San Onofre Nuclear Waste Problems

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INTRODUCTION

In August 2018, a near-accident during the loading of nuclear waste into dry storage triggered a federal investigation and brought new urgency to the debate of how best to store some of the most dangerous waste known to humankind – spent nuclear fuel. The San Onofre Nuclear Generating Station (S.O.N.G.S.) closed in 2012 after a number of serious failures. Since then, Southern California Edison and its contractor, Holtec International, built a concrete storage vault to hold 3.6 million pounds of nuclear waste in dry storage. That vault is footsteps from the rising Pacific Ocean. In our brief report, we explore the fatal flaws of this location and recommend moving the storage facility to a technically defensible storage facility at a significantly higher elevation with distance from the ocean. We address the inadequacy of the equipment used to move and contain the nuclear waste material. We explore the gouging that occurs when stainless steel canisters are lowered into the storage vault and how gouging compromises the integrity of the containers. Finally, we examine management practices at San Onofre and an apparent lack of supervision, training and protocols. The examination of the perils of S.O.N.G.S. Independent Spent Fuel Storage Installations' poor location, poor technology and poor management, presents an urgent situation for regulators to: order Edison to permanently stop the loading of canisters into dry storage, require Edison to store the waste in canisters that may be inspected, and secure an independent analysis and risk assessment of canister loading procedure.

RATIONALE

Most serious of the issues facing the interim storage of nuclear waste at S.O.N.G.S. include the gouging damage to fully-loaded steel canisters upon downloading into the storage vault. These 54-ton thin-walled steel canisters are loaded with nuclear waste in wet storage – spent fuel pools – and are transported to the on-site concrete storage vault, adjacent to the reactor domes. With the Brinell hardness scale calculations our team demonstrates the depth and width of canister gouges upon downloading into the storage system. The current downloading procedure and on-site storage configuration provides the factors necessary to create gouges in the external steel walls of the canisters: operators have no visibility of the canister during downloading and precise adjustments to canister orientation cannot be made. These gouges remain undetected and unrepaired due to the lack of thorough inspection and monitoring at

the San Onofre Independent Spent Fuel Storage Installations (ISFSIs). The preliminary findings are found in this report.

1. POOR LOCATION

Today, two separate Independent Spent Fuel Storage Installations (ISFSIs) exist at San Onofre. The newest, built by Holtec, is located about 100 feet from the Pacific Ocean on the 85-acre grounds of S.O.N.G.S. The property is part of Marine Corps Base Camp Pendleton and is owned by the Department of the Navy. Two of the nation's busiest transportation corridors -- Interstate 5 and the Los Angeles-San Diego-San Luis Obispo Rail Line -- flank the site. The ISFSIs are clearly visible in Google Earth images and in numerous published photographs. The high accessibility and visibility of the site leaves it extremely vulnerable to an act of malfeasance.

