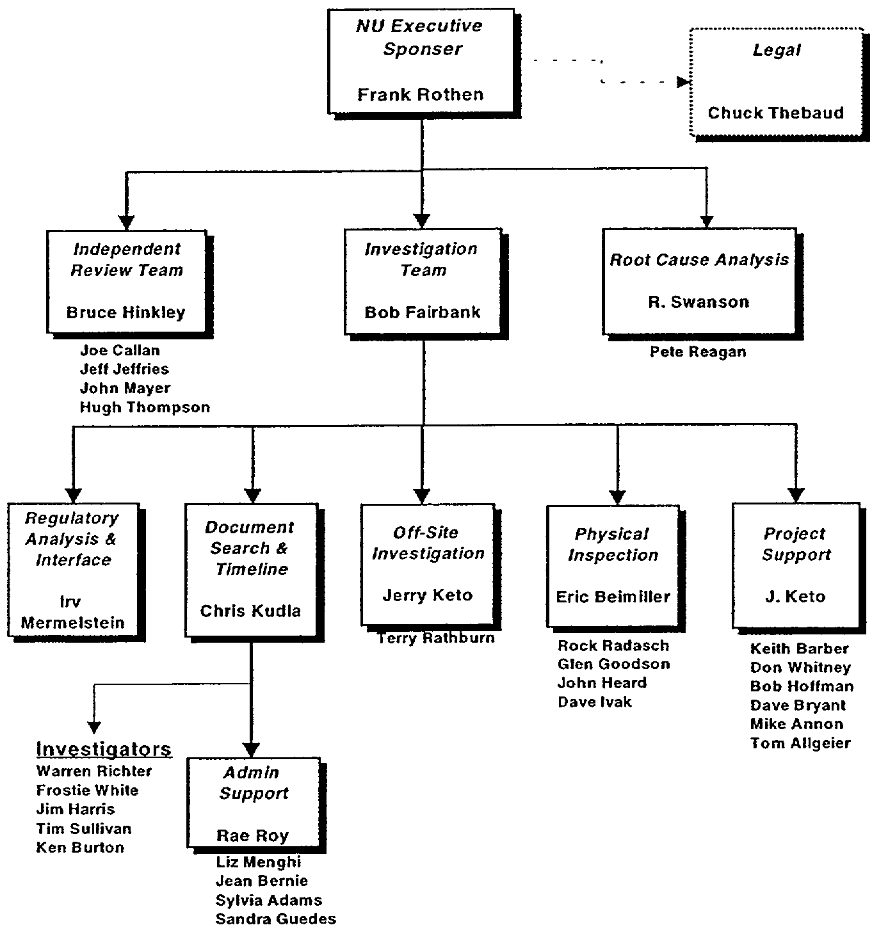
Jeffrey D. E. Jeffries, Ph.D., P.E.
A member of the IRT, Dr. Jeffries has 33 years of nuclear experience and is an internationally recognized expert in the areas of nuclear safety and applied risk assessment. He has been a senior manager with a nuclear utility, the Electric Power Research Institute, and a consulting firm. In addition, Dr. Jeffries has

taught nuclear engineering at two major universities. He has a Ph.D. in nuclear engineering and is a registered professional engineer.

John Mayer
A member of the IRT, Mr. Mayer has over 15 years expertise in the specialized field of nuclear fuels reliability and spent fuel characterization. He provides fuel and core component design review, fuel performance monitoring, failure prediction analysis, Special Nuclear Materials reports, and spent fuel inspection and characterization services. He also conducts fuel fabrication technical assessments at various vendor facilities, acting both as an Independent Technical Auditor and Technical Specialist during quality assurance audits.

Hugh L. Thompson, Jr.
A member of the IRT, Mr. Thompson has over 35 years of nuclear experience including several senior management positions with the U.S. Nuclear Regulatory Commission. He was Director of the Office of Nuclear Materials Safety and Safeguards and served as the Deputy Executive Director for Regulatory Programs. At present, he serves as an expert consultant to the nuclear industry in the areas of nuclear safety, nuclear waste management, and licensing.

