Blue Ribbon Commission, Yucca Mountain Closure, Court Actions - Future of Decommissioned Reactors, Operating Reactors and Nuclear Power – 13249

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ABSTRACT

Issues related to backend of the nuclear fuel cycle continue to be difficult for the commercial nuclear power industry and for the decision makers at the national and international level. In the US, the 1982 NWPA required DOE to develop geological repositories for SNF and HLW but in spite of extensive site characterization efforts and over ten billion dollars spent, a repository opening is nowhere in sight. There has been constant litigation against the DOE by the nuclear utilities for breach of the "standard contract" they signed with the DOE under the NWPA. The SNF inventory continues to rise both in the US and globally and the nuclear industry has turned to dry storage facilities at reactor locations. In US, the Blue Ribbon Commission on America's Nuclear Future issued its report in January 2012 and among other items, it recommends a new, consent-based approach to siting of facilities, prompt efforts to develop one or more geologic disposal facilities, and prompt efforts to develop one or more consolidated storage facilities. In addition, the March 2011 Fukushima Daiichi accident had a severe impact on the future growth of nuclear power. The nuclear industry is focusing on mitigation strategies for beyond design basis events and in the US, the industry is in the process of implementing the recommendations from NRC's Near Term Task Force.

INTRODUCTION

In the US, the issue of what to do with the Spent Nuclear Fuel (SNF) and the High Level Radioactive Waste (HLW) has stymied the national decision making for decades. Its impact has been a long term impasse that has resulted in the decommissioned reactors still having onsite storage of SNF to deal with. The operating reactors at many sites have little pool storage capacity left and have resorted to dry storage facilities constructed at the reactor sites.

Dating back to the Nuclear Waste Policy Act (NWPA) of 1982, the DOE is responsible for taking SNF from commercial power reactors and the utilities have continued to contribute money to the Nuclear Waste Fund. Note that while some countries have regarded SNF as a resource and proceeded with reprocessing programs, the US national policy has been to treat SNF as waste. DOE was initially set to begin accepting commercial SNF by January 31, 1998. However, a series of delays due to legal challenges, concerns over how to transport nuclear waste, as well as the political pressures have kept a site from being developed.

The industry's response to the lack of progress at the national level has been the design, fabrication, and installation of dry storage cask facilities at reactor sites. As a look at the map of Independent Spent Fuel Storage Installations (ISFSIs) at the NRC website shows the current

1 The views expressed in this paper are those of the author and do not necessarily reflect the views of his employer or the clients.

status is essentially that of many small storage sites scattered across the country (see following location on NRC website http://www.nrc.gov/waste/spent-fuel-storage/locations.html).

As amended in 1987, the NWPAA provided only for the evaluation and licensing of a single repository site at Yucca Mountain, Nevada. The DOE has been studying the site located near the former Nevada Test Site for almost three decades. After an expenditure of approximately 13 billion dollars ($) on the project and pursuing a NRC license for the site in 2008, the DOE started backtracking in 2009 with a changed direction from the new Administration and a motion for withdrawal of the licensing application was made by the Secretary of Energy in 2010. The project funding was zeroed out in the 2011 budget cycle.

As it happens, a number of developments have happened that are also very significant to the nuclear industry. First, the Fukushima accident of March 2011 has severely impacted the nuclear power growth and the nascent renaissance it was beginning to enjoy after a long period of hiatus after the 1986 Chernobyl accident. Second, the DOE continues to have constant litigation under the "standard contract" with utilities for failure to accept the SNF. Third, the Blue Ribbon Commission on America's Nuclear Future (BRC) issued its report in January 2012. Among the recommendations is a consensus based process for repository location. So essentially, it is a reset for the SNF disposition program and the country starts all over again to search for a repository site. The recommendations also call for a centralized storage facility for the SNF as the efforts to develop a disposal site continue.

Discussed below are the issues and developments related to SNF and their impact on the decommissioned reactor sites, operating reactor sites and the nuclear power in general.

DIMENSIONS OF THE ISSUE IN US AND GLOBALLY

The energy demand continues to rise and in projections from the International Energy Agency (IEA), the overall electricity generation is expected to increase 70% from 2010 to 2035, driven by the need for electricity in emerging economies [1]. Nuclear energy currently supplies about 13% of the total electricity produced in the world. The nuclear share had some setbacks due to the Fukushima accident and the IEA projections scaled back the nuclear capacity projections in World Energy Outlook (WEO) 2011 and then further reduced it in WEO 2012 from earlier projections in 2010. By 2035, the nuclear capacity is anticipated to rise to 580 Giga Watt electric (GWe), approximately 55% more than the current capacity. It is also worth recognizing that of the new generation capacity that is built to 2035, about one-third is needed to replace plants that are retired. The currently operating reactors (439 commercial power reactors in 31 countries) have a combined capacity of 372 GWe. The 104 reactors in the US make it the largest fleet of commercial power reactors in one country and provide about 20% of the electricity generation in the US. Worldwide, over 60 reactors are under construction in 13 countries, with major construction activity in China, South Korea, Russia, and India.