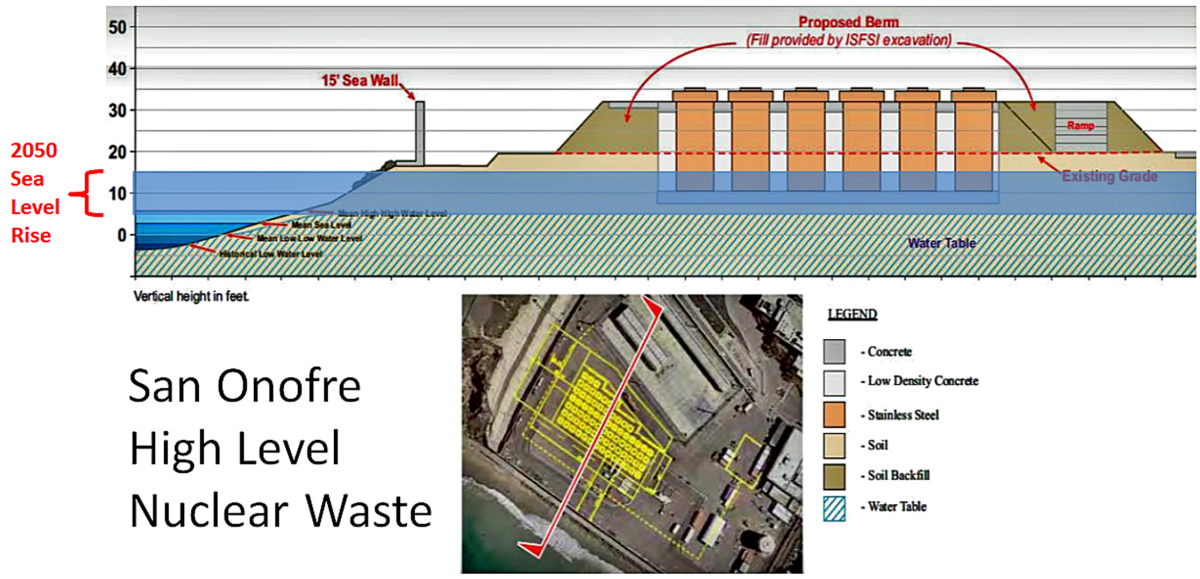

Figure 1. Independent Spent Fuel Storage Installations and Storage Vault.

Forces of nature, exacerbated by sea-level rise, carry further risks. Frequent high humidity and coastal fog make the metal at the site susceptible to short-term corrosion and stress-induced corrosion cracking. Also located at this site is a second, older ISFSI, which contains 51 thin-walled steel canisters that are up to 15 years old.

Numerous reports show that mean high tide level is about 18 inches below the base of the newer, oceanfront ISFSI, which was designed by Holtec. Since this is the mean height, the sea level frequently exceeds this height. Hence, it is likely the present ground water table will leach into the storage vault and result in at least damp storage. Further sea level rise due to climate change will make this problem far worse.

Dr. James Hansen, who managed NASA's climate change program for about 25 years, predicts sea levels could rise up to 10 feet during the next 50 years. At San Onofre, this would cause the bottom seven feet of the Holtec nuclear storage canisters to be submerged in seawater, unintentionally resulting in wet storage. This would invite a crisis similar to that of Fukushima, where spent fuel was exposed to moisture.

A second estimate appears in a comprehensive report by the Working Group of the California Ocean Protection Council Science Advisory Team. Published in 2017, the report shows 75% likelihood sea levels will rise by two feet by 2100. Either of these scenarios envisions that a major portion of the nuclear storage canisters as San Onofre would be submerged in seawater. The combination of the effects of sea-level rise and ground water inundation at the current location would change the Holtec ISFSI to wet storage site, for which it was not designed. Hence, little if anything would be accomplished by moving the waste from the spent-fuel pool to the dry storage ISFSI. The dangers would not be decreased. If anything, the inability to adequately measure and mitigate the impacts of corrosion on the underground nuclear canisters would lead to a significant increase in risk.

All of this can be avoided. If the nuclear waste at the two ISFSIs is transferred into thick-walled casks and then moved to a technically defensible storage facility at higher ground, the problems of ocean water and ground water intrusion can be avoided. As an added benefit, the waste would be easier to secure from an act of malfeasance.

2. POOR TECHNOLOGY

In California, the storage tanks at gas stations must be double-walled; painful experience has shown that single-walled containers can leak gasoline into the groundwater system. With a double-walled fuel tank, if a leak occurs it can be detected and the storage container can be repaired or replaced before any gasoline is released. At San Onofre, we certainly should expect that some kind of leak prevention system would be in place to contain extremely toxic high-level radioactive waste. Additionally, the canisters should be able to be monitored and inspected. The thin-walled canisters at the San Onofre ISFSIs cannot be adequately monitored or inspected. Regulators and Holtec officials have stated that the canisters cannot be inspected from the inside or the outside for cracks or other degradation and that, even if damage could be identified, it would be impossible to fix.

