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OVERVIEW OF DECOMMISSIONING ACTIVITIES IN THE US

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ABSTRACT

The U.S. has been involved the successful decontamination, decommissioning and reutilization of nuclear facilities for over 20 years. A number of commercial power plants in the United States have either completed their decommissioning, or will be in the next few years. In addition, the U.S. DOE has taken an aggressive approach to site remediation focusing on site closures so as to better utilize its financial resources.

The U.S. initiative to deregulate the electrical generation industry to promote competition and presumably to reduce electricity prices to the consumer, is again in flux. Some utilities, facing the real or perceived threat of competition in its markets decided to shut down the "costly" nuclear plants to alleviate the drain on their financial reserves. The older nuclear units experienced serious mechanical problems, entailing expensive repairs and replacements. Such difficulties have caused owner-operator utilities to decide to decommission these facilities rather than incur the expense of upgrading or repairing the plants to meet current regulatory and design criteria. Plants that were marginally cost-competitive, or not at all competitive, were shut down and decommissioned. Other utilities have bought some of the older nuclear plants in the Northeast (a high power demand region) to operate them and to extend their licenses for continued life.

This paper will discuss the decommissioning lessons learned, management approaches, site characterization and challenges faced in disposition of radioactive waste and large components, contracting practice, and the status of several of these shut down reactor-decommissioning programs. The industry has proven that nuclear power plants can be cost effectively and safely decommissioned.

1. LESSONS LEARNED IN DECOMMISSIONING PLANNING

There is a significant amount of decommissioning experience in the US on large-sized power reactors. While to date most of the decommissioning activities have been successful with respect to public health and safety, and safety to the workers, there are a number of lessons learned during the planning process that can help in the planning of future projects. Probably the most important lesson is for owner-utilities to use the funds allocated in the cost estimates for engineering and planning. All too often owners try to bypass this important planning process in the interest of showing some field progress, at the expense of the orderly progression of the project. Often, premature decisions made early in the project preclude use of existing personnel and equipment resources needed later in the project.

1.1 Pre-Planning

A significant amount of valuable time and expense can be saved if licensing submittals (safety analyses or cases, technical specification changes, and organizational changes) are made prior to shutdown of the reactor. A core team of experienced reactor personnel, assisted by consultants experienced in decommissioning planning should be organized as early as two years before shut down to start the planning process.

The owner-utility should begin to identify options for the disposition of the plant and site. A significant amount of good planning can be wasted if management has not set pre-shutdown guidance to the planning team. Last minute changes can be wasteful of resources, and result in morale problems if clear management direction is not given at the outset.

A thorough characterization program should be conducted of the plant, site, and environs. This is the key-planning tool to a successful decommissioning project. The disposition of equipment and structures, waste streams, cost and schedule control all hinge on a comprehensive and accurate characterization program.

Management should define the transition process from operations to decommissioning. The identification of owner responsibilities and personnel requirements should be made early in the decommissioning planning.

Operating records important to decommissioning should be archived in a retrievable manner to facilitate decommissioning planning. In the event decommissioning activities are delayed for several years, the availability of knowledgeable personnel familiar with the equipment and structures may become an important issue.

1.2 Transition Planning

Transitioning from an operating power plant to decommissioning involves a major culture change within the owner-utility organization. For many personnel, there is a traumatic change that requires clear direction from management as to the employee's future with the company and their careers. A transition plan must be developed with specific milestones as to when key events are to occur, and when selected personnel will no longer be needed.

The transition plan should identify essential management resources and associated personnel. This will usually involve an incentive plan to retain key personnel to complete specific milestones, and a severance plan to cover redundant personnel. The plan must recognize differences in management as well as organized labor groups with respect to the types of compensation each receive.

The transition plan should be coordinated with human resources department, public relations groups, and local and federal legislators. The shutdown of the plant will have significant impacts on company policies, the local public in terms of services companies and local stores, restaurants, hotels, etc., and legislators who will have to deal with local unemployment issues, among others.

1.3 Risk Reduction

Preemptive planning and engineering to anticipate potential problem areas and accidents or injuries during decommissioning can achieve risk reduction. Every major activity in the decommissioning process should be examined for potential accidents or problems, and recommended solutions proposed and evaluated by the decommissioning planning team. Characterization of the facility is another way to minimize risk to personnel in the form of exposure reduction, and risk of cost overruns by eliminating uncertainties in the work scope. The characterization plan is used to bound the potential hazards to workers and the public by providing the scope and extent of contamination and high radiation areas. These are key planning tools for risk reduction.