According to World Nuclear Association (WNA), 290,000 metric tons (t) of heavy metal (tHM, mostly uranium) SNF has been discharged so far, worldwide, from the commercial power reactors and about 90,000 t of the total has been reprocessed. Reprocessing capacity is about 4,000 t per year, primarily in France, UK and Japan. The US has a policy not to reprocess the SNF [2]. A typical nuclear power plant generates about 20 t of SNF in a year and the US nuclear

industry generates a total of about 2,000 - 2,300 t SNF per year. Over the past four decades, about 67,500 t of used nuclear fuel has been produced [3].

The stored amount of SNF will continue to rise both in the US and globally from the operation of the existing reactors and those under construction when they come on line. Thus, both in the US and globally, the SNF will need a path to ultimate disposal (such as in a geologic repository). In the meanwhile, long term storage facilities will be required as the process for repository development has faced many obstacles in almost all countries that have tried to site one.

Most of the SNF is currently in wet storage pools at the reactor sites but dry storage is increasingly becoming the preferred option for the longer term storage of SNF that has been sufficiently cooled over the years. The reasons are:

- SNF pool capacity is nearing the limit. Even with re-racking, there is little room for future capacity and SNF pools are expensive to build and operate.
- SNF cooled for five or more years is typically cooled enough for transfer to dry storage.
- Technology for dry storage is mature and many vendors offer various storage cask systems (for example: Holtec's HI-STAR; and AREVA's NUHOMS).
- Industry has substantial experience with these facilities. For example, in the US, there are currently 48 ISFSIs at nuclear power plant sites under the general license, 15 at or away from reactor sites under the specific license, and an additional 10 reactor sites are pursuing a general license.
- The pathway to disposal had recent and major setbacks in US with the 2010 Yucca Mountain project stoppage and it is clear that any other repository based solution is distant into the future.

It is clear that this is a long term issue and solutions such as dry storage that were considered interim may actually need to be in place for a much longer term. The ISFSIs for example have a licensed period of 20 years even though extensions of the license are possible and typically the cask systems are designed for 60 years. In the US, the Yucca Mountain project impasse and potential closure has led the DOE to start investigating centralized storage options as the search for a repository site might need to start all over again.

NWPA TO BLUE RIBBON COMMISSION

Summarized in the sections below are the key topics and issues that explain "How did we get to where we are today".

NWPA, Yucca Mountain and the US Nuclear Waste Policy

In the 1982 NWPA [16], the DOE was tasked to develop schedule and site for geological repositories for SNF and HLW, and NRC was to license the repository site or sites. The DOE was going to look at several sites and present a minimum of 3 finalist sites to the President for selection. Nine sites were originally identified which were then down selected to three sites: Yucca Mountain in Nevada, Deaf Smith County in Texas, and Hanford Reservation in Washington. In May 1986, the Yucca Mountain site was approved by President Regan for

characterization. Then, under the amended NWPA, the NWPAA of 1987 signed into law by President George H.W. Bush, Yucca Mountain was designated as the nation's only candidate geologic repository site.

Between 1987 and 2001, the DOE spent about $4 billion on the characterization of the Yucca Mountain site. To override the veto from the Governor of Nevada on the 1987 decision, which was allowed for in the NWPA, US Congress affirmed the approval of the Yucca Mountain site as the sole candidate repository through the Yucca Maintain Development Act in July 2002 under the Administration of President George W. Bush. By this time, a total of $7 billion had been spent on characterization activities (at Yucca Mountain and other sites). Another $1.5 billion were then spent on the construction license application for Yucca Mountain site which was submitted to NRC in June 2008. In March 2010, under the Obama Administration, the DOE filed a motion with NRC to withdraw the 2008 licensing application for the geologic repository at Yucca Mountain. The funds for the Yucca Mountain project were zeroed out in the Administration's 2011 Budget.

It is not the purpose of this paper to discuss the merits or concerns related to used nuclear fuel reprocessing, but it needs to be noted that reprocessing has not been a policy of the US, even though technically it was an option for the back end of the fuel cycle when the first wave of nuclear power plants was built. The option was formally eliminated in the late 1970's. The NWPA required each utility to sign a "standard contract" with the DOE and DOE was to remove SNF from commercially-operated nuclear plant sites no later than January 31, 1998. To fund the development of one or more SNF disposition (storage and/or disposal) facilities, each nuclear utility was required to pay fees into the Nuclear Waste Fund based on the amount of nuclear-based electricity generated through levies on a kWh basis.