To illustrate the importance of adequate monitoring, we analyze a scenario in which one vent of a canister clogs. We refer to a Holtec non-proprietary safety analysis report[1] that calculates a temperature rise to about 90% of the maximum permissible limit (MPL) in 24 hours. This infers that within the next 12 hours the system will exceed the MPL rating and lead to a meltdown[2].

[1] Table 4.I.9, page 1050, Holtec International Final Safety Analysis Report for the HI-STORM 100 Cask System. USNRC Docket No.: 72-1014, Holtec Report No.: HI-2002444.

[2] S. Alyokhina, Thermal analysis of certain accident conditions of dry spent nuclear fuel storage, Nuclear Engineering and Technology 50 (2018) 717-723.

Through our own statistical analysis,[3] we prove that if the probability of clogging one of the vents during an event is 1%, then the chance that one of the 146 total vents (two vents on each of 73 canisters) will clog in such an event is 78%. This chance reduces to 53% if we reduce the probability of occurrence to .5% from 1%. Tsunamis followed by clogging are dependent events and thus the combined chance of such an event is about 11% during a 30-year period. The sea level rise, the rise of tide levels and the associated rise in the coastal aquifer are all interlinked, as discussed previously. These climate-related phenomena could cause serious damage to the ISFSIs. Therefore, close monitoring and the use of proven thick-walled cask technology for all nuclear waste storage containers is not only necessary but urgent. A mishap could imperil the lives and livelihoods of more than 8 million people who live within 50 miles of the ISFSIs.

2.1 NEAR MISS EVENT

David Fritch, an industrial safety inspector turned whistleblower, remembers August 3, 2018, as a bad day. Fritch worked at San Onofre during a loading failure that left a fully-loaded 54-ton canister of high-level radioactive waste stuck on the lip of a guide ring. Above the 17-foot-tall canister, the slings that attached it to the behemoth loading rig had gone slack.

The canister was, “hanging by about a quarter inch,” Fritch told attendees of the community engagement panel on August 9. “It’s a bad day. That happened, and you haven’t heard about it, and that’s not right. What we have is a canister that could have fallen 18 feet.”

Subsequent investigations revealed that the operators and managers could not see Canister No. 29 as it was being loaded into the storage cavity and became stuck for nearly an hour.

Since the near-accident, regulators have halted further loading of canisters into the seaside storage vault and researchers have explored what could have happened if Canister No. 29 had fallen.

Our own research explores the basic physics of a fully-loaded 54-ton canister in free fall to extrapolate the upper energy involved in the initial impact.

For example, the falling canister could hit the steel-lined concrete floor of the nuclear waste storage facility with explosive energy greater than that of several large sticks of dynamite. The resultant damage to the canister could cause a large radiation release.
At point of contact at the bottom of the storage cavity, damage to the concrete and metal structure could ruin the cooling system. The damage to the concrete would equal that of a fully-loaded 18-wheeler truck, with a gross weight of 80,000 pounds, crashing into reinforced concrete at 23 miles per hour. Our preliminary calculations show the combination of the weight and velocity of the dropped canister exceeds the ISFSIs’ “design criteria for tornado missiles,” by a factor of 4. Future experiments should include drop tests of the actual canisters with non-

[3] Chakraborty and English, 2019, ES&H Risk Estimation from “Interim Storage” of SNF at the Beach: The San Onofre NPP, WM2019 Conference, March 3-7, 2019, Phoenix, Arizona, USA (under review).

radioactive loads that simulate the weight of the spent fuel assemblies and fuel baskets to determine what would happen to the actual canisters.

Southern California Edison is set to move 73 canisters into the seaside storage vault and, at the time of publication, has moved 29. Each nuclear storage canister contains 37 spent fuel assemblies, which generate enormous amounts of heat. The systems are cooled by a simple air duct system, which could have been blocked by the damage caused by the canister's fall. If that had happened, great quantities of water would have been needed to cool the reaction and prevent or control a meltdown. The enveloping water would instantly become radioactive steam, as we saw at Fukushima. In the heavily-populated area surrounding San Onofre, however, radioactive steam could prompt the evacuation of millions of people. What's more, since both the canister and the surrounding structure could be badly damaged, there would be no available way to pull the damaged canister from the storage cavity.