The use of a Decommissioning Operations Contractor (DOC) to perform most if not all of the decommissioning activities is another way to transfer risk to other parties. With a well-defined work scope, a DOC can bid fixed-price for virtually all of the work and assume the associated risks, thereby bounding the cost and transferring the risk. The use of performance-based fixed-price contracts with the DOC or other subcontractors transfers the risk away from the owner-utility. The DOC will usually set its fixed-price sufficiently high (including contingency) to cover its estimate of risk.

1.4 Management

There are a number of management options that may be exercised to decommission a facility. One method already described is a turnkey transfer of responsibilities to a DOC. All management responsibilities for the project are given to the DOC. The owner-utility usually retains the license and associated responsibilities of regulatory control. The second method is a partnership wherein the owner-utility retains a portion of the work, and a major contractor is retained for specific activities such as a major rigging company for heavy lifts, or a shipping/barging contractor with specialized equipment. The third method is where the owner-utility manages the project and subcontracts the work to numerous smaller contractors. Each of these methods has been applied in US decommissioning projects.

One contractor acting as the DOC at the Maine Yankee Decommissioning project incurred financial problems and was relieved of its responsibilities at the site. The owner/licensee had to take over the responsibilities and self-perform the decommissioning activities. This example drives home the point that the owner/licensee has a continuing responsibility to see the project through to completion. There is a definite risk in expecting the DOC to perform all the high-risk activities without utility involvement. The utility must maintain full cognizance of the DOC's activities at all times.

Another issue management must evaluate is productivity of the workforce and site management. Whether to use in-house management staff and craft workers to perform the decommissioning work or to subcontract out these responsibilities is often a difficult decision. On the one hand, the owner-utility may feel some responsibility to its employees to retain them to work on the decommissioning project. The owner-utility must be prepared for worker apathy, wherein there is no driving force or incentive to complete the project in a timely manner. As one owner put it, "You're asking the employees to dig their own graves." If the owner-utility subcontracts the work, there may be issues of disgruntled employees and potential lawsuits. Management needs to set a clear policy on this issue and establish reasonable guidelines.

1.5 Decontamination and Dismantling

Characterization again is a major element in decommissioning planning with respect to the amount of radioactivity and hazardous materials that needs to be addressed. Decisions regarding the need for full system or partial system decontamination for exposure reduction to workers can only be made on the basis of an accurate characterization program. Disposition of the site after decommissioning may also hinge on the characterization data.

The decommissioning program should be simplified by using off-the-shelf tools wherever possible. Most decommissioning tasks can be accomplished with well-established and proven techniques. This is not a time for research and development programs fostered by aggressive but well-meaning vendors. If such "new" techniques appear to offer some advantage, be sure to recognize its use as research and development, so as not to rely too heavily on its reported results.

In the interest of reducing monthly and annual carrying costs for maintenance and surveillance, some owner-utilities have adopted a "cold and dark" approach of temporary plant lay-up, waiting decommissioning. This approach has been found to be cost effective, but several precautions should be observed. In high-humidity regions, it is prudent to maintain ventilation and dehumidification within all buildings. This will reduce the potential for the potentially deadly Legionnaire's disease, caused when spores of bacteria within ventilation systems grow in the cold and dark environment. High humidity will also cause asbestos insulation to begin to break apart and become airborne. High humidity in frigid regions may lead to condensation and ice formation within the unheated buildings, adding to the hazards to contend with. Without adequate ventilation flow, radon and its daughter products will build in closed buildings. Some surveillance will have to be maintained throughout the dormancy period to ensure hazards will not be introduced into the project.

Some owner-utilities have approached decommissioning as a "hobby." Work is performed on an as-available basis with respect to personnel and support equipment. This leads to inefficiencies in the work performed, higher costs, and personnel productivity and morale problems. Don't start decommissioning unless sufficient funds are available to perform all the work on a continuous basis. Once started, keep the momentum going with an aggressive program of activities for the workers.

Some owner-utilities have performed full-system decontamination for dose reduction. Planning activities should include a cost-benefit analysis of the expected dose reduction and associated cost. Look to alternative methods to reduce dose to workers including administrative controls, stronger safety training and awareness programs, temporary shielding, robotic tooling, or simple radioactive decay to reduce exposure levels. Take a hard look at the assumptions made in the expected dose estimate to ensure it is not too conservative, driving up the dose estimate.

Chemical or mechanical decontamination is best applied where the component or structure can be free-released. If successful in free-releasing the item, waste volumes are usually minimized. If you don't free-release, you increase the waste volume in the form of secondary wastes from decontamination, and you ultimately will have to remove, package, ship, and bury the item later.

