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INDEPENDENT THIRD-PARTY REVIEW OF SONGS' INSPECTION AND MAINTENANCE PROGRAM FOR THE HOLTEC ON-SITE INDEPENDENT SPENT FUEL STORAGE INSTALLATION

JUNE 12, 2020

PREPARED FOR

CALIFORNIA COASTAL COMMISSION
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EXECUTIVE SUMMARY

LPI, Inc. (LPI) performed an independent third-party review (ITPR) of San Onofre Nuclear Generating Station's (SONGS) "Inspection and Maintenance Program" for the Holtec International (Holtec) independent spent fuel storage installation (ISFSI), located on the SONGS site. The review was performed at the request of the California Coastal Commission (CCC) to ensure that the Holtec multi-purpose canisters (MPCs) at the SONGS ISFSI remain structurally sound to allow on-site transfer and off-site transport when an off-site facility becomes available. At this time, the Holtec ISFSI at SONGS is approved by the CCC for temporary storage through 2035. Based on current plans, the MPCs are to be transferred off-site for permanent storage at that time. The Inspection and Maintenance Program was prepared in response to Special Condition 7 of the ISFSI Coastal Development Permit (CDP).

This report summarizes LPI's ITPR of SONGS' draft Inspection and Maintenance Program (IMP). Work was performed under the California Marine Sanctuary Foundation (CMSF) Contract No. 8003 [3][1].

The ITPR focused on the MPCs' structural integrity, corrosion, material compatibility with operating environment, type and frequency of Non-destructive Examination (NDE) inspections, proposed monitoring and data evaluation, and remediation and repair processes. The ITPR is performed to address potential cask condition issues identified by inspection processes to ensure that the MPCs will remain in a physical condition sufficient to allow on-site transfer and off-site transport through October 6, 2035 [1]. The review also assessed whether any industry lessons learned have been incorporated in the SONGS IMP – including inspection findings disposition, and planned remediation methods.

LPI reviewed the draft SONGS IMP and supporting documents. Southern California Edison (SCE), the SONGS licensee was responsive to LPI questions and comments; conference calls were also held as necessary to expedite information requests and provide clarification.

In summary, based on the documents reviewed for this ITPR and extensive discussions with SCE, LPI is of the opinion that the canister fabrication methods (incorporating

[1] Numbers in [xx], refer to references listed in Section 9 of this document.

methods of over-rolling and laser peening) will induce residual compressive stresses in the outer surface, which will effectively minimize susceptibility to stress corrosion cracking – the most credible degradation mechanism at the SONGS site. Furthermore, LPI is of the opinion that the Type 316L Stainless Steel Canisters incorporating an additional 0.125 in. of wall thickness (for an overall design wall thickness of 0.625 in.), combined with the fabrication methods should effectively minimize susceptibility to stress corrosion cracking. The SCE IMP sets-out MPC inspection schedules, on an earlier and more frequent basis than mandated in the Certificate of Compliance (CoC) 72-1040 [49] for the spent fuel storage system canister design licensed by the United States Nuclear Regulatory Commission (NRC) for ISFSI temporary storage. LPI generally finds that the IMP satisfactorily establishes a plan to effectively observe any potential degradation mechanisms that may occur during the storage period through 2035. Additionally, the IMP presents credible maintenance actions, using best available current technology, that could be implemented to address degradation mechanisms if they should occur.

However, an item of note was associated with the statistical evaluation that was performed to predict the maximum (bounding) depth of MPC scratches that may occur during insertion and extraction from the vertical ventilated modules (VVMs) used to store the MPCs at SONGS. These analyses employed a Normal distribution to predict a 95 percent probability bounding flaw depth, with 95 percent confidence level, that wear marks identified in future inspections would not be deeper than the bounding flaw depth of 0.035 in. for a single canister based on visual inspections of 8 MPCs (out of 29 MPCs) ([1], Exhibit 4). A Normal distribution is not appropriate for predicting maximum flaw depths as is done via extreme value statistics. The application of a Normal distribution underpredicts maximum flaw depth and the probability of finding a flaw depth greater than the bounding flaw depth.