Nuclear Regulatory Commission (NRC) computer simulations show what happens when a nuclear storage canister with slightly thinner walls[4] drops from 19 feet. In the test, a canister falls from a transfer cask onto a storage pedestal. The canister failure rate was 28%. Similar calculations must be performed at San Onofre to determine if that storage system has a similar probability of canister failure. At 28%, that is more than a one-in-four chance of catastrophic failure. Would you fly on an airplane with those odds? Our analysis alone should place the NRC, policymakers and Edison on alert. A more substantial analysis must be completed to examine the potential damage that can be caused by a falling, fully-loaded 54-ton nuclear storage canister.

Continued loading of the nuclear waste into canisters threatens the lives and livelihood of more than 8 million people. Software and computer resources are available by which estimates can be made of the impacts of a dropped canister on both the reinforced concrete and the canister walls. The NRC-approved Holtec technical specifications state that a canister drop of more than 11 inches requires the contents of the canister to be inspected for damage. This specification assumed the canister was in a transfer cask. The impact of an un-casked canister was never analyzed because Holtec and the NRC assumed it could never happen, citing triple-redundancy of the fuel transfer system. But a subsequent NRC inspection revealed that on August 3rd, all three components of this system simultaneously failed. Only the accidental snag of a quarter-inch of the 54-ton canister on the lip of the guide ring prevented a catastrophe.

Our research suggests the entire storage system may need to be redesigned to reduce the probability of canister failure to levels that are acceptable in such a highly-populated area.

[4] Pg. 4-24 Table 12, NUREG-1864 - A Pilot Probabilistic Risk Assessment of a Dry Cask Storage System at a Nuclear Power Plant, March 2007, A. Malliakos, NRC Project Manager

RESULTS

2.2 GOUGES IN DROPPED CANISTER

In their 2007 report, the NRC's analysts did not consider the impact of gouges on the strength of canister walls. There was no need, the analysts and a Holtec official said, as gouges were not important to the system under examination. We disagree. A detailed analysis of gouging is necessary to properly evaluate the damage to Canister No. 29 during the botched loading and to every other canister loaded into the ISFSI.

We established preliminary results of such an analysis using the Brinell hardness scale approach to estimate the depth and width of expected gouges in 316 stainless steel, of which the Holtec canisters at San Onofre is made.

While the canister is stuck, the guide ring gouges the bottom of the canister.

As the canister drops it is gouged on two sides by a combination of the guide ring, the storage cavity wall and the inner diameter of the transfer cask. This gouging absorbs some of the kinetic energy of the canister.

When the canister smashes into the bottom of the cavity, the kinetic energy and momentum from the fall will be dissipated by damage to:

- the ISFSI;
- the canister; and
- the contents of the canister.

The formation process of gouges will exert a force on the canister. This is the force, P, shown in Figure 2.