The Blue Ribbon Commission on America's Nuclear Future

The Blue Ribbon Commission on America's Nuclear Future (BRC) was set up by the government in March 2010 to provide a comprehensive review of policies for managing the backend of the nuclear fuel cycle and issued its report to the Secretary of Energy in January 2012 [15]. In September and October of 2011, BRC also held five public meetings to gather feedback on its June 2011draft report. Of the eight "key elements" contained in the 2012 BRC report, six are noted below as relevant to the discussion here.

- A new, consent-based approach to siting future nuclear waste management facilities.
- A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.
- Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.
- Prompt efforts to develop one or more geologic disposal facilities.
- Prompt efforts to develop one or more consolidated storage facilities.
- Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available.

DOE and Current Court Actions

The DOE was required by the NWPA to start accepting SNF and other HLW no later than January 31, 1998**.** Funds have been collected since 1982, from the consumers of electricity from the nuclear power plants as a levy on kWh basis and currently the Nuclear Waste Fund has an unspent balance of about over $25 billion. However, the date has come and gone and, in 2012, DOE is no closer to accepting the SNF or HLW in near future. Over the years the DOE has been the subject of numerous court actions, starting with an industry petition to US Court of Appeals for the District of Columbia (D.C.) Circuit in 1998 when it was clear that DOE would not be able to accept the SNF on time. Numerous damage lawsuits have followed and as of 2012, court actions have been filed by most of the nuclear utilities for breach of contract and to recover costs.

The industry is incurring costs by having to build facilities such as the ISFSIs and storing the SNF at the reactor sites. In the past five years, the US Court of Federal Claims has awarded large sums to numerous utilities as damages from the DOE due to its failure to comply with the Standard Contracts. While some of the utilities have settled confidentially, it is estimated that the combined damages awarded so far could be above $2 billion. This amount is expected to increase as further cases are decided.

In the latest of the litigation saga, the US Court of Appeals for the D.C. Circuit ruled on June 1, 2012 that DOE had failed to justify continued payments by consumers of electricity from nuclear power plants into the Nuclear Waste Fund and the court ordered DOE to conduct a complete reassessment of this fee within six months, even though the court did not order DOE to suspend the fee payments [5]. In September 2012, Entergy filed suit against DOE for failing to accept SNF from the Palisades plant. Note that prior to Entergy acquiring the plant in 2007, the original owner Consumers Energy had also won a settlement against the DOE [6].

Waste Confidence

In another development, in a court action on June 8, 2012, the US Court of Appeals for the D.C. Circuit ruled that NRC's updated 2011 nuclear waste confidence rules allowing the temporary storage and permanent disposal of nuclear waste stood in violation of NEPA. The NEPA requires an environmental impact statement or assessment for all major government agency actions. As a result, on August 8, the NRC suspended action on licenses for new US nuclear plants and plant life extension until the NRC can address the court decision on waste confidence. The NRC directed the agency’s staff to develop an environmental impact statement (EIS) and a revised waste confidence decision and rule on the temporary storage of spent nuclear fuel. The EIS and rule, which are in response to the June 8 court ruling, are to be completed within 24 months [7].

Added to the above, it can be noted that a number of states have legislation that requires that waste disposal path be available i.e., a disposal facility exists and is accepting waste before nuclear power plant construction in the state is allowed.

Clearly, US is at a critical juncture where timely and justified decisions at the national level and the industry level are needed to provide a solution to the SNF storage problems through a long-term central storage facility while the disposal site planning distant into the future continues.

INTERNATIONAL DEVELOPMENTS

Of the countries that have decided on a strategy for SNF, the US, Canada, Finland and Sweden have opted for disposal of it while France, Russia, Japan, India and China have opted for reprocessing the used fuel. Many countries have not yet decided what strategy to use for disposal and have opted to continue storing it for now. The IAEA estimates total cumulative amount of used fuel by 2020 at 445,000 t, of which about 324,000 t will be in storage [8].

In previous sections, the Yucca Mountain project and its closure have been discussed. However, inherent siting and political difficulties appear to make SNF disposal projects difficult to proceed within almost all countries.

