Long-term Maintenance of the

AREVA TN NUHOMS and Holtec HI-STORM UMAX

Dry Cask Storage Systems at

San Onofre Nuclear Generating Station

Prepared by Southern California Edison | November 2019

1.0 Introduction

This paper provides a synopsis of current and future programs to inspect and maintain the dry cask storage systems in place at the San Onofre Nuclear Generating Station (SONGS), the state of inspection capabilities, and technologies under development to address the potential need to mitigate a degraded or cracked spent fuel canister. The paper will also summarize licensing actions, activities which will be required to satisfy Federal and State requirements, and transportation of the canisters to an off-site facility.

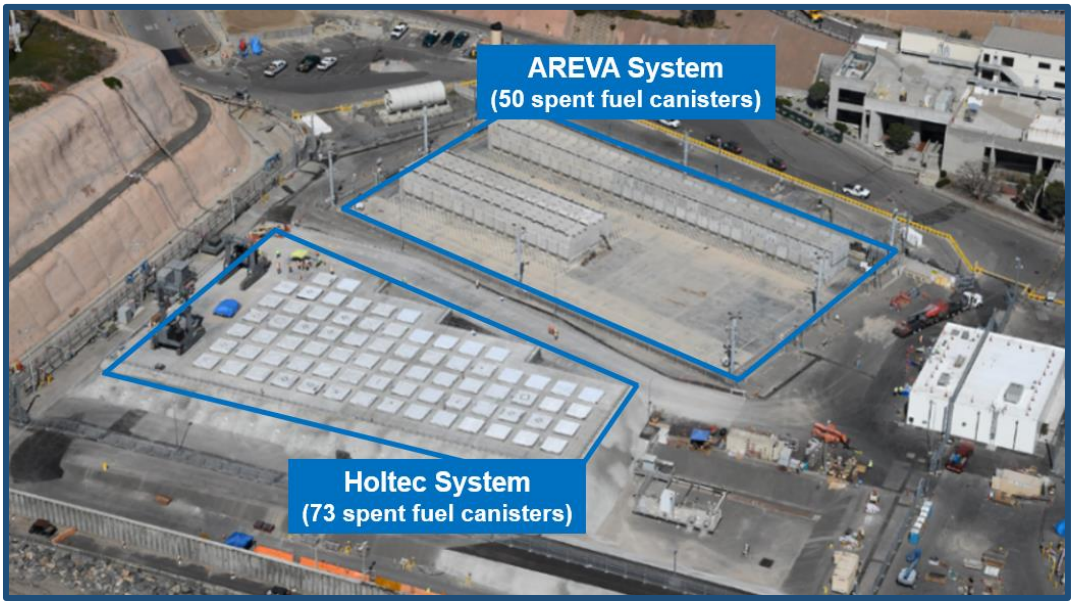
Dry Cask Storage at SONGS

Dry cask storage systems at nuclear plants such as SONGS are known as an independent spent fuel storage installations (ISFSIs). An ISFSI is used to store spent nuclear fuel on site until the U.S. Department of Energy (DOE) takes possession of the spent fuel as mandated by law.

There are two specific storage designs used at SONGS:

The **TransNuclear (TN) NUHOMS** system stores 50 loaded canisters that collectively contain 1,187 spent fuel assemblies. The initial NUHOMS loading campaign began in 2003. The last NUHOMS canister was loaded in 2012. The NUHOMS modules contain fuel from SONGS Units 1, 2, and 3.