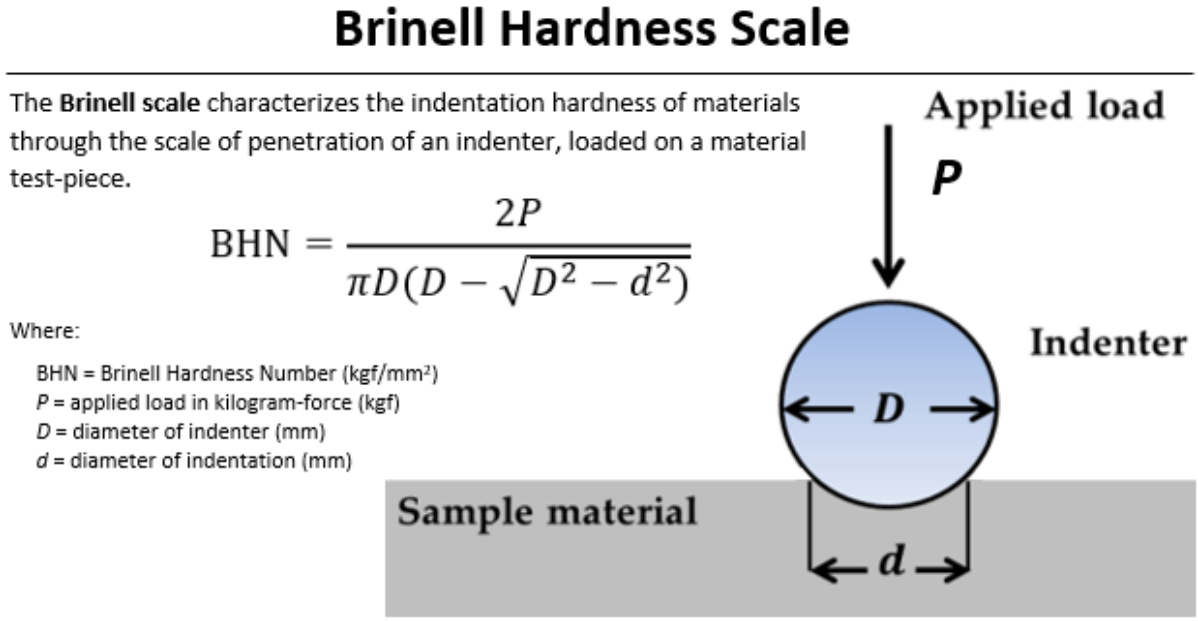

Figure 2. Brinell hardness scale calculation. Credit: *The Samuel Lawrence Foundation*.

In Figure 3, the width of a gouge is shown in relationship to the canister's weight. The expected range of gouge widths is shown in Figure 3. A variety of indenter widths are used as a surrogate for the gouging. The gouging widths range from 2 mm to 16 mm. This is highly significant, since the thickness of the nuclear canisters is 5/8", which is close to 16 mm. We recommend that tests be performed on actual canisters to experimentally determine the accuracy of these predictions.