FRAP Organization Chart



SECTION 4

FRAP GOVERNING DOCUMENTS

FRAP Governing Documents

M10063 Project Description

NNECO initiated the Fuel Rod Accountability Project ("FRAP"), project number M10063, in response to Condition Report M1-00-0548, dated November 16, 2000. The objective of the project was to determine the ultimate disposition of the two Unit 1 spent fuel rods. The Project Description includes broad guidance for project organization and staffing, process and methods for the investigation, internal and external communications, document control, quality assurance, training, and corrective actions.

M10063-0 FRAP Investigation Team Project Plan

The FRAP Investigation Team Project Plan provides a general overview of the investigation. It also sets forth a detailed description of the Investigation Team's responsibilities and tasks in determining the location of the two spent fuel rods. The document describes the Team's organization, roles, responsibilities, specific tasks, milestones, and success criteria.

FRAP Guidelines

There are ten Project Guidelines that apply to various aspects of the investigation. A brief description of each guideline follows.

M10063-1 Guideline for Development and Control of Project Guidelines, Correspondence, and Record Keeping

This guideline provides instructions and standards for adhering to other guidelines, correspondence controls, and record keeping. The guideline discusses the need and process for guideline development, formatting, approval, control, and review, along with the establishment of a centralized project file.

M10063-2 Guideline for Physical Inspections

This guideline addresses the physical inspection of the Unit 1 spent fuel pool. The document notes the scope of pool inspections, the need for inspection plans for each discrete inspection effort, and the completion of a written evaluation regarding the inspection results.

M10063-3 Guideline for Document Investigation

This guideline defines the process for the search and retrieval of documents, the subsequent document review, additional searches, and records retention. As an aid to the Investigation Team and the preparation of scenario dispositions, the guideline calls for the development and maintenance of a data base of collated document searches and the subsequent search results.

M10063-4 Guideline for Interviewing

The guideline provides instructions and guidance to FRAP Investigation Team interviewers in preparing for and conducting interviews. The document also sets forth the steps for evaluating and documenting the information obtained in the interviews.

M10063-5 Guideline for Scenario Development and Investigation

This guideline establishes the process for evaluating evidence leading to the identification of potential outcomes or scenarios for the missing fuel rods. The document describes the steps to identify, describe, screen, and prepare disposition documents for scenarios.

M10063-6 Guideline for Project Training

The guideline provides the training methods to be used and the requirements for documenting project-related training.

M10063-7 Guideline for Project Quality Assurance Plan

This guideline identifies potentially applicable procedures that may apply to the FRAP efforts. The document noted that it was likely no QA records would be produced by the project.

M10063-8 Guideline for Verifying the Inventory of Nuclear Fuel

This guideline was established to govern the creation of a detailed inventory of all the nuclear fuel at Millstone Unit 1. The document sets forth the process to create the inventory and verify fuel quantities on-site and those shipped to other locations.