2. STATUS OF DECOMMISSIONING PROGRAMS

There are currently six major commercial decommissioning projects under way in the U.S. They are Yankee Rowe, Trojan, Maine Yankee, Connecticut Yankee, Big Rock Point, San Onofre Unit 1, Millstone Unit 1, and Rancho Seco. Two others, Humboldt Bay Unit 3, and LaCrosse are in the very early stages of decommissioning and are not included here.

The current decommissioning programs in the U.S. have employed existing state-of-the-art equipment and techniques to successfully remove systems, components, and structures safely. No new cutting or demolition equipment was needed, nor any extensive research and development effort conducted to achieve the objectives of the programs. This fact has provided a level of confidence to the industry that decommissioning is neither high-risk work, nor an impossible task involving space-age technology. The activities accomplished at each of these reactor sites will be described in the following sections.

2.1 Yankee Rowe

Yankee Rowe, located in Rowe, Massachusetts, was a 167 MWe pressurized water reactor (PWR) owned by Yankee Atomic Electric Company (YAEC). It started up in 1961 and operated for almost 30 years. The plant was shut down for economic and technical reasons. YAEC acted as the Decommissioning Operations Contractor (DOC) by providing program oversight of time-and-material subcontractors.

Engineering and Planning

A radiological characterization program and component inventory was conducted to identify the contamination levels and vessel activation levels. This information was used in the preparation of the Decommissioning Plan and for the detailed planning for decommissioning. TLG and YAEC estimated the total cost of the decommissioning program to be $369 million in 1994 dollars. This cost included a three-year safe storage period, decontamination and dismantling of components, final site surveys, site restoration, and $45 million for on-site dry storage of spent nuclear fuel until 2018. It was assumed the US DOE would remove the spent fuel to the federal repository (presumably at Yucca Mountain in Nevada) by that date. The incurred and expected costs to decommission Yankee Rowe is $636.4 million.

YAEC decided to adopt an early large component removal program, whereby the large radioactive sources and components would be disposed of as soon as possible to take advantage of available waste disposal facilities. The program included removal of the four steam generators, pressurizer, and reactor vessel internals. Spent nuclear fuel was discharged to the fuel storage pool located in the adjacent fuel storage building for temporary storage. The fuel was transferred to multi-purpose storage and transport casks for on-site storage until the US DOE transfers it to the high-level waste repository.

Steam Generator, Pressurizer Removal Project

In preparation for steam generator and pressurizer disposal, YAEC prepared an application to use the steam generator and pressurizer vessels (the “vessels”) as their own containers for radioactive waste. The vessels were filled with lightweight grout to contain the interior contamination, and to provide additional shielding. To protect the vessels in transit by truck, barge, and rail, YAEC designed impact limiters to absorb the energy of a one-foot drop, as specified by US NRC design criteria. The vessels were transported to Barnwell, SC and buried.

Reactor Vessel Internals Removal Project

The next phase of the program was to remove the reactor vessel internals. The internals contained over one million curies, requiring totally remote segmentation. The subcontractor designed an underwater plasma arc torch positioning system, thereby allowing cutting from a movable bridge assembly directly over the reactor vessel. An underwater cutting station was established for shielding and contamination control and a high flow filtration system was also located under water in the reactor service pool. Segments from the lower radiation level components of the internals were safely packaged and transported in casks for controlled burial. The core former and baffle (closest to the fuel) were highly radioactive (greater-than-class C waste), and particulate formed by the plasma arc torch cutting could not be filtered fast enough to remove it from the pool water. The direct dose from the water particulate required the periodic shutdown of cutting operations to allow the particulate to settle, or to be manually vacuumed under water. The core former and baffle were segmented to fit within failed fuel canisters (22 cm x 22 cm x 305 cm). These canisters were stored in the fuel storage pool along with spent fuel for later transfer to dry storage casks.

Reactor Vessel Removal Project

In 1996, YAEC licensed and had constructed a large container to ship the reactor vessel for disposal. Since all greater-than-class-C-wastes had already been removed, the vessel qualified as Low-Specific Activity (LSA) waste, suitable to be shipped in a Type B container. The container was large enough to enclose the entire vessel, and a closure head was welded onto the container to seal it for transport and burial. The existing polar crane inside the containment building was restored and upgraded to handle the load of the cask and its contents -- a total weight of 363 tons. In December 1996, the NRC approved the Decommissioning Plan and YAEC made the necessary preparations to ship the vessel to Barnwell, SC for disposal. Although the extraction was in the early winter months of 1997, transport was postponed until weather conditions would be better. The package was loaded onto a multi-wheeled transporter, moved across a bridge (reinforced to handle the load), and then about eight miles south to a tunnel. There the package was transferred to a railcar for the trip to South Carolina, where it was off-loaded for a three-mile road trip to the disposal facility in Barnwell.