It was recommended, therefore, that the statistical analyses be revised at this time to reflect a more appropriate distribution method, and then updated after the scheduled 2024 MPC inspections, and every time MPCs inspections are performed thereafter to incorporate the additional wear depth data. The number of canister inspections and inspection frequency should be revised (as appropriate) based on the revised statistical analyses. The revised statistical analyses should include all wear depth data, and employ extreme value statistics to predict 95 percent probability bounding flaw depth, with 95 percent confidence level for the entire MPC population and not just a single canister. Furthermore, unloading operations employed for future removal of MPCs should be assessed and modified as appropriate to minimize gouge wear depths. SCE accepted these recommendations and updated the wear depth statistical analyses (see Attachment G).

A second item of note was associated with the acceptable flaw limit for the Holtec MPCs at the SONGS ISFSI. LPI recommends that a 10% flaw allowable limit for preservice and in-service inspection requirements in ASME Code section XI (Table IWB-3514-1) [6] be the acceptance criterion for determining maximum allowable flaw depths of MPCs, and subsequent repair efforts. This conclusion is based on maintaining the benefit of the compressive residual stresses at the canister welds. Specifically, the NRC Supplemental Inspection Report [34] indicates that the protective layer over the welds and heat affected zones is approximately 0.080 in. Therefore, employing a 10% flaw depth acceptance limit of 0.0625 in. ensures that the compressive stresses in the outer surface of the Holtec MPCs (induced by over-rolling and laser peening) will not be compromised.

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Revision	Approval Date	Preparer[5]	Reviewer[5]	Design Verification[5]	Approver[4,5]
1	JUNE 12, 2020	*C. Guzmán-Leong* *J. Cluever*	*P. Bruck* *R. S. Vecchio*	*n/a*	*R. S. Vecchio*

[4] The Approver of this document attests that all project examinations, inspections, tests and analysis (as applicable) have been conducted using approved LPI Procedures and are in conformance to the contract/purchase order.

[5] Electronic signatures may be used only with prior concurrence.

Page	5	of	93	Total Pages	(include any Title Sheet and Attachments in page count. Document Back Cover, if utilized, not included in page count)

Form: LPI-3.1-Rev-10-Fig-5-2

RECORD OF REVISION

Revision No.	Date	Description of Change	Reason
0	June 04, 2020	N/A	Original Issue
1	June 12, 2020	Added Attachment G: SCE Comment Responses 05/29/20, updated discussion on statistical methods to reflect the addition of Attachment G.	SCE implemented LPI recommendations and provided updated statistical analyses.

Form: LPI-3.1-Rev-10-Fig-5-7

TABLE OF CONTENTS

1. INTRODUCTION

On October 6, 2015, the California Coastal Commission (CCC) approved storage of spent nuclear fuel on-site at the San Onofre Nuclear Generating Station (SONGS) [7]. The authorization requires Southern California Edison (SCE) to return to the CCC in 2035 for an amendment to authorize the retention, removal, or relocation of the approved independent spent fuel storage installations (ISFSI) [2]. SONG's Inspection and Maintenance Program (IMP) [1] is to be "designed to ensure that the fuel storage casks will remain in a physical condition sufficient to allow both on-site transfer and off-site transport." Commensurate with Special Condition 7 of CDP 9-15-0228, the IMP shall include a description of [2]:

1) The cask inspection, monitoring and maintenance techniques that will be implemented, including prospective, nondestructive 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 SONGS ISFSI is based on Holtec International's Underground MAXimum Capacity (UMAX) dry spent fuel storage system, as shown in Figure 1-1**.** This Holtec UMAX system is comprised of underground vertical ventilated modules, where each module contains a multi-purpose canister (MPC). MPCs are seal-welded Type 316L stainless steel canisters, 76 in. diameter, 17 ft tall, and 0.625 in. wall thickness (identified as MPC-37) that contain SONGS' spent nuclear fuel. The MPCs are stored vertically inside 0.75 in. thick steel cavity enclosures (cavity enclosure containers) that provide support and protection for the MPCs. In addition, the MPC-37s are placed within concrete monoliths (for radiation shielding) below an ISFSI top pad (35,000 lb steel and concrete lid) for physical protection [33]. The heat produced by the spent fuel inside the MPCs is transferred to the ambient environment by an air recirculation flow path such that natural convection air flow between the concrete casks and stainless steel canisters maintain spent fuel in a safe condition (i.e., no water or fans are used for cooling). Up to 75 MPCs will be stored at the SONGS' ISFSI [1,33,34,35].