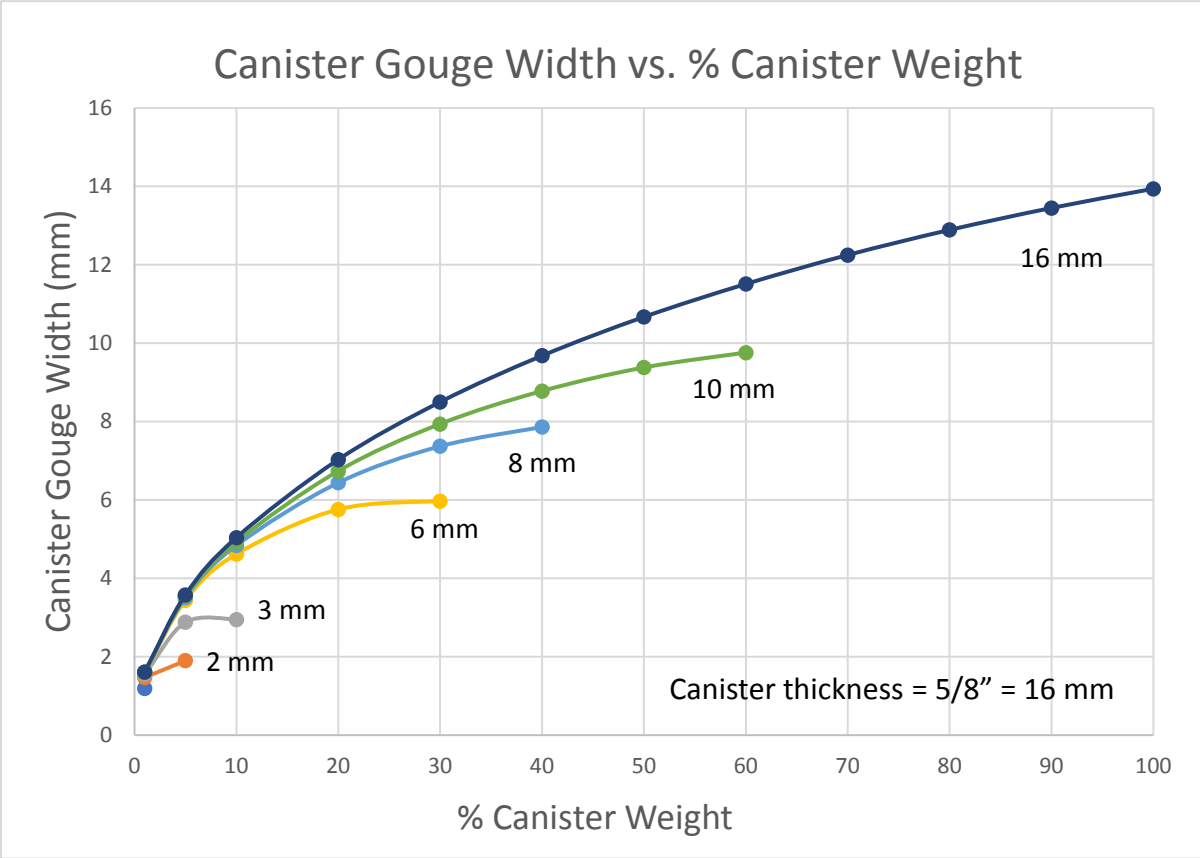

Figure 3. Calculated penetration width of gouge as a function of load for different intender diameter. The hardness number in Brinell scale for stainless steel 316 (BHN) is 217 kgf/mm^2. Saturated zone is eliminated.

The expected range of gouge depths is shown in Figure 4. A variety of indenter depths are used as a surrogate for the gouging. The gouging depths expected to be found range from 1 mm to 4.5 mm. This is highly significant, since 4.5 mm is 28% of the thickness of the nuclear storage canister.