Other Decommissioning Activities

In 1999, YAEC re-estimated the total cost at $407 million in 1999 dollars. This increase was to account for scope changes (PCBs and barium in painted surfaces, and additional contaminated soil), schedule-related differences (on-site spent fuel storage costs), and changes in regulatory assumptions (reduced US NRC and US DOE related fees, and insurance costs).

The spent fuel was transferred to dry storage casks located on site in an Independent Spent Fuel Storage Facility Installation (ISFSI).

The remaining radioactive equipment in the containment building, turbine-generator and condensate systems, and auxiliary building was removed and shipped for disposal. The reactor cavity activated concrete was removed, and contaminated soil was excavated and disposed of by controlled burial.

The demolition of the spherical vapor container (containment building) is under way, and preparations for demolition of the remaining structures of the primary auxiliary building, reactor support structure, and spent fuel building have begun. The final site radiological survey is scheduled to be completed by June of 2005. The License Termination Plan was prepared and approved by the US NRC.

2.2 Trojan Nuclear Plant

The Trojan Nuclear Plant was a 1095 MWe Pressurized Water Reactor (PWR), owned by Portland General Electric Company (PGE) and located in Rainier, Oregon. It operated from 1976 through 1992 when it was shut down because of problems with steam generator tube leakage. PGE determined that the cost for replacement steam generators would not be cost effective. The Trojan plant was shut down, primarily for economic reasons.

Engineering and Planning

PGE evaluated various options for removal of large components, and decided it was more cost effective to remove them in one-piece rather than segmentation. The Hanford commercial disposal site was contacted to arrange for one-piece disposal, and a favorable rate was negotiated for disposal of all radioactive wastes from Trojan.

Steam Generator, Pressurizer Removal Project

PGE removed the steam generators, pressurizer, reactor coolant pumps, and all other equipment from the containment building. These components were packaged for transport as their own containers. The components were moved by barge from the site up–river to the Port of Benton in Washington, where they were transported by multi-wheel transporter to the burial location.

Reactor Vessel and Internals Removal Project

The reactor vessel and internals contained over one million curies. They were removed intact, and the reactor vessel sealed and shielded as its own container for transport by barge to the Hanford, WA commercial disposal facility. This one-piece removal approach saved the project over $25 million.

Other Decommissioning Activities

The containment building interior contaminated concrete floors and wall surfaces were removed and shipped for controlled burial. An ISFSI was constructed on site, dry storage casks were procured, and the fuel transferred from the fuel storage pool. All other contaminated equipment in the auxiliary, control, and turbine buildings was also removed and shipped for disposal in July 2004.
Final site survey activities were completed in October 2004, and the License Termination Plan was prepared and submitted to the US NRC for approval. Following NRC approval of the final surveys, the license will be terminated. The Trojan site will remain as an industrial facility owned by PGE.

2.3 Rancho Seco

The Rancho Seco Nuclear Plant, located in Sacramento, California, was a 913 MWe PWR owned by the Sacramento Municipal Utility District (SMUD). It operated from 1975 to 1989, when it was shut down by a state public referendum because of its poor operating record. The reactor vessel and internals contain over one million curies. The decision was made to place the facility in SAFSTOR initially, and store the fuel in the wet storage pool until 1997. This would provide sufficient time to construct an ISFSI for on-site spent fuel storage until a federal repository is available. Decommissioning was scheduled to begin in 2008 and be completed by 2011, including site restoration. In 1994 TLG estimated the decommissioning program at $340 million with an assumed low-level waste burial cost of $450 per cubic foot at a California burial facility. With escalating waste disposal costs, TLG re-estimated the total cost at $420 million in 1999 dollars. The current estimated cost is $529.6 million

Engineering and Planning

SMUD is a member of the Southwest Low-Level Waste Compact (California and Arizona). Development of the proposed Ward Valley site has stopped because of government and public intervention delays tied to land ownership and environmental issues. During these delays, the projected cost for disposal at Ward Valley escalated at about $100 per year because of interest charges and licensing fees. The projected cost of disposal was approximately $1,000 per cubic foot.