M10063-9 Guideline for Condition Report Initiation

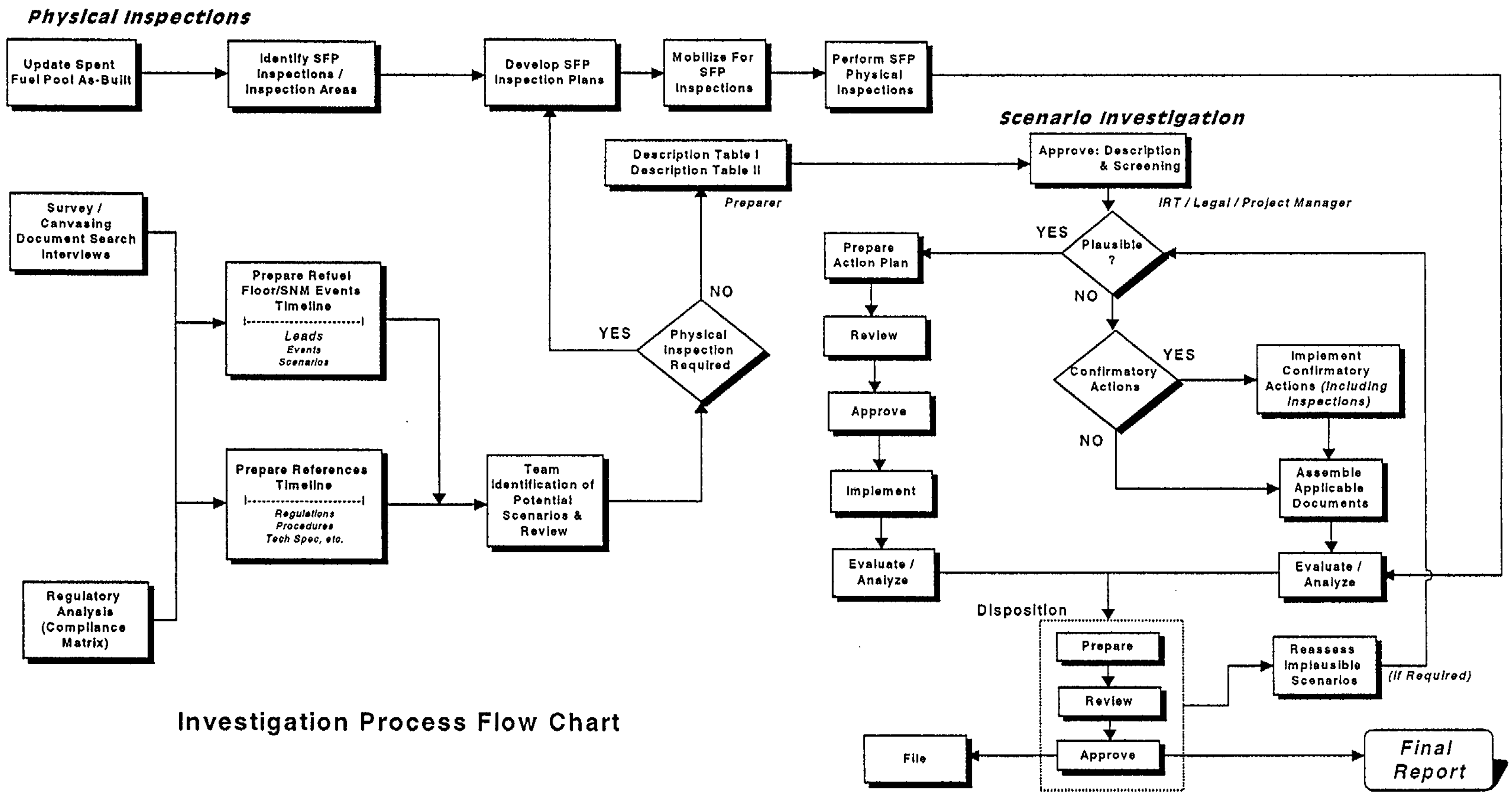
The guideline provides guidance for documenting deficiencies discovered while conducting the FRAP investigation. The guideline does not limit or prohibit any individual from writing a Condition Report.

M10063-10 Guideline for Weighing Evidence

This document provides general guidance to FRAP Team members on weighing and evaluating information obtained from documents, interviews, and other sources during the investigation. The document also establishes a "clear and convincing evidence" standard of proof.