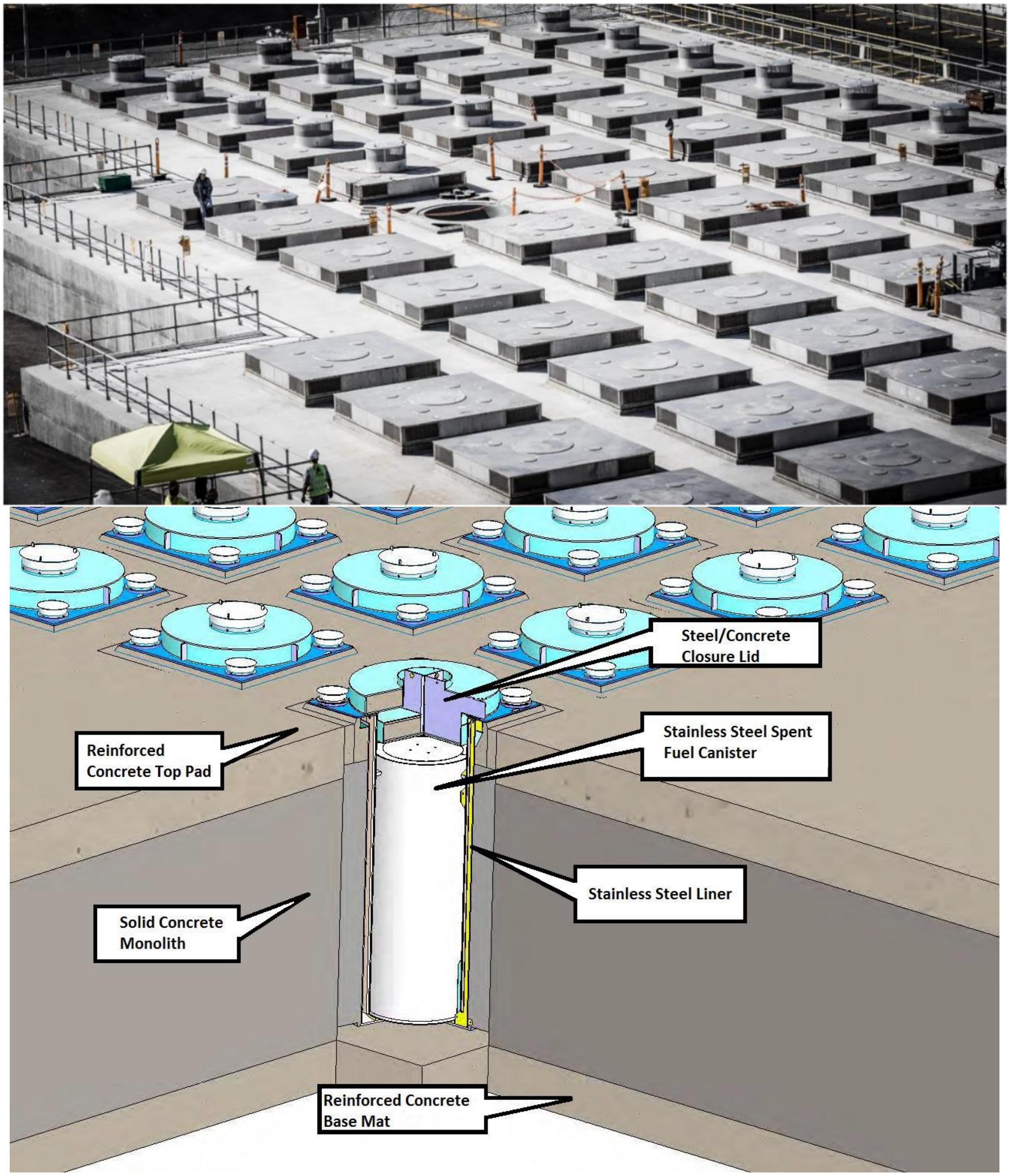

Figure 1-1 SONGS ISFSI: Holtec UMAX Storage System [1]