With these escalating costs, TLG recommended that SMUD initiate decommissioning activities using state-of-the-art decontamination methods to free release as much of the contaminated materials as possible. Maximum use of off-site waste processors and recyclers would reduce the overall decommissioning costs by millions of dollars. SMUD agreed to a limited demonstration program of removal activities to determine whether the Rancho Seco staff could cost-effectively manage the work. They initially authorized a total of $15 million per year to be spent on such activities. Recently, this amount has been increased to $22 million per year.

Limited Removal Activities

To date, Rancho Seco has completed work on removal of asbestos in cooling towers and within the secondary side buildings. Secondary side systems including the turbine, moisture separators, condenser, condensate and feedwater systems, diesel-generators, steam piping and components have been removed and shipped to recyclers for decontamination and release or burial.

Dry Casks and the ISFSI

The dry cask vendor for Rancho Seco experienced difficulties in delivery of a licensed dry storage cask. The ISFSI facility was ultimately constructed, all necessary cask handling equipment delivered to the site, and all fuel safely stored in the casks.

The fuel pool was drained, and the stainless steel liner removed by a milling cutter to cut the welds between liner panels and wall embeds. The concrete floor of the pool is being cored to sample for leakage to the soil beneath the pool. One internal wall is contaminated from liner leakage and will be decontaminated or removed.

Reactor Vessel Internals

Removal of the reactor internals is under way, using mechanical cutting and milling to remove the internals underwater. The core baffles and formers are GTCC and will be placed in a fuel-type storage canister for ISFSI storage. Class B and C internals will be stored in liners onsite until disposal is arranged. Class a waste will be shipped to Envirocare in Utah for disposal. This work is expected to be complete by late 2005. The reactor vessel will be segmented for disposal at Envirocare. Various cutting methods and shipping configurations are being considered.

Large Components

The pressurizer was shipped to Envirocare in April 2004. The steam generators measured about 80 feet in height and 12 feet in diameter. They were cut into two sections by diamond wire saw to allow them to fit through the equipment hatch, capped on the ends and coated with a special paint to contain contamination, and transported by heavy-duty railcar to Envirocare in December 2004.

2.4 Connecticut Yankee

The Connecticut Yankee Atomic Power Plant located in Haddam Neck, Connecticut, was a 582 MWe pressurized water reactor owned by the Connecticut Yankee Atomic Power Company (CY), which in turn is owned principally by Northeast Utilities, Inc. The plant achieved commercial operation on January 1, 1968, and operated for almost 28 years before being permanently shut down on December 6, 1996. The decision to shut down the unit was based on the cost of competing power in the area. The relatively high operating costs and capital cost additions needed to continue operation was not warranted.

Engineering and Planning

TLG Services estimated the cost to decommission Connecticut Yankee at $427 million in 1996 dollars. This cost included wet storage of fuel on site until the year 2022. Northeast Utilities subsequently adopted the dry storage option. The total incurred and expected cost for competing decommissioning is about $820 million.

CY initiated a preliminary site characterization program to identify the major factors that would likely affect decommissioning cost. As part of this characterization effort, CY identified that early in the plant's operating history approximately 93,000 cu ft of very low-level contaminated soil had been temporarily stored outside of the controlled area, but on CY property. The soil was immediately fenced in and posted with guards. When the local newspapers and politicians learned of this contaminated soil, numerous articles appeared in the papers and politicians demanded investigations of mismanagement. In fact, the soil contamination levels were low enough to dispose of it on site without an NRC license. Additional low-level contaminated concrete blocks were also determined to have left the site during earlier operating years. CY has documentation that these blocks had been properly surveyed for contamination and separated into clean and contaminated piles. Somehow, both clean and contaminated piles of blocks left the site for use by local residents in their homes. CY has initiated a program for removal and retrieval of these blocks, and the repair or replacement of residential structures where necessary. The estimated cost is approximately $18 million for all sites. This event was also exposed to extensive newspaper and politician coverage.

CY staff prepared the Post-Shutdown Decommissioning Activities Report (PSDAR) and submitted it to the NRC for approval. Technical specifications were revised to reflect the defueled status of the reactor so as to reduce costs during this early phase of the decommissioning program. CY contracted for the services of a decommissioning operations contractor (DOC). A contract was awarded to Bechtel for an estimated amount of $200 to $300 million. Bechtel initially contracted to perform all the management, engineering, and planning, and to contract for specialty services such as asbestos removal, major component removal and disposal, and building demolition. CY management staff was to perform oversight of the DOC. However, a dispute arose between Bechtel and CY as to the scope of work involving contaminated soil. CY ultimately terminated the Bechtel contract, and the two parties are in litigation. CY has decided to self-perform the remaining work at the plant.