Of the international repository projects, the Swedish program has operated a centralized SNF storage facility since the mid-1980s and is currently proceeding with the geologic repository. Sweden is scheduled to open one of the world's first SNF repositories with a projected operation beginning in 2025. The Swedish Nuclear Fuel and Waste Management Company (SKB) selected Forsmark in 2010 as the site where SNF from Sweden's 12 nuclear reactors will be permanently disposed. The selection of the site culminated almost 40 years of work during which SKB conducted surveys throughout Sweden and feasibility studies at several locations.

Recently, the OECD/NEA conducted an international peer review of the "The Post-closure Radiological Safety Case for a Spent Fuel Repository in Sweden", the post-closure radiological safety analysis report produced by SKB in support of the application. The OECD/NEA report was released in June 2012 [9].

Several international reports from the IAEA are also of note on the subject of SNF storage and disposal; for example, see references [8, 10, 11, and 12].

In addition to the SNF storage and disposal issues, the 2011 Fukushima Daiichi accident has significantly impacted the future of nuclear power worldwide. Prior to this accident, the nuclear power industry had been in the early stages of a "renaissance" and it had been estimated that anywhere from 60 to 130 new nuclear power reactors might be built worldwide over the next twenty years. The net effect of Fukushima accident on nuclear renaissance will not be known for some time, but it has slowed the momentum of the nuclear growth in the near term. Many countries, especially in Europe, have re-examined the role of nuclear power and some plan to phase out nuclear power, while others are planning to curtail its use.

Germany has not only reversed an earlier decision to extend the service life of the country's seventeen nuclear reactors but has now permanently shut down eight reactors and plans to close the remaining nine in stages by 2022. In a referendum held on June 13, 2011, Italians overwhelmingly voted against the use of nuclear power, leading to cancellation of any future nuclear power plants planned during the previous years. Switzerland has put all plans to build new nuclear reactors on hold, at least temporarily. However, other European countries (e.g. Finland, Russia, United Kingdom and Slovakia) have kept their nuclear programs unchanged.

The emerging economies, especially in Asia, are expected to continue with their nuclear expansion because of the limited fuel options for energy production and a substantial need for energy now and even greater need projected in the future.

IMPACT ON DECOMMISSIONED REACTORS, OPERATING REACTORS AND NUCLEAR POWER

Decommissioned Reactors

The SNF is stored at several decommissioned reactor sites in the US in dry storage systems: Main Yankee, Connecticut Yankee (Haddam Neck), Trojan, Rancho Seco, Yankee Rowe, Big Rock Point, Humboldt Bay, and La Crosse - for a total of about 1,756 t. In addition, the Zion station, which is in decommissioning, has SNF stored in the pool. Once it is transferred to dry storage, it will add 1,019 t to the total. Thus, a total of about 2,813 t [13] remains in storage at the decommissioned reactor sites that needs to be dealt with.

At those sites where decommissioning is complete, the ISFSIs are the only facilities left at the site i.e., stand-alone facilities, a legacy of the situation that DOE has been unable to accept the SNF. With Yucca Mountain being stopped and opposed by the current Administration, the hopes have faded that SNF will find a path to geologic disposal any time soon. However, in the DOE's quest for a centralized SNF storage facility the decommissioned sites are expected to be at the top of the list for removal of SNF to such a facility.

Operating Reactors

US Near Term Impact of Recent Developments

Commercial US nuclear power plants generate 2,000 to 2,400 t of SNF annually and the stored inventory of approximately 70,000 t is about one third in dry storage and about two thirds in pool storage. Projected SNF quantity in storage by 2020 is expected to be about 88,000 t.

Consolidated storage for SNF is a key recommendation of the BRC. The DOE's Office of Nuclear Energy has been conducting research under the Used Nuclear Fuel Disposition Program since 2010 and the program has begun laying the groundwork [14] for evaluating consolidated storage concepts through participation solicited from the industry. The focus of the efforts is on:

- Evaluation of design concepts for consolidated storage; and
- Evaluation of transportation of SNF.

The current impasse and uncertainty about the future of the Yucca Mountain SNF and HLW disposal project has put great emphasis on the development of a consolidated SNF storage site. Concepts that may be examined include a storage facility that may be designed for 100 year life, with limited but large capacity (not a substitute for disposal) and with possible operation starting in 10 to 15 years from now. The disposal facility may be developed in 30 to 40 year time frame and the consolidated storage facility may become a gateway to the disposal site for repackaging of SNF for disposal and for transportation to the disposal site.