SONGS' IMP includes inspection and remediation activities, and reporting requirements. Design and fabrication enhancements generally utilized in the design for SONGS include corrosion-resistant material, increased MPC wall thickness, and welding and fabrication improvements to reduce residual tensile stresses were employed by Holtec International (Holtec) to reduce the system's susceptibility to likely degradation mechanisms. The most likely degradation mechanisms, based on NUREG-2214, Section 3.2.2 [31], are considered to be fatigue, general and pitting corrosion, and stress corrosion cracking (together with galvanic corrosion and wear). SONGS will be employing robotic technology to inspect the MPCs sooner and more often than required by the Nuclear Regulatory Commission in their license of the facility [1]. SONGS will also utilize a test canister program that simulates the operating environment and loading conditions (except radiation exposure) of the MPCs to be inspected and monitored to detect MPC degradation ahead of time, enhance data analysis (trending), and to demonstrate the ability of canister repair (if required) using a metallic overlay process. Based on test canister inspection results, SCE may increase the MPC and test canister inspection frequency as appropriate.

2. SCOPE OF WORK

As requested by the CCC, LPI, Inc. (LPI) has performed an independent third-party review of SONGS' "Inspection and Maintenance Program" for the Holtec on-site ISFSI. The focus of the ITPR is to ensure the on-site and off-site transportability of the MPCs at SONGS' Holtec ISFSI for when future permanent storage becomes available.

LPI's ITPR included a review of the SONGS' draft IMP (and supporting documents) and considered:

- technical basis of methods and conclusions with respect to referenced codes and standards
- Nondestructive Examination (NDE) (including planned remote surface inspections),
- methods for storage and maintenance of canisters,
- approach for handling findings of inspections, remediation plans, and
- areas requiring clarification in the draft IMP.

LPI's ITPR excludes radiological aspects of the Holtec ISFSI at SONGS as the NRC has exclusive jurisdiction over radiological aspects of the ISFSI; the NRC's exclusive jurisdiction preempts states from imposing any regulatory requirements related to radiation hazards or nuclear safety.

This report summarizes LPI's ITPR of SONGS' draft IMP for the Holtec on-site ISFSI, conclusions, and recommendations for mitigating potential concerns.

3. METHODOLOGY

LPI's ITPR began with the review of SONGS' draft IMP, followed by initial comments and document requests (see Attachment A) to CCC (CCC was the interface between LPI and SCE). A Non-Disclosure Agreement was signed before certain proprietary documents were provided to LPI. It should be noted, as indicated in Attachment B, that several proprietary documents were not provided even with the NDA. In addition, CCC scheduled conference calls to expedite resolution of LPI's questions and comments, as well as to track the status of document requests. SCE provided written responses to LPI's comments (see Attachments B, C, D, E, and F).

LPI provided technical comments on the draft IMP which are summarized in Section 4 through Section 7 (editorial comments were also provided). Section 4 summarizes comments on the technical bases for susceptibility to degradation mechanisms, and determination of repair efforts; Section 5 summarizes comments on ISFSI inspections; Section 6 addresses repair and remediation comments; Section 7 presents comments on data collection and analysis efforts for SONGS' Holtec ISFSI; and Section 8 provides conclusions and recommendations.

4. TECHNICAL BASIS DOCUMENTS

SONGS' draft IMP references NRC, American Society of Mechanical Engineers (ASME) Boiler Pressure and Vessel Code, and several NRC and Electric Power Research Institute (EPRI) reports as the bases for the operation, inspection, potential repair, and maintenance of the ISFSI by Holtec. Section 4.1 identifies review comment and resolution regarding design and fabrication of the MPCs; Section 4.2 and Section 4.3 summarize comments and resolution (as applicable) regarding degradation screening criteria and repair screening criteria, respectively.

4.1 Design and Fabrication Specifications

The design, material selection, and operating conditions of ISFSIs and MPCs have been documented in NRC Regulatory and EPRI Reports [8, 9, 30, 31]. The MPC design incorporated the following:

- selection of Type 316L Stainless Steel,

- nominal wall thickness increased from 0.5 in. to 0.625 in [39], and
- fabrication and welding processes to induce beneficial outer surface compressive residual stresses [1].

LPI comments and SCE responses regarding design considerations are summarized below.