SECTION 5

FRAP INVESTIGATORY PROCESS



Investigation Process Flow Chart

SECTION 6

LIST OF SCENARIOS

Unit 1 Spent Fuel Pool	
5.1. 1	Inspection of MS-508
5.1. 2	Inspect gap btwn MS-508 and "gun barrel"
5.1. 3	Inspect SFP floor for rod segments
5.1. 4	Look for pellets separated from rods
5.1. 5	Inspect SRP 2D fuel bundle
5.1. 6	Inspect water rod sites (in 8x8 bundles)
5.1. 7	Inspect fuel assembly MS-557
5.1. 8	Inspect unchanneled fuel bundles
5.1. 9	Inspect channeled assemblies for gaps
5.1.10	Examine area inside CRB guides
5.1.11	Examine rack cell area holding CRB guides
5.1.12	Inspect square cans (2)
5.1.13	Inspect boxes of LPRMs
5.1.14	Inspect filter baskets
5.1.15	Examine STR fuel assembly MSB-125
5.1.16	Inspect empty fuel storage racks w/channels
5.1.17	Examine two cells containing debris
5.1.18	Examine channel storage racks w/channels
5.1.19	Inspect control rod storage racks
5.1.20	Inspect pipe(s) on north side of SFP
5.1.21	Inspect cask liner used for instrument tubes
5.1.22	Inspect internal area of fuel prep machine
5.1.23	Inspect external areas by fuel prep machine
5.1.24	Inspect two dummy assemblies
5.1.25	Inspect free space between racks
5.1.26	Examine area between racks and SFP wall
5.1.27	Examine two boraflex coupon containers
5.1.28	Examine area btwn SFP the reactor gates
5.1.29	Examine scavenged fuel bundles
5.1.30	Inspect new fuel vault area/racks
5.1.31	Inspect NW wall area
5.1.32	Inspect top of fuel racks
5.1.33	Examine raised fuel assemblies
5.1.34	Inspect free space under fuel racks
5.1.35	Examine bundles for signs of disassembly
5.1.36	Examine misc. SFP items
5.1.37	Inspect SFP sump
5.1.38	Examine space btwn cylinders of "gun barrel"
Millstone Unit 1, 2 & 3	
5.2. 1a	Fuel rods sent to "Bunker" for storage
5.2. 1b	Fuel rods sent to "Bunker" for storage
5.2. 2	Unauthorized disposal (on-site)
5.2. 3	Fuel rods sent to Warehouse #9 for storage
5.2. 4	Fuel rods sent to MRRF for storage
5.2. 5	Drywell Sump
5.2. 6a	Rods sent to MP2 (whole/recognized)
5.2. 6b	Rods to MP2 (whole/unrecognized)
5.2. 6c	Rods sent to MP2 (cut/unrecognized)
5.2. 7a	Rods sent to MP3 (whole/recognized)
5.2. 7b	Rods to MP3 (whole/unrecognized)
5.2. 7c	Rods sent to MP3 (cut/unrecognized)
5.2. 8	MP1 RX
5.2. 9	MP1 Steam Separator Area
5.2.10	MP1 TIP Room
5.2.11	MP1 Storage Areas
5.2.12	Other
Hanford	
5.3. 1	IF-300 Shipment - 3/21/85
5.3. 2	IF-300 Shipment - 5/29/85
5.3. 3	IF-300 Shipment - 7/31/85
5.3. 4	Other shielded shipments (e.g., resin / LSA)
Barnwell	
5.4. 1	TN-8L - 1988 (1, 2)
5.4. 2	TN-RAM - 1989-90 (2)
5.4. 3	TN-RAM - 1992 (1,2,3)
5.4. 4	TN-RAM - 2000 (1,2,3,4,5)
5.4. 5	Other shielded shipments (e.g., resin / LSA)
Vallecitos	
5.5. 1	GE-1600 shipment - 1980
5.5. 2	Shipment #2 - 1981
5.5. 3	Shipment - 1983
5.5. 4	Shipments - 1984 (1); 1985 (3)
5.5. 5	Other Shipment
Morris	
5.6. 1	Shipment of LSA - 1985 (1,2)
Uncontrolled	
5.7. 1	Unauthorized disposal (off-site)
5.7. 2	Unauthorized disposal (off-site)
5.7. 3	Theft from owner property
Other	
5.8. 1a	MP1 direct shipments
5.8. 1b	MP1 direct shipments

SECTION 7

REGULATORY COMMUNICATIONS

List of Significant Regulatory Communications

NRC and Stakeholder Notification of Event

In accordance with the requirements of 10 CFR 50.72(b)(2)(vi), Northeast Nuclear Energy Company ("NNECO"), the then licensee of Millstone Unit 1, notified the U.S. Nuclear Regulatory Commission ("NRC") of its inability to determine the location of the two fuel rods on December 14, 2000 via NRC's Emergency Notification System. The notification provided a summary of the fuel rod event as understood at the time. NNECO also notified the NRC Region 1 and the State of Connecticut of the event on December 14, 2000.