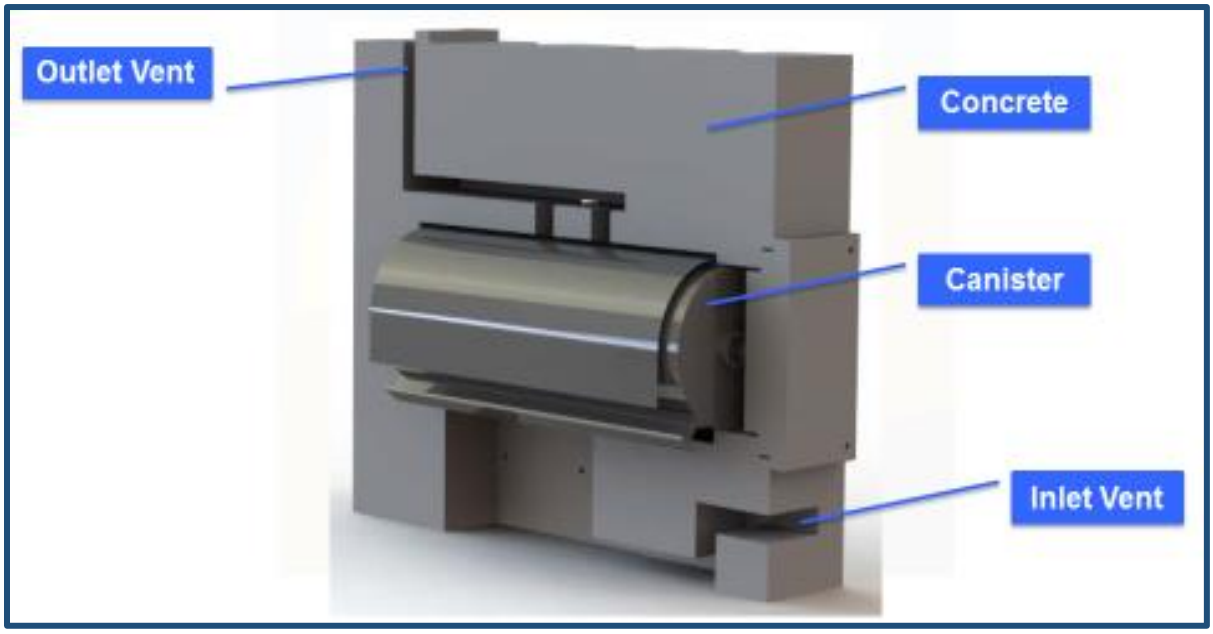
The second design is the **Holtec HI-STORM UMAX** system. At the time of this paper, the transfer of spent fuel assemblies from the Unit 2 and 3 spent fuel pools to the UMAX system is ongoing. Seventy-three canisters containing 2,668 spent fuel assemblies will eventually be loaded from Units 2 and 3. Once this UMAX project is completed, all of the spent nuclear fuel on the SONGS site will be in dry cask storage, awaiting eventual transport to an off-site storage facility or a permanent repository as required by the federal Nuclear Waste Policy Act of 1982. The law required the DOE to begin removing spent nuclear fuel from commercial nuclear power plants starting in 1998.



The two dry fuel storage systems at SONGS.

2.0 AREVA TransNuclear NUHOMS System

The AREVA TransNuclear NUHOMS system is a dry storage system containing a maximum of 24 spent fuel assemblies stored within each stainless steel canister. A graphical representation of the TN NUHOMS system is shown below.



The canisters are stored horizontally in a concrete module, and are licensed by the Nuclear Regulatory Commission (NRC) pursuant to Certificate of Compliance (CoC) 72-1029, which became effective Feb. 5, 2003, and expires on Feb. 5, 2023. The California Coastal Commission (CCC) allowed construction of the NUHOMS System on the SONGS site per Permit E-00-014, with a commitment to the CCC to request a permit extension by Nov. 15, 2022.

2.1 On-going and Future Licensing Actions

Federal (NRC) Licensing

The NUHOMS CoC 72-1029 License expires on Feb. 5, 2023. To date, there have been three amendments to the CoC. Amendment 1[1] has been implemented and Amendment 4[2] will be implemented at a future date at the SONGS facility. Amendment 3, which added the 32PTH2 canister, will not be implemented at SONGS because SCE chose not to move forward with using that canister design.

It is very unlikely that a federal repository (or, a licensed consolidated interim storage [CIS] facility) will be available to SONGS prior to the end of the current license period. In addition, even if a facility were licensed and operational today, it is unlikely that SONGS could transfer all loaded NUHOMS canisters

[1] Amendment 1, approved May, 2005, added the 24PT4 Canister.
[2] Amendment 4, approved in March 2019, removed implied statements regarding the need for a spent fuel pool after all fuel has been loaded into an ISFSI, credits the installed temperature monitoring system (including new temperature rise values for the 24PT4) and provides peak dose rates on the AHSM module.

to the new facility by the end of the current license period as the transfer process is expected to take several years to complete. As such, it will be necessary to request renewal of CoC 72-1029. Since CoC 72-1029 is a "generic" license (meaning the same system could be built and used at other NRC-licensed facilities), and TN is the CoC holder, the request for extension to the NRC is initiated by TN. In order to meet NRC requirements, the license renewal request must be submitted at least 30 days prior to the expiration of the current license.