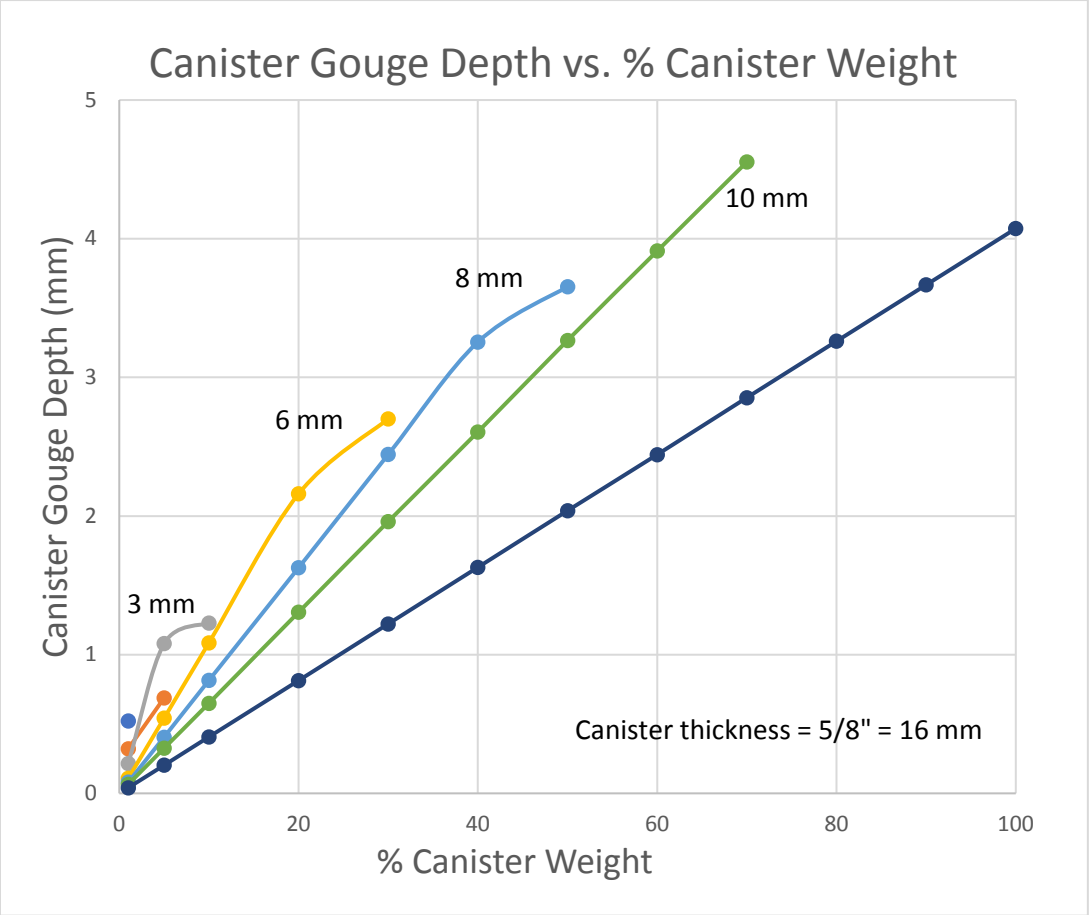

Figure 4. Calculated penetration depth of gouge as a function of load for different intender diameter. The hardness number in Brinell scale for stainless steel 316 (BHN) is 217 kgf/mm^2.

2.3 GOUGES DURING ROUTINE LOADING

Extensive gouging will also occur during routine loading of the nuclear storage canister into the storage cavity. By moving the Vertical Cask Transporter, shown in Figure 5, crude adjustments can be made to the alignment of the canister as it is lowered into the storage cavity. The bulky, tank-like machine travels on steel treads, like those found on earth-moving or military equipment. The transporter is not equipped to make the fine adjustments required to insert the nuclear storage canister into the narrow spacing of the storage cavity without banging the canister against the guide ring. This banging gouges the canister and causes the canister to move side-to-side, similar to a pendulum. An Edison official has referred to this process as “jiggling.” This jiggling process continues for 15 to 30 minutes as the canister is lowered to the bottom of the storage cavity. Each “jiggle” causes the type of gouging shown in Figure 3 and

Figure 4. We expect that this routine loading process produces a multitude of gouges that significantly damage the canister walls, rendering them unsuitable for storage of nuclear waste.

Figure 5. Vertical Cask Transporter during downloading and alignment of a canister. Credit: *San Onofre Special Inspection Webinar Presentation (NRC)*.

We strongly recommend that a sampling of the canisters previously lowered into the storage vault be removed and inspected so the extent of gouging can be experimentally determined. We expect the damage will be so severe that the current ISFSI will need to be replaced.

3. POOR MANAGEMENT

During the late 1970s and early 1980s, Rear Admiral Len Hering, USN (ret) served as a Nuclear Weapons Safety Officer, Handling Officer and Surety Officer. Admiral Hering provides the following assessment of management practices at the S.O.N.G.S. ISFSI.

When it comes to the handling and movement of nuclear material, you would expect that only those specifically qualified and trained for such an important task would be deployed to ensure the safe movement of that material. In the Department of Defense (DOD), strict requirements are in place to make sure this very dangerous material is properly handled, transported and stowed.

The DOD and Navy programs were created and built to make certain nuclear material was secure, safely handled and accounted for. Every person who has any contact with nuclear material is required to have a security clearance. A “two-person rule” is in effect at all times. Personnel at all levels perform countless hours of training, obtain certifications of qualification, and complete rigorous inspection and training events to both prove and assure their proficiency in performing the job they are assigned. All of this is all done before anyone is permitted to even gaze upon a real weapon.