Licensee Event Report

On January 11, 2001, NNECO submitted Licensee Event Report ("LER") 2000-02-00 to the NRC pursuant to the requirements of 10 CFR 20.2201(b). The LER provided a description of the event, a chronology, a description of the investigative effort, information regarding any impact upon health and safety, current investigative action, and future actions. On March 30, 2001, NNECO supplemented the LER by providing an update of the progress made in the ongoing investigation.

Weekly Telephone Calls

Open communications have existed between the NRC, NNECO, Dominion Nuclear Connecticut, Inc. ("DNC"), the States of Connecticut, South Carolina, and Washington to ensure that all parties are informed and kept abreast of current issues, schedules, and the status of ongoing activities. The primary communication vehicle was a weekly conference call with stakeholders. These conference calls began in December 2000, and have continued throughout the investigation.

Public Meeting at King of Prussia

On April 23, 2001, DNC and Project leaders met with officials from NRC Region I at their office in King of Prussia, PA. The purpose of the presentation was to provide the NRC with an understanding of the status and progress of the investigation.

NRC Inspections

The NRC completed an inspection, No. 2000-18, of Millstone Unit 1 on April 27, 2001. This inspection focused on the Conduct of Operations and Radiation Protection and Chemistry ("RP&C"). As part of the RP&C inspection, the NRC reviewed the licensee's effort to locate the two spent fuel rods.

The inspection results were documented in the NRC Inspection Report No. 05000245/2000018, dated June 4, 2001. In this Report, the NRC Inspector noted that dedicated staffing for the investigation had expanded through the end of the inspection period, with 21 professional/technical staff working on the project as of April 23, 2001. Also, the Inspector noted that an independent oversight review team had been formed to review investigation activities as they were being developed. The Report concluded that the investigation effort was progressing in a thorough and systematic manner and the investigation results would be reviewed as they became available.

Section 8

Industry Communications

Industry Communications

Northeast Nuclear Energy Company submitted information to the Institute of Nuclear Power Operations ("INPO") describing the missing fuel rod event. In turn, INPO issued OE11903, "Location of Two Full - Length Irradiated Fuel Rods Can Not be Determined" to INPO members on February 9, 2001. The INPO report summarized the Millstone Unit 1 missing fuel rod event.

SECTION 9

COMMUNITY COMMUNICATIONS

Community Communications

As part of the effort to maintain an open dialogue with the public, the Fuel Rod Accountability Project ("FRAP") leadership met with community groups to discuss the status of the investigation. Project management met with the Millstone Unit 1 Decommissioning Advisory Committee ("M1DAC") on a near monthly basis from January to May 2001. These public meetings took place on:

- January 4, 2001
- February 1, 2001
- March 1, 2001
- May 3, 2001

Also, project management met with the Nuclear Energy Advisory Committee ("NEAC"). The meeting with the NEAC occurred on May 17, 2001.

In these meetings, the Executive Sponsor, the Project Manager, and, on some occasions, a representative from the Independent Review Team, discussed the ongoing investigative activities, searches of the Unit 1 spent fuel pool, and upcoming activities. Members of the Project also responded to questions from the committees and the public.

SECTION 10

INTERNAL COMMUNICATIONS

Internal Communications

The Millstone Nuclear Power Station internal publication "*To the Point*" carried articles summarizing events associated with the missing fuel rods. These articles, dated January 29, 2001 and April 29, 2001, solicited assistance from anyone in the Millstone site community with information related to the two missing fuel rods.

In addition, on March 2, 2001, Frank C. Rothen, the Executive Sponsor for the Fuel Rod Accountability Project, sent an email communication on the Millstone network requesting assistance from anyone with knowledge that would assist the investigation.