SCE has contracted with TN to perform the work necessary to create the CoC renewal submittal, submit the CoC renewal package to the NRC for review, respond to NRC questions concerning the submittal, and seek approval of the CoC renewal from the NRC.

At present, the CoC license renewal engineering analyses have been completed, and the submittal package is in review by the NRC. The license renewal package will request a 40-year extension to Feb. 5, 2063, and was submitted to the NRC on May 22, 2019. While the NRC requires submittal at least 30 days prior to CoC expiration, in this case, the license renewal package was submitted early to comply with the CCC Permit E-00-014 extension, which is discussed below.

State CCC Permitting

California Coastal Commission Permit E-00-014, which was a part of SCE's 2015 coastal development permit to expand its ISFSI, also requires a license extension for the NUHOMS system based on a commitment to the CCC and the lack of an off-site CIS facility or repository which would allow for termination of the permit. The extension request is planned for submittal to the CCC by May 15, 2022, which is six months prior to the commitment date.

Since the regulatory and technical requirements for the SONGS ISFSI are contained in the NRC CoC, and the CCC would use the NRC review as a basis for the state review, the License Extension for CoC 72-1029 has been submitted earlier than required, in order to enable the NRC to complete its review prior to the submittal date for the CCC permit extension request. This will allow the state reviewers to have the NRC review information available for consideration in the state extension request process.

2.2 Activities which will be required to satisfy Federal and State requirements

The NUHOMS system at SONGS is currently monitored per technical specifications which are part of the approved CoC 72-1029. The technical specifications require temperature monitoring of the loaded modules, and a radiation protection program. Although not required by regulation, SCE has also implemented periodic inspections of the visible surface of the ISFSI concrete pad and modules at SONGS. Any deviations are noted in the SONGS Corrective Action Program, which provides for corrective actions to be taken as necessary to ensure the ongoing safe operation of the system.

As part of the initial CoC 72-1029 license, and consistent with industry regulations and standards, visual inspections of the loaded fuel canisters themselves are not required during the initial 20-year NRC license period.

Once the license renewal period is entered, the extended license will contain requirements which will include the periodic monitoring already performed, any additional requirements as designated by the NRC, and the creation and implementation of an Aging Management Program (AMP), which will require additional inspections of the NUHOMS system. The AMP will include visual inspections of

selected loaded canisters, using best available technology. At present, the best available technology is to use in situ inspections utilizing a remote controlled robot mounted with a high-resolution camera.

As part of the AMP, it will be necessary to perform baseline visual inspections of the in situ accessible exterior surfaces of selected canisters prior to entry into the license renewal period. The baseline data will be used to provide initial documentation that the canisters are acceptable for future operation in the license renewal period, and provide a baseline data set, which can be used to compare against future canister inspections. The baseline inspections currently are planned for late 2021, and will consist of robotic visual inspections of a loaded NUHOMS canister, which will be selected based on several factors, including age, likelihood of degradation, and heat load.

Future inspections of loaded canisters will be performed consistent with the AMP. The inspection periodicity as defined in the proposed AMP is five years, and the frequency can be adjusted based on inspection results. The number of canisters to be inspected each period will be based on ongoing industry best practices.

To date, more than 10 commercial nuclear sites have performed robotic inspections of spent fuel canisters. So far, inspections have not revealed any degradation significant enough to warrant mitigation or corrective actions. There have been systems very similar to the SONGS system—horizontal systems designed by TN and licensed by the NRC—that have been inspected, such as at the Rancho Seco Nuclear Generating Station (Calif.), with no degradation discovered.