Decommissioning Activities

The removal of asbestos from the plant is complete. This removal work is typically completed before radiological removal work begins because of the difficulty of working in an asbestos contaminated environment.

The spent fuel cooling pool was isolated and powered independently from the plant power systems. This greatly simplifies decommissioning work since there is virtually no risk of inadvertently cutting into an active fuel pool cooling system.

The primary reactor coolant system was given a full system chemical decontamination flush was performed using the Siemans CORD process to reduce radiation levels and exposure to workers. The reactor vessel was isolated from the steam generators by installing nozzle dams in the reactor vessel outlet nozzles to the steam generators. The reactor vessel was not decontaminated, as there is no significant benefit to removing surface contamination when the activation levels in the vessel internals is so high. The chemical decontamination sufficiently reduced component exposures to permit direct contact for cutting and removal.

The four steam generators, pressurizer, and reactor coolant pump motors have been removed from the Containment Building and were shipped to Barnwell, SC for disposal. A drought condition in South Carolina delayed the shipment of heavy barge traffic on the Savannah River because of low water levels.

The low-pressure turbine casings have been removed and were sectioned and sold as clean scrap. The high-pressure turbine was dismantled for disposal at a waste processing facility.

Segmentation of the reactor vessel internals was accomplished by the high-pressure water and grit blasting cutting for reactor vessel internals. This was the first application of this technology applied to vessel internals. There were considerable problems with secondary waste generation, filtration of the reactor cavity water, high personnel exposure rates (as much as one man Rem/day), and low productivity. The GTCC internals segments were packaged in fuel type casks and stored on the ISFSI for ultimate disposal. The remaining reactor vessel was removed in one piece, loaded into a steel container and disposed of at Barnwell, SC.

The CY License Termination Plan was prepared and submitted to the NRC for approval in November 2003.

Spent Fuel Storage

CY decided to store the spent fuel in dry storage casks in an ISFSI onsite until the US DOE has a facility ready at Yucca Mountain, Nevada to accept shipments for disposal. There are 43 Vertical Concrete Casks on the ISFSI containing spent fuel and GTCC wastes. Fuel transfer to the ISFSI was completed in June 2003.

Other Decommissioning Activities

Demolition of the ventilation stack, emergency diesel generator building waste disposal building and the former health physics is complete. The turbine pedestal and the administration building demolition are nearly complete. The containment building components including the neutron shield tank are being removed in preparation for turnover of the building for demolition. A portion of the primary auxiliary building has been removed to facilitate remediation of the ion exchange system and removal of contaminated soil in the area.

The Integrated Site closure plan has been completed, which focus on groundwater characterization and monitoring, final status survey and RCRA corrective Action program implementations.

2.5 Big Rock Point

The Big Rock Point plant is located in Charlevoix, Michigan (on Lake Michigan), and is a 67 MWe boiling water reactor owned by Consumers Energy. It achieved commercial operation in 1962 and was shut down in 1997 after a successful 35-year operating history (the longest operating period of any plant in the U.S.). The plant would have required extensive capital costs to upgrade its safety systems to meet current NRC safety design criteria. The capital cost to perform this work did not justify the remaining five years on its operating license. Consumer's Energy decided to use as many of its on-site staff and operations personnel to manage and perform most of the routine decommissioning activities. BNFL, Inc., was awarded the fixed-price contract for large component removal. GTS Duratek was awarded a contract for waste processing and disposal on a fixed-unit price basis. NUKEM was awarded a contract for cleaning out the spent fuel pool of old tools and equipment.

Engineering and Planning

TLG estimated the cost to decommission Big Rock Point at $294 million in 1997 dollars, including $27 million for on-site dry storage of spent fuel until the year 2012. The current estimate is $430.8 million. The Consumers staff prepared the PSDAR and submitted it to the NRC and it was approved. Plant Technical Specifications were revised to reflect the defueled status of the plant. Detailed planners and schedulers were retained to assist in coordinating the planning for the integrated team approach to the work. In general, Consumers drained down systems and removed most of the piping, valves, small components, cable tray, and conduit to clear each of the major components for removal by a contractor. The plant power systems were isolated from the major equipment so that there would be no danger of cutting into a live power line, potentially causing injury to workers. The utility ordered dry storage casks to temporarily store spent fuel on site; it incurred a two-year delay in delivery because of NRC licensing review of the cask design.

Decommissioning Activities

Consumer's Energy has completed the asbestos removal program. This work was completed before the radiological removal work began. The reactor primary system was decontaminated using a difluoroboric acid chemical decontamination process. Decontamination factors of 10 to 15 were achieved overall, removing more than 400 curies of contamination from the systems. A new switchyard was installed, and the decommissioning power supply was established.