US Near Term Activities In Response to the Fukushima Daiichi Accident

The Fukushima accident on March 11, 2011 was caused by the combination of a magnitude 9 earthquake and a related tsunami and has led to a global a re-examination of the design basis for nuclear power plants for natural events. While the Fukushima reactors/site have been stabilized, cleanup of contaminated water from cooling of the reactors and the SNF pools continues and decommissioning of the site will take decades. The impacts of the accident continue to be assessed from a technical perspective. However a number of actions have already been taken in most countries where the existing nuclear power plants and nuclear construction projects have been examined from a perspective of coping with extreme natural events. As examples, Japan has initiated stress test for the nuclear power plants and in the US, the Near Term Task Force (NTTF) was set up by the NRC and it published its recommendations in July 2011 [4]. These recommendations build on the longstanding defense-in-depth philosophy and NRC has started pursuing these recommendations for industry implementation. Of the twelve recommendations made, several (summarized and re-paraphrased below) are related to the design of the reactors:

- Re-evaluate and upgrade the necessary design-basis seismic and flooding protection of Structures, Systems and Components (SSCs) for operating reactors.
- Potential enhancements to the capability to prevent or mitigate seismically induced fires and floods.
- Station blackout mitigation capability at all operating and new reactors for design-basis and beyond-design-basis external events.
- Reliable hardened vent designs in boiling water reactor facilities with Mark I and Mark II containments.
- Enhancing SNF pool makeup capability and instrumentation for the SNF pool.

Post-Fukushima accident lessons have led the industry to examine existing strategies and equipment related to loss of offsite site power (LOOP), coping capability for station blackout (SBO), beyond-design-basis flexible mitigation strategies, hardened vents for BWR plants, and the SNF pool cooling and instrumentation.

Related to Mark I and Mark II BWR designs, it should be noted that out of the fleet of 104 operating reactors, U.S. has 23 BWRs similar to the Fukushima Daiichi reactors with Mark I containments. An additional 12 reactors have the later Mark II or Mark III containment systems.

The NTTF recommendations are now being implemented and the NRC is requiring the nuclear industry to comply with the orders as they are issued based on these recommendations. Three Orders originating from the NTTF were issued in 2012: Order EA-12-049 (Mitigating Strategies), Order EA-12-50 (Hardened Vents) and Order EA-12-51 (Spent Fuel Pool Instrumentation). In addition, the industry has begun assessing the flooding issues where relevant to the plant site and has conducted comprehensive flooding walkdowns.

CONCLUSIONS

What Does the Future Look Like?

The closure of the Yucca Mountain after more than three decades of intense characterization effort and an expenditure of about $13 billion is a major setback to the management of SNF in the US. Over fifty years after the first commercial nuclear power went on line, we may be no closer to managing the back end of the fuel cycle more effectively. It is not a technology issue but a national policy issue.

Irrespective of the commitments originating from the NWPA, the DOE has not been able to accept SNF from nuclear utilities and court actions thus continue. The BRC recommends a consensus based approach to selecting a new SNF and HLW disposal site; however, given the past experience with NWPA and Yucca Mountain there is no certainty this will lead to a disposal site selection any time soon. The optimistic scenario would be that in 2040 or 2050 we could be looking at a new repository site open for operation.

The disposal canisters and disposal systems as a whole have been researched extensively, studied systematically, and the technology is considered mature. Site selection and acceptance will continue to be the Achilles' heel for construction and operation of a repository. Internationally, most countries with direct disposal programs for SNF are in nearly the same situation except Finland and Sweden, which may stay on track for their repository openings in 2020 and 2025, respectively.

The industry has coped with the lack of progress on the waste disposal site by constructing onsite dry storage facilities at reactor sites. This technology is mature and substantial experience now exists in this area. The BRC's recommendation on a consolidated SNF storage facility is a long overdue step in the right direction for the US as efficiencies can be gained in cost, uniformity of design, long term operation, and security as opposed to the over sixty dry storage sites scattered around the country. However, even if the current path is followed, the earliest a consolidated SNF storage facility can be operational is in the 2022-2025 time frame. It is supposed to be an interim facility even though it may be designed for the 100 year life. The repository may be planned to come on line 20 or 30 years after the start of the operations at the consolidated SNF storage facility. But given the past experience it may not be certain. Yucca Mountain came the closest to actually becoming a real SNF and HLW repository. National decisions not only affect the power industry but also the public perceptions of nuclear as a viable energy source. Clearly, the long term future of nuclear power and for that matter nuclear technology is at stake.

The Fukushima Daiichi accident on March 11, 2011caused by a very large earthquake and tsunami has severely impacted the nuclear plans in many countries, especially in Europe and Japan, even though the emerging economies are expected to continue with their nuclear growth. In US, the industry is in the process of implementing the recommendations from NRC's NTTF.

Overall, the nuclear power is at a critical juncture due to the recent events. Strong and sustained national policy can ensure that the nuclear energy option stays relevant, cost effective, and acceptable to public.

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