2.3 New Inspection Technologies which likely will be Available When Inspections of Selected Loaded Spent Fuel Canisters are required

As part of the AMP, it will be required to visually inspect selected NUHOMS loaded canisters just prior to, and during, the period of extended operation after license renewal. These inspections will be performed using the best available technology taking into consideration the ISFSI design, accessibility, and potential risks/costs involved with movement of a canister (such movement may allow for more detailed and comprehensive inspections).

The Electric Power Research Institute (EPRI), a research institute sponsored by power generation facilities including commercial nuclear power plants, has guided the development of several robotic inspection systems which currently are available and in use. These systems have performed detailed visual in situ inspections of accessible portions of loaded fuel canisters. Depending on the ISFSI design for various vendors, these robotic systems allow for visual inspections (through existing vents within the system) of 25-90% of the exterior surface of the loaded canister, and have been successfully performed throughout the industry. Further information regarding development of inspection technologies can be found in EPRI Report 3002010617 and EPRI Report 3002010621.

SCE likely will use one of the current systems—with any applicable improvements made over the next one to two years—to perform baseline inspections to support license renewal.

It is unlikely that significant degradation will occur on the loaded canisters, due to their design and fabrication. The known degradation mechanisms such as chloride-induced stress corrosion cracking (CISCC) are very long term events that require specific conditions in order to occur. These conditions include low temperature on the canister surface along with stresses in the steel and this set of

conditions are not present during the initial license period but potentially could be met during extended storage operation.

Inspection Ring

Because of the remote possibility that a spent fuel canister could degrade over time or degradation is discovered during robotic inspections, SCE has contracted with TN to design and fabricate an inspection ring that will be available for deployment, if needed, by the end of 2019 (as previously mentioned, the initial baseline inspection is planned for 2021). The Inspection ring, as configured for the initial performance testing in January 2019, is shown in Figure 4.

The inspection ring is a toroidal shaped device which is installed on the exterior surface of the NUHOMS concrete module. The loaded spent fuel canister will be moved through the ring using currently available equipment, while detailed inspections are performed on areas discovered by the initial robotic inspections. The inspection ring is designed to deploy a range of technologies such as a high-resolution camera, and ultrasonic and eddy-current tooling to support a better characterization of any degradation.

Inspection ring for TN-NUHOMS dry fuel storage canisters.

Since the use of the inspection ring involves the movement of a loaded spent fuel canister, which does involve risk to plant workers, the Inspection ring would be a secondary inspection technique, in that it would be deployed and used if significant degradation requiring further evaluation is discovered during initial robotic inspections. Because the spent fuel canister is removed from its module in order to pass through the inspection ring, 100% of the canister shell can be inspected.

As noted above, the inspection ring is expected to be fully qualified, and ready for deployment to SONGS, if needed, by the end of 2019. At present, the inspection ring has been constructed and has successfully passed its initial testing. Ongoing activities include the construction of the shielding bell which will surround the inspection ring (as the canister is removed from its module and passed through the inspection ring, radiological shielding will be required to minimize exposure to employees), procedure development, and final testing.

The inspection ring is designed to allow for adaptation to technology developed and available in the future as the inspection ring has slots which can be fitted with applicable inspection equipment. It also can accommodate mitigation equipment, should mitigation—such as weld repair or patching—

of the canister exterior surface is determined to be necessary to assure the continued safe operation of the ISFSI system. The mitigation options are discussed in the section below.

2.4 Mitigation Technologies

In the unlikely event a canister did become degraded to the point of a through-wall crack, the actual site and public consequences that would occur are minimal[3]. However, a degraded canister with a through-wall flaw would pose issues in the future transportability of the canister to an off-site facility.

As an industry leader with a commitment to the safe, long-term storage of spent nuclear fuel, SCE has been participating in development of technologies which could be used to mitigate/repair a flawed canister. The solutions can be grouped into two areas:

1. Mitigation of the flaw via a repair or patch of the canister (via tooling that could be installed on the Inspection ring),
2. Containment of the flawed canister in a licensed transportation cask for storage on site.

SCE continues to work with industry organizations such as EPRI and vendors to develop canister mitigation technology in the event it is needed sometime in the future. It is anticipated, based on current progress, that SCE will have mitigation technology available for use in the timeframe of the initial baseline inspections. EPRI and DOE continue to make progress on mitigation and repair processes. An updated status can be found in EPRI Report 3002013130.