An access opening was cut into the Containment Building sphere and a trolley system installed to facilitate removal of equipment and materials. Equipment was removed from the Containment Building (except for the reactor vessel) in preparation for vessel internals removal. Equipment was also removed from the Turbine Building and the building demolished. The administration building and the stack were removed in 2004

Current work is proceeding on reclamation of the discharge canal. This included relocation of fish and animal life and final survey to free release the canal. The canal was backfilled with soil and beach stone to match the adjacent area.

Reactor Vessel and Internals Removal

The vessel internals were segmented using a mechanical cutter, and the GTCC segments packaged in fuel type casks for on site storage in the ISFSI. The reactor vessel was removed in one piece in a specially designed container. The vessel was disposed of at Barnwell, SC.

Spent Fuel Storage

Consumers decided to store the spent fuel in dry storage casks in an ISFSI onsite. There are approximately 30 casks on the ISFSI containing spent fuel and GTCC wastes.

2.6 Maine Yankee

Maine Yankee Atomic Power Plant, located in Wiscasset, Maine, was an 840 MWe pressurized water reactor owned by Maine Yankee Atomic Power Company (MYAPCO). The plant achieved commercial operation in 1972, and operated for 25 years before being permanently shut down. Management decided to shut down the unit for decommissioning; the steam generators were in need of replacement and the local competition was driving down the competitive cost of electricity.

Engineering and Planning

TLG estimated the cost to decommission the Maine Yankee power plant at $508 million in 1997 dollars. This cost included $128 million to construct and maintain an on-site spent fuel storage facility until the year 2023. MYAPCO management (with the assistance of Entergy Nuclear) decided to contract the decommissioning work on a turnkey basis to a Decommissioning Operations Contractor (DOC). That is, a single contractor would perform all detailed engineering, planning, component removal, and disposal activities. A site characterization program was conducted, and all prospective DOC contractors (vendors) were required to participate in the characterization program at their own expense. In this manner, MYAPCO there would be minimal basis for the successful contractor to request change orders to the contract for unidentified radioactivity or hazardous materials. A DOC contract was awarded to Stone & Webster. To minimize the maintenance and electrical costs during the engineering and planning phase, MYAPCO has placed the plant in a “cold and dark” configuration.

Management Changes

The DOC Stone & Webster Corporation announced it was in financial trouble as a result of major project overruns on other non-decommissioning projects. As a result Maine Yankee terminated its contract with Stone & Webster and placed them on a 30-day interim contract to maintain project continuity. Maine Yankee decided to self-perform management of the project.

Large Component Removal

The steam generators, pressurizer, and reactor coolant pumps were removed from containment in one piece and were shipped by barge to Barnwell for disposal. A drought condition in South Carolina delayed the shipment of heavy barge traffic on the Savannah River because of low water levels.

Reactor Vessel and Internals Removal

Reactor vessel internals segmentation contractor used high-pressure water and grit jet cutting. After some initial problems with control of cutting grit, the internals were successfully segmented. The GTCC portions were loaded into fuel type canisters and stored on the ISFSI pad for ultimate disposal. The remaining internals were returned to the vessel, and the vessel sealed for one-piece removal. The vessel was loaded into a specially designed container and temporarily stored on site until transport conditions improved to Barnwell. The vessel was ultimately shipped successfully by barge to Barnwell, SC.

Spent Fuel Storage

Maine Yankee completed transfer of the spent fuel in dry storage casks to an ISFSI onsite. There are 60 casks on the ISFSI containing spent fuel and GTCC wastes.

Other Decommissioning Activities

The spent fuel pool and associated systems were isolated and placed on an independent cooling system. Piping, cables and small components were removed and shipped to waste processors for disposition. All remaining systems were removed from the buildings and the buildings demolished by conventional shear and controlled blasting.

The containment building was "softened" by cutting arches in the vertical sides of the building using hydraulic rams on an excavator. Once the building was emptied of equipment and all interior structures demolished, the building was demolished by controlled blasting to bring the down section down to accessible levels for further hydraulic ram demolition.

2.7 San Onofre Unit 1

The San Onofre Unit 1 (SONGS 1) plant is located on the coast of Southern California in San Diego County, was a 410 MWe pressurized water reactor owned by Southern California Edison (SCE) and San Diego Gas & Electric Company (SDG&E). The plant achieved commercial operation in 1968, and operated for 24 years before being permanently shut down in 1992. SCE decided to shut down the plant rather than incur $125 million in required modifications.