As a result of the 8/3/2018 transfer incident that placed MPC No. 067 [1] in a misaligned condition with lifting devices not supporting the MPC weight, LPI requested that:

- SCE summarize the safety margin on the MPC lift cleat and attachment methods considering a dynamic load from a potential drop,
- explain whether a degradation mechanism was evaluated for the attachment methods of the lift cleats to the MPC, and
- identify the effect (if any) that degradation mechanisms would have on the lift capacity of the cleat attachment points.

After the 8/3/2018 downloading event, the ability of the MPC downloader slings to withstand a sudden load application resulting from momentary contact between the MPC and the divider shell shield ring during MPC transfer operations was evaluated as follows:

- Case 1: MPC comes to rest on the shield ring assembly resulting in a complete loss of tension in the MPC downloader slings, but the slings remain taut (i.e., no slack in the slings)
- Case 2: MPC comes to rest on the shield ring assembly resulting in a complete loss of tension and the slings are slack by 1.25 in. (i.e., slings must be raised 1.25 in. to become taut and restore tension in the slings).

According to the design calculation for the MPC lift cleats, the ultimate capacity of a lift cleat is 588,265 lb, relative to an MPC dynamic weight of 137,600 lb. Thus, the safety margin is:

= 588,265 lb / 137,600 lb – 1.0

= 3.275, or 327.5%

These results indicate that there is over 300% safety margin between the ultimate capacity of an MPC lift cleat and the peak applied load (static and dynamic) resulting from a hypothetical drop.

The lift cleats are attached by bolts threaded into tapped holes in the lid of the MPC. SCE also stated degradation of the threads during storage is not expected, but if it is observed, degradation will be evaluated and repaired as appropriate. The lift cleat attachment uses special purpose ACME threaded bolts. A minimum safety factor of 1.263 times code requirements was calculated for the bolted joint between the lid and the lift cleats by assuming the minimum (conservative) dimensions for each thread parameter (see Attachment B). Furthermore, SCE indicated that at the time when the MPC is to be withdrawn, the threads in the lid will be checked to ensure they meet the specified tolerances – prior to MPC lift.

LPI requested the basis document for the dynamic evaluation of the lift cleats attachment; however, it was not provided by SCE because it is considered proprietary (even with an NDA in-place between the parties). A conference call was also held in lieu of SCE providing the basis document and to supplement written responses on the lift cleats (see Attachment A, item number one).

LPI also submitted an inquiry on whether the ISFSI's vulnerability to flooding from storms, tsunamis, and other natural disasters was considered in the design, as well as the inspection procedure that would be implemented following a major flooding event. SCE indicated that the ISFSI's susceptibility to geologic hazards, including seismic ground shaking, slope failure, tsunamis, and coastal erosion were considered by the Coastal Commission in its approval of the 2015 Coastal Development Permit (CDP) for the SONGS Holtec ISFSI, CDP No. 9-15-0228 (the 2015 ISFSI CDP [7]), and that corrective actions in the event of a flooding event are described in Section 12.2.4.3 of the final safety analysis report (FSAR) for Holtec's ISFSI [39]. Based on input from SCE, if such events were to occur, they would be addressed through their normal Corrective Action process (see Attachment A, item number 8).

LPI requested canister welding inspection reports (including radiographs if radiographic testing was performed), and plate mill certifications[2]. Given the large number of these reports, SCE provided samples of canister welding inspection reports for five MPCs [12 through 16] and five plate mill certification reports [17 through 21]; LPI did not observe

[2] Plate mill certifications are material test reports that document a material's chemical composition and physical properties, and indicate whether the material meets an international organization's standards (for example, ASME).

any discrepancies. LPI also requested to review the welding procedure specifications (WPSs) to gain a better understanding of the "optimized welding techniques" referenced in the SONGS IMP [1], as well as to determine if the welding processes employed would make the Type 316L Stainless Steel MPCs vulnerable to sensitization – which increases susceptibility to SCC. Since the WPSs are propriety, a welding summary table was provided by SCE, as shown in Table 4-1, and a conference call was held to discuss the summary table [26].