2.5 Transportation of NUHOMS Loaded Spent Fuel Canisters

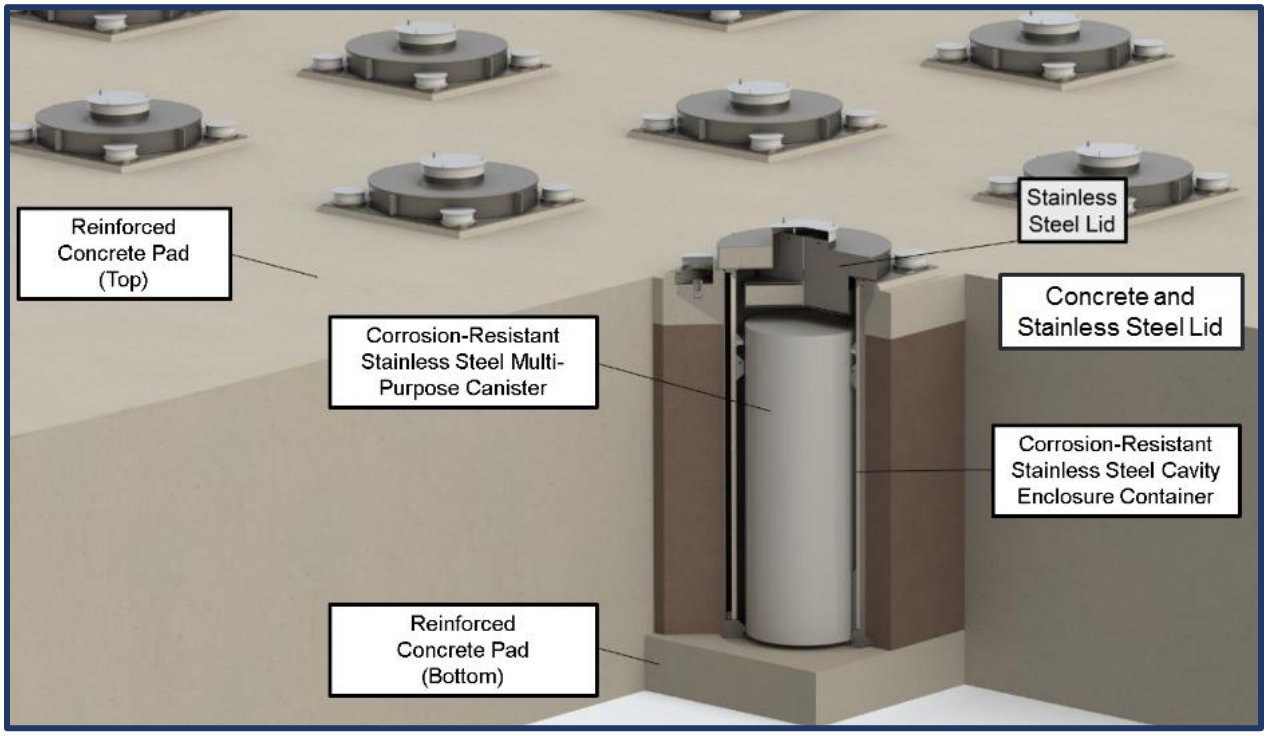
Transportation casks are licensed for all of the fuel canisters loaded in the NUHOMS system. For the Unit 1 spent fuel, loaded in NUHOMS 24PT1 canisters, the canisters can be transported using the AREVA MP-187 Transportation Cask, which is licensed by NRC CoC 71-9255. The Units 2 and 3 spent fuel that is loaded in the NUHOMS system is loaded into NUHOMS 24PT4 canisters, and can be transported in a MP-197HB Transportation Cask, which is licensed per NRC CoC 71-9302.

Transportation of the loaded canisters cannot occur until a destination is available, whether a licensed CIS facility or a geologic repository such as Yucca Mountain. There are still many open issues that need more certainty regarding the transportation and storage of spent nuclear fuel at a consolidated interim storage site. For instance, the commercial terms of any storage agreement or the extent and nature of the government's commercial involvement or participation in the CIS facility.