Engineering and Planning

After an evaluation of whether to continue delaying or to proceed, SCE decided to proceed with active decommissioning in 1998. SCE notified the California Energy Commission and the NRC of its intention to decommission SONGS 1, and submitted an updated PSDAR. SCE and SDG&E requested access to the Decommissioning Trust Fund. The PSDAR estimate to complete decommissioning was $459 million in 1998 dollars. SCE decided to self perform the management of the project instead of using a DOC. Most of the SONGS 1 staff was transferred to the other two operating units at the site, and a small dedicated staff was assembled to manage the project, using specialty subcontractors for specific dismantling experience.

The initial activities involved separating Unit 1 from Units 2 and 3, and preparations for the demolition of the diesel generator building to make room for an ISFSI for spent fuel storage on site. All fuel from Unit 1 was transferred from the pool to the ISFSI, and Unit 1 fuel stored in Units 2 and 3 fuel pools would be transferred later (in 2005). The ISFSI was designed for 31 concrete storage modules, 18 of which would be used for Unit 1 fuel and GTCC wastes. A detailed engineering analysis was performed, and the cost revised to $622 million in 2001 dollars. The large cost increase was attributed to the significantly greater cost to build an ISFSI in a high-seismic environment, and the then greater cost for reactor vessel and internals removal.

A new entry point for the Radiologically Controlled Area was made that allowed demolition of a major building north of the containment. The diesel generator building was demolished, and the turbine generator dismantled, control room relocated, and the remainder of the plant placed in a cold and dark condition. A temporary electrical distribution system was installed to support decommissioning.

Reactor Vessel and Internals Removal

Segmentation of the vessel internals was begun in April 2000, and was completed in 2002. The high-pressure grit blasting cutting method was used for segmenting the internals. The reactor vessel was removed through a large opening cut by diamond wire sawing in the top of the containment building, and loaded in a transport and disposal container for ultimate disposition.

Large Components Removal

The steam generators and pressurizer were removed through the roof opening, and shipped to Envirocare for disposal. After removal of the components, the roof was enclosed with weather covers to allow further decommissioning activities to be completed.

Other Decommissioning Activities

The SONGS 1 site is located on land owned by the U.S. Government within the Camp Pendleton Marine Corps Base under an easement. The terms of the easement requires the plant owners to remove all materials from the plant site, including residual radioactivity, except as requested by the U.S. Government. In addition, the off-shore circulation water intake and discharge system are located on land used under an easement granted by the California State Lands Commission. These circulation water system components are to be removed in their entirety before the land is returned to the owner.

2.8 Millstone Unit 1

The Millstone Unit 1 plant located in Waterford, CT was a 660 MWe Boiling Water Reactor on the same site as Unit 2, an 870 MWe Pressurized Water Reactor, and Unit 3, an 1,150 MWe Pressurized Water Reactor. The three plants were originally owned by Northeast Utilities and later sold to Dominion Nuclear Connecticut on March 12, 2001. The determination was made that Unit 1 did not show sufficient customer value to return the plant to service after a prolonged outage and the unit would be decommissioned.

Engineering and Planning

The first activities contracted by Northeast Utilities was to Entergy Nuclear, to isolate Unit 1 from Units 2 and 3, as the three unit systems were closely tied together. The objective was to isolate the Unit 1 plant, place the spent fuel into the fuel pool and separately power the pool as a spent fuel pool island. The remaining plant was placed in a cold and dry condition in anticipation of leaving the plant in SAFSTOR.

When Dominion took over the plant the strategy was changed to immediate removal of portions of the reactor vessel internals, and partial dismantling of the remaining structures. Dominion prepared and submitted its PSDAR in June 1999, for a combined DECON and SAFSTOR option.

Reactor Vessel Internals

The reactor vessel internals containing GTCC wastes were segmented using a mechanical cutting method, and segments removed packaged in fuel type canisters for storage on site until final disposition.

Spent Fuel Storage

Spent fuel is currently stored in the fuel pool. Dominion is evaluating the construction and operation of an onsite ISFSI.

3. CONCLUSIONS

Recent experience with decommissioning programs in the U.S. has clearly demonstrated that decommissioning technology is available to safely remove radioactivity and to terminate licenses. The cost estimating methodologies used in the U.S. seem to be sufficiently reliable for future funding purposes. The technical lessons learned from these projects will help in the planning for future projects and build confidence that difficult, potentially high radiation exposure projects can be performed safely. Adequate funding mechanisms are already in place to ensure sufficient funds will be available when any future plants are ultimately shut down for decommissioning.