Table 4-1 Welding Summary Table [26]

Seam orientation	Materials of construction	bevel prep	Max Heat input (KJ)	Welding process
Longitudinal seams/shell	316L	double bevel	55,000	Submerged Arc
Shell to Base Plate	316L	Double Bevel /corner joint	55,000	Submerged Arc
Shell to Lid	316L	Single bevel/partial penetration 3/4" depth	140,000	GTAW
Welding filler material	316L			

LPI also requested grinding, canister plate rolling, and surface peening procedures. SCE indicated that there are no specific procedures for grinding or canister plate rolling and provided the licensing drawing as an alternative [11]. SCE employed a rolling process to induce compressive stresses on the outer surface (i.e., reduce tensile stresses to prevent susceptibility to SCC) such that the MPC flat steel plates were over-rolled to a smaller diameter, then expanded to the correct diameter. SCE also provided a peening procedure that specifies the process for laser peening of confinement boundary welds on the SONGS MPC-37s [22]. SCE also provided sample figures [23] from a peening sourcebook and peening coupon test results summary table [24, 32, 38]. All welds and the adjacent heat affected zones (HAZs) with the potential to make incidental contact during downloading operations had a protective peened layer applied during manufacturing [1].

Consistent with the reported depth of compressive stress penetration reported in the SONGS IMP [1] and as shown in Figure 4-1, the residual stress is compressive to a maximum depth of approximately 0.08 in. from the outer surface. The top chart and bottom graph of Figure 4-1 illustrate the stress profile along the length and height of the weld coupon, and the residual stress profile in the hoop direction along the surface of the weld coupon (where 0 in. represents the coupon surface) after peening. Laser peening induces compressive stress on material surfaces and, hence, is an effective method for reducing susceptibility to stress corrosion cracking because SCC requires tensile stress to be present.

In summary, LPI reviewed the design and fabrication documentation provided for the SONGS MPC-37s, and LPI's inquiries on this subject were addressed. Based on the information provided, LPI concludes that the welding and fabrication methods employed on the MPCs at SONGS significantly reduce the susceptibility to SCC by simultaneously minimizing tensile stresses and increasing compressive residual stress.

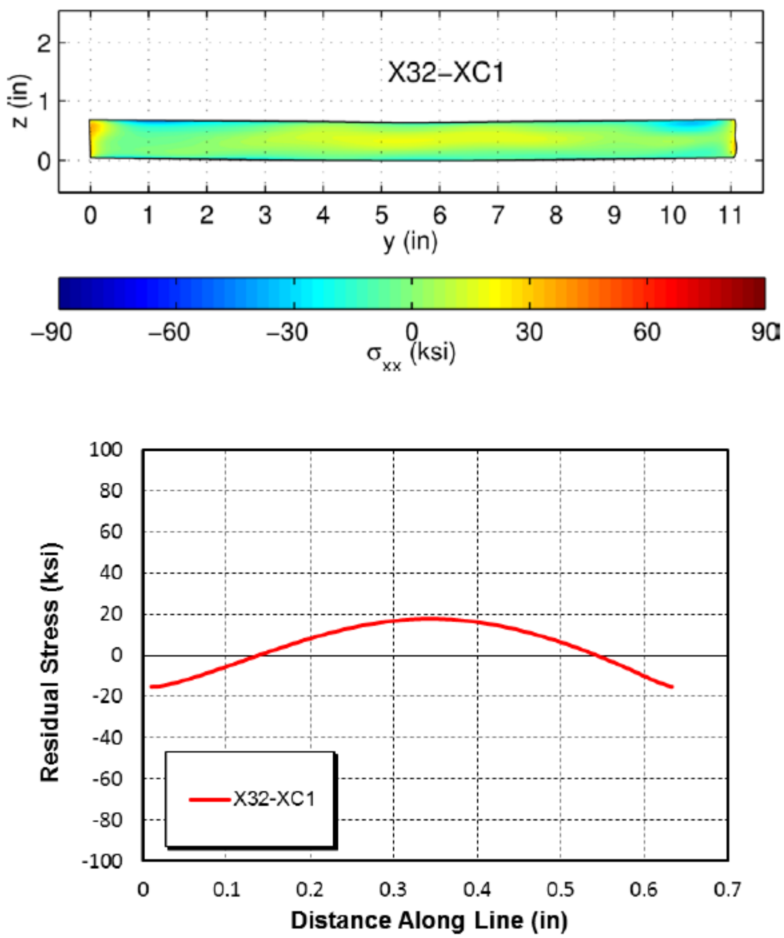

Figure 4-1 Through Thickness Residual Stress Results after Peening [23]