[3] NUREG-1140, "A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees", Final Report, August 1991, pp 61-62

3.0 Holtec UMAX System

The Holtec HI-STORM UMAX system is a dry storage system capable of containing a maximum of 37 spent fuel assemblies stored within stainless steel canisters. A graphical representation of the Holtec UMAX system is shown in Figure 2. The canisters are stored vertically in concrete vaults and are licensed by the NRC per CoC 72-1040 effective April 6, 2015, and which expires on April 6, 2035. The CCC approved construction of the UMAX system on the SONGS site per Permit 9-15-0228, effective Oct. 6, 2015 with an expiration date of Oct. 6, 2035.



Detailed view of the Holtec UMAX system at SONGS.

3.1 Ongoing and Future Licensing Actions

Federal/NRC Licensing

The UMAX system is in its initial license period, with a current NRC license expiration date of April 6, 2035. As such, it is possible that a federally licensed repository or CIS facility will be available and the canisters shipped off site by the time the CoC expires.

There are two amendments[4] to the CoC 72-1040 license under review by the NRC. A final decision on amendment approval by the NRC will be determined at a later date.

[4] CoC 72-1040 Amendment 3 requests addition of the 24PT1-DSC container for storage in the UMAX System CoC 72-1040 Amendment 4 requests changes to the generic dose calculations, and includes the 'Shim Standoff' design change used in 4 canisters at SONGS

In the event that the fuel canisters remain on the SONGS site near the end of the initial license period, actions will be taken as necessary to extend CoC 72-1040. Since Holtec is the certificate holder for the CoC, they will be the lead organization to develop and submit the license renewal request (with support from users, such as SCE). These actions will not be taken for many years, probably beginning in the 2031 timeframe.

State CCC Permitting

As part of the discussions with the CCC during the state permitting of the UMAX system for installation and use at SONGS, SCE agreed to develop an Inspection and Maintenance (I&M) program to be effective during a portion of the NRC initial license period.

The I&M Program is required to contain the following elements:

1. The cask inspection, monitoring and maintenance techniques that will be implemented, including prospective non-destructive examination techniques and remote surface inspection tools,
2. What data will be collected and how often the results of the inspection and maintenance program will be reported to the CCC,
3. All available evidence related to the physical condition of the casks and their susceptibility to degradation processes such as stress corrosion cracking, and
4. Remediation measures that will be implemented, including the submission of a coastal development permit amendment, if the results of the cask inspection and maintenance do not ensure that the fuel storage casks will remain in a physical condition sufficient to allow on-site transfer and off-site transport for the term of the project.

The submittal due date to the CCC for the I&M plan is March 31, 2020. Engineering analyses necessary to support the I&M program are on-going.

3.2 Activities which will be required to Satisfy Federal and State Requirements

As discussed previously, the UMAX system is in its initial license period. As such, the inspections required to support the CoC 72-1040 requirements are contained in the Technical Specifications. The Technical Specifications require temperature monitoring of the loaded modules, and a Radiation Protection Program. SONGS will also implement periodic inspections of the visible surface of the ISFSI concrete pad and vertical ventilated module (VVM), as specified in Chapter 10 of the UMAX safety analysis report. Any deviations are noted in the SONGS Corrective Action Program, and corrective actions are taken as necessary to ensure the on-going safe operation of the system.

As part of the initial CoC 72-1040 license, and consistent with NRC regulations, no visual inspections of the canisters are required during the initial license period.

The state requirements—development and implementation of the I&M program—which may require visual inspections of loaded canisters, are discussed in the previous section of this report.

3.3 New Inspection Technologies which likely will be Available When Inspections of Selected Loaded Spent Fuel Canisters are required

The I&M program for the UMAX system will be implemented as required by CCC permit 9-15-0228. Inspection requirements delineated by the I&M Plan are under development and will be determined prior to submittal of the I&M program to the CCC.

As previously discussed, EPRI has guided the development of several robotic inspection systems which are currently available for use for the baseline and future inspections. These systems can and have performed detailed visual inspections of accessible portions of the loaded fuel canister. Depending on the ISFSI design for various ISFSI vendors, these robotic systems allow for visual inspections (through existing vents within the system or, in the case of the UMAX system, removal of the closure lid) of 25-90% of the exterior surface of the loaded canister, and have been successfully performed throughout the industry. Further information regarding development of inspection technologies can be found in EPRI Report 3002010617 and EPRI Report 3002010621.