Handling gear and all aspects of the evolution are vigilantly maintained, inspected, weight-tested and inspected again. Cranes and dollies or hoist equipment are tested, placed under extreme loading conditions and prepared for specific tasks. Nothing goes untested. Nothing. We leave nothing to chance and we never hypothetically presume. If it isn’t tested and proven, it isn’t done with the actual material in question.

Ashore, and specifically at S.O.N.G.S, I find that virtually none of the protocols that should be expected for the safe handling of this dangerous material are present. I find that personnel and companies are being hired virtually off the street, no specific qualification standards are present or for that matter even required, training is not specific to the risks of the material involved, and there is no fully-qualified and certified team assembled for this highly-critical operation. They have not been required to conduct dry runs to ensure handling teams are proficient and, more importantly, they have never trained specifically to be ready to execute emergency procedures should the unexpected occur. The manuals are not on site, nor are they being followed to step a team through the evolution of moving the nuclear waste. Team leaders have no specific handling qualifications or training. Even the industrial safety inspectors are not specifically nuclear-certified but are general industrial specialists. No manuals are available for procedural review and, by their own admission, the required number of safety officials are often absent during movement of the nuclear storage canisters. In the Navy, if a near-accident such as the one at S.O.N.G.S is uncovered, the Commanding Officer, Weapons Officer -- and anyone else with a significant position on the team -- are relieved. The ship is then ordered to stand-down while a team of experts off-loads its cargo.

The widely reported incident in which a 54-ton, thin-walled container nearly fell 18 feet while it was being lowered into its silo rocked me to the core. What made things worse was narrative in a follow-up report that stated the canister was left suspended for nearly an hour, held up by a mere guide ring installed in the silo, cables slack and operators clueless. There is no doubt that this incident occurred because those on-scene were completely unqualified, unprepared, untrained and incompetent. This very dangerous operation was being performed as if this crew were moving a simple stack of wood around a construction site when, in actuality, the crew was conducting one of the most dangerous operations in the industrial sector. No one was relieved, fired or held accountable. The investigation being conducted is flawed in that those responsible for this deplorable safety environment are the same people who will feed findings to the investigation.

The handling of nuclear waste at San Onofre and other sites across our country should scare every single American. We have a regulatory agency that has failed to make sure the most basic safety precautions are being applied to one of the most dangerous industrial evolutions of our time. The number of waivers being issued where safety is of concern is staggering.

In the DOD, the reason why there were and continue to be no significant accidents with the handling of nuclear material is because there are no waivers and there are no quick wins. Workers are fully qualified, inspected and certified to handle this very dangerous material. In this case, there is no room for error. One mistake is too many. It is my professional opinion that we need to hit the reset button before a disaster of unparalleled portion occurs.

CONCLUSION

The nuclear waste at San Onofre requires a much better storage configuration and must be moved to a technically defensible storage facility to reduce threats. From a security standpoint, the waste should be moved further away from major transportation corridors. The thin-walled nuclear waste storage canisters are at risk of failure due to gouging when downloaded into the seaside storage vault. Once lowered into the storage system, the canisters cannot be thoroughly inspected, monitored or repaired. A near-accident on August 3rd demonstrated that safety protocols are lacking, and that further study is needed to understand the consequences of dropping a fully-loaded 54-ton canister of nuclear waste. The incident revealed that the loading equipment is imprecise and revealed a pattern of mismanagement in canister loading procedure. A complete analysis of canister loading procedure and comprehensive risk assessment must be conducted by an independent party with absolute transparency. If an accident, natural disaster, negligence, or an act of terrorism were to cause a large-scale release of radiation, the health and safety of 8.4 million people within a 50-mile radius would be put at risk. To secure the nuclear waste properly, we recommend a permanent stop to the loading of nuclear storage canisters into the seaside storage vault, placing spent fuel into reliable canisters that can be monitored, inspected and repaired, and moving these canisters to an acceptable storage facility at a significantly higher elevation.

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