4.2 Degradation Mechanism Screening

Guidance for identifying susceptibility to degradation mechanisms in stainless steel components and mitigation and management methods is well documented. NUREG-2214 [31] and other EPRI Reports [9, 36] describe the degradation mechanisms that may affect integrity of the stainless steel MPCs. In particular, NUREG-2214 evaluates the aging-related degradation mechanisms for ISFSI system components that operate in the United States. The degradation mechanisms that could impact the structural integrity of the MPCs include pitting and crevice corrosion, galvanic corrosion, chloride-induced stress corrosion cracking (CI-SCC), fatigue, and wear. However, CI-SCC is considered the most likely degradation mechanism that could impact long-term operation of the stainless steel MPCs at SONGS [9, 31].

The SONGS IMP describes the five degradation mechanisms based on the source references, listed below as [1]:

- Pitting and Crevice Corrosion: a localized form of corrosion that is confined to a point or small area of a metal surface.
- Galvanic Corrosion: occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution.
- Chloride Induced Stress Corrosion Cracking: occurs under the presence of a susceptible material, corrosive environment, and tensile stress. Chloride stress corrosion cracking is a specific form of SCC that occurs in the presence of chloride ions.
- Fatigue: degradation caused by cyclic loading due to mechanical and/or thermal effects.
- Wear: occurs when susceptible metal components such as austenitic stainless steel, slide against each other under an applied load.

Degradation resulting from any of these mechanisms will be visible on the surface of the canister, and additional volumetric inspections will be performed as necessary to characterize the degraded area, and mitigation would be performed [1]. Given that all five degradation mechanisms are credible per NUREG-2214 [31], none of them will be screened out, and, as such, visual inspections will be used to monitor degradation as outlined in the IMP.

CI-SCC is considered the most likely degradation mechanism that could adversely affect long-term operation of the stainless steel MPCs at SONGS. The SONGS ISFSI is in a coastal region, and key stressors that promote SCC initiation include temperature and deliquescence. Higher temperatures generally increase corrosion rates, however the

MPC temperatures are high enough to decrease the propensity for deliquescence[3] which will reduce the likelihood of CI-SCC [9, 36]). Given these conditions, LPI requested SCE to provide the estimated maximum values of stressors of CI-SCC such as temperature of the MPCs (outer surface), and the chloride concentration and humidity of the air that will be used to cool the MPCs.

As shown in Attachment D, SCE provided values or the references to where values could be found in EPRI Reports [9, 36]. SCE indicated that the maximum temperature is approximately 225ºF. SCE stated that chloride aerosol concentration monitoring for the SONGS site have not been performed as they are assumed to be high enough to support SCC initiation and propagation.

LPI asked whether SCE planned to identify baseline MPC conditions, test (periodically), and trend the halide concentration with the MPC environment. SCE indicated that baseline efforts have been performed. High-resolution photographs of the entire surface of each MPC including the test canister (a total of 68 photos per MPC) were taken prior to canister loading at SONGS and will be available to compare to future inspection results. SCE also inspected eight MPCs that have been positioned into the vertical ventilated modules (and are storing spent nuclear fuel) in 2019; video and photographic records were made and retained for future inspections to be compared to these previous inspection results. Furthermore, the test canister will be inspected via the same methods approximately every 2.5 years, and inspection results will be compared to previous results to evaluate for long term degradation. SCE will not be measuring halide concentration because SONGS is a seaside environment, and a high halide concentration is assumed.

LPI submitted an inquiry on whether inspections would be targeted at high tensile stress regions (e.g. welds, etc.). SCE explains that MPC inspections are able to cover more than 95 percent of the canister vertical surfaces and include, but are not limited to, specific regions such as the welds. Furthermore, SCE will perform susceptibility assessments described in EPRI Report 3002005371 [36] to determine the MPCs considered most susceptible to degradation and, therefore, selected for subsequent inspection. These susceptibility assessments will consider storage time, canister shell material, canister decay heat load (surface temperature), and other considerations to prioritize MPC

[3] Deliquescence refers to a process where salt absorbs water from the air in conditions of high relative humidity [31].

inspections. The current inspection capabilities SCE can employ via remote robotics can observe greater than 95 percent of the canister vertical surfaces where SCC would be most likely to occur. The weld areas are clearly visible and could be inspected to a visual acuity to observe SCC if it were present. As such, any indications of degradation (no matter the reason) can be identified and assessed, as necessary, to ensure the canisters remain acceptable for both on-site storage and off-site transport.