SECTION 11

OVERSIGHT AND ASSESSMENT

Oversight and Assessment

The Fuel Rod Accountability Project ("FRAP") team included over 20 full-time professionals and various administrative support personnel. These professionals averaged over 28 years of experience in the industry. The team members included former managers in engineering, operations, and regulatory assurance. Other team members served as former first-line supervisors, project managers, and engineers.

FRAP work practices were standardized and governed by written guidelines and, where applicable, procedures. Project personnel were trained on the requisite guidelines and procedures to ensure a high degree of quality and consistency. Furthermore, FRAP deliverables were reviewed by the Independent Review Team ("IRT"), legal advisor, and Project Manager for accuracy, quality, consistency, and auditability. Additionally, third-parties performed nine assessments to ensure the effectiveness of complying with FRAP Guidelines and processes.

The Project anticipated that the results of the FRAP investigation would not produce any Quality Assurance ("QA") records. However, the Project's efforts have been guided by QA principles. That is to say, reviews conducted in accordance with FRAP Guidelines have been conducted by technically competent personnel to assure completeness of the activity performed. All Project documents, such as correspondence (internal/external), interviews, and records reviewed and deemed pertinent, have been retained to assure completeness.

Training

The Project trained personnel to assure that those assigned to this project had the appropriate level of understanding to perform their assigned tasks. FRAP guidelines assured a consistent approach to training. The guidelines also provided for the methods of training to be used and for documenting an individual's qualification for a specified task, with the justification for that qualification.

The training methods used were drawn, in large measure, from the requirements stated in Unit 1 Decommissioning Document U1-TQ-1, Rev.1, "Personnel Qualification and Training." (The requirements of 10 CFR Part 50, Appendix B; 10 CFR 50.120; and ANSI 18.1 -1971 were not applicable to the project, even though U1-TQ-1 was designed to meet these criteria.)

The FRAP team conducted two "self-assessments" to evaluate whether project personnel were acting in compliance with project guidelines. In June 2001, the first assessment determined that personnel were following the procedures set forth in the Document Investigation Guideline, M10063-3. The second assessment, completed in July 2001, reviewed the documentation of project training in accordance with Guideline M10063-6 and document review procedures in M10063-3. The second self-assessment concluded that the FRAP Team was conducting training in conformance with the applicable guidelines.

Independent Review Team

The IRT was comprised of five independent (non-NU or DNC) personnel with significant, relevant industry experience. They reported directly to the FRAP Executive Sponsor. As noted, the IRT was independent of the line functions with the FRAP Investigation Team structure so that it could provide the Executive Sponsor with an unbiased perspective on matters pertaining to the project. The IRT provided oversight and ongoing review of key decisions, conclusions, plans, procedures, guidelines, methods, scenarios, schedules, external communications, selected internal communications, root cause investigation, and other areas necessary to provide added assurance of the respective accuracy, quality, consistency, and auditability of project activities.

Third-Party Assessments

A total of nine third-party assessments were performed. The assessment team was comprised of highly-qualified individuals from Duke Engineering and Services. The purpose of these third-party assessments was to evaluate the effectiveness of complying with FRAP Guidelines and processes established to disposition the location of the two missing fuel rods. The scope of the independent assessments included, but were not limited to, physical inspections, document searches, personnel interviews, scenario dispositions, adequacy and responsiveness of corrective actions, and administrative controls.

The third-party assessments identified 33 issues that were individually tracked to closure by the Project. Many of these issues were process improvements that the Project adopted and promulgated in guideline revisions. In some instances, the issues related to recommended improvements of project deliverables, such as the physical inspection report. One of the more significant recommendations concerned the addition of a second applicability and relevance review of documents after the scenarios were developed. The Project implemented these recommended improvements.

In two instances, the Project wrote corrective action reports (or condition reports) due to an identified deficiency in the implementation of an existing guideline. The Project corrected these two deficiencies.