SCE has deployed a robotic system similar to the systems developed through EPRI to inspect eight loaded canisters during 2019. SCE likely will use one of the current systems—with any applicable improvements—to support future Holtec canister inspections as required.

In addition, SCE has commissioned an additional action which will be used to both provide further information on the condition of loaded fuel canisters through the use of a "Test Canister."

Holtec Test Canister

During the permitting process, there were discussions with the CCC regarding the ability to obtain further information about the potential degradation processes which could potentially impact the loaded fuel canister. As such, SCE commissioned the creation of a "Test Canister," which is a Holtec UMAX canister with the same dimensions as a loaded canister, but would not contain spent fuel. Instead, the test canister will be electrically heated to the approximate level as a representative loaded canister, loaded into an existing vault location, and will be monitored and inspected as part of the I&M program. The test canister is scheduled to enter operation in 2019, and is intended to be used for the duration of the I&M program.

Future Developments for the Holtec UMAX System

It is highly unlikely that significant degradation will occur on the loaded canisters, due to their design and construction. All of the known degradation mechanisms are very long term events and require specific conditions (including canister surface temperature, and stresses on the canister) in order to occur. Many of these conditions are not met during the initial license period, but potentially could be met during long-term extended operation.

As discussed previously in the TN NUHOMS system, an Inspection ring is expected to be operational for supplemental inspections of the NUHOMS system (if required) by the end of 2019.

Although there are differences between the NUHOMS and Holtec systems (for example, the NUHOMS system stores canisters horizontally, while the Holtec system stores them vertically) it could be feasible to develop an Inspection ring-like device to support supplemental inspections of Holtec canisters. SCE is pursuing this option, and will provide more information as it is available.

3.4 Mitigation Technologies

It is highly unlikely that the Holtec loaded fuel canisters are degraded, as discussed above. The consequences would be minimal[5] to the site or the public were a canister to become degraded to the point of a through-wall crack. However, a degraded canister with a through-wall flaw would pose issues in the future transportation of the canister to an off-site facility.

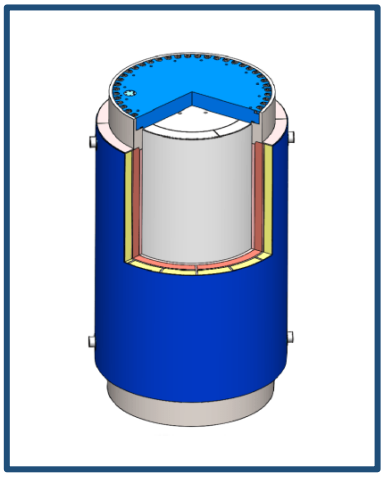
As such, SCE has been participating in development of technologies which could be used to mitigate/repair a flawed canister. The solutions can be grouped into two areas:

1. Mitigation of the flaw via a repair or patch of the canister,
2. Containment of the flawed canister in a licensed transportation cask for storage on site.

SCE continues to work with industry organizations (such as EPRI) and specific vendors to develop canister mitigation technology in the event it is needed. It is anticipated, based on current progress, that SCE will have mitigation technology available for use in the timeframe of the initial baseline inspections. EPRI, along with the DOE, continue to make progress on mitigation and repair processes. An updated status can be found in EPRI Report 3002013130.

SCE will continue to communicate advancements in this area, as well as future plans.

3.5 Transportation of Holtec Loaded Spent Fuel Canisters



Graphic of HI-Storm 190 transportation cask.

Transportation casks are licensed for all of the fuel canisters loaded in the Holtec UMAX system. The Holtec canisters can be shipped in a HI-STAR 190 Transportation Cask, licensed by NRC per CoC 71-9373.

Transportation of the loaded canisters can only occur once a destination, such as Yucca Mountain or a licensed Consolidated Interim Storage (CIS) facility is available.

It should be noted that the federal Nuclear Waste Policy Act (NWPA) would likely need revision if fuel transport to a CIS facility were to occur.

[5] NUREG-1140, "A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees", Final Report, August 1991, pp 61-62