4.3 Repair Screening Criteria

Inspections will be performed every 2.5 years on the test canister and every 5 years on select MPCs to assess the occurrence or propagation of degradation. If observed degradation requires repair there are several technologies that have been considered for repair of the dry cask storage systems' MPCs [10]. LPI requested SCE to identify the flaw acceptance criteria that will be used to determine when repairs are to be performed. To this end, SONGS will perform repairs using a metallic overlay process when any of the following conditions occur [1]:

- the existing observed degradation exceeds the maximum allowable degradation depth (10% of nominal wall thickness or 0.0625 in. [34] per ASME Code Section III [37] and XI requirements [6])
- the predicted rate of degradation indicates that the existing degradation will exceed the maximum allowable degradation depth prior to the next scheduled inspection interval
- a through-wall degradation (such as a crack due to SCC) is detected
- SCE management conservatively decides to proactively implement canister mitigation and repair

In summary, based on the documentation provided for the degradation screening and repair screening criteria of the MPCs at SONGS, the proposed degradation detection and repair methods to be employed at the SONGS Holtec ISFSI are consistent with current guidance.

5. INSPECTIONS AND MONITORING PROGRAM

As noted in the SONGS IMP [1], the NRC licensing process establishes the requirements for the operation, inspection and maintenance of ISFSIs in the United States. The requirements for the initial license period include periodic monitoring of canister conditions through monitoring air vents, and inspection and evaluation of accessible surfaces (normally concrete surfaces) of the ISFSI. Although the NRC does not require any canister inspections during the initial license period of 20 years, such inspections are required after 20 years of operation as part of the Aging Management Program.

LPI comments and SCE responses regarding SONGS' inspection and monitoring program are summarized below.

5.1 ISFSI System

The scope of inspections outlined in the SONGS IMP include inspecting the Holtec ISFSI's material condition. The type of ISFSI inspections and frequency vary as follows:

- Vertical Ventilated Module (VVM) outlet temperature and inlet/outlet vent screen inspections for blockage will be monitored daily
- VVM inlet/outlet vent screen will be inspected monthly for damage, holes, and other evidence of degradation
- ISFSI pad and VVM accessible external surfaces will be visually inspected annually for any evidence of degradation
- ISFSI structure will be inspected for any indications of settlement every 5 years

LPI requested SCE to provide additional information on how the ISFSI structure settlement inspections were to be performed and to specify the acceptance criteria that would warrant MPC extraction. SCE reported that a baseline survey will be performed by a licensed professional-approved land surveyor using standard survey methods, although advances in the methods and techniques will always be considered. This initial survey will be performed after fuel transfer operations to the ISFSI are complete. Subsequent inspections will be performed every 5 years thereafter as previously stated. Surveys will be performed in accordance with SCE's Quality Assurance (QA) program. The acceptance criteria for allowable settlement is 0.2 in. even though settlement greater than 0.2 in. is not expected to impact MPC extraction even if only one corner or one side of the ISFSI structure exhibited differential settlement.

5.2 Test Canister

The test canister is an unloaded canister that is identical to the MPCs storing spent fuel; it contains an electric heat source to simulate the heat load from stored spent fuel, and is stored in the ISFSI subjected to the same conditions as an in-service MPC. The simulated heat load will mimic the coolest of the MPCs (see Attachment B item number 6). The test canister is designed to be accessible for monitoring and inspection. Periodic inspections will be performed on the test canister to detect and monitor any potential canister degradation. As stated previously, the test canister simulates an MPC and its operating environment (although it does not contain spent nuclear fuel), and will be inspected more often to detect initial signs of degradation and used to demonstrate MPC repair activities – if warranted. SCE has developed high resolution robotic monitoring capability to remotely inspect the exterior surface of an in-service MPC.

LPI requested information on whether test canister extraction and transportability testing has been performed to guide future MPC extractions and prevent misalignment incidents. SCE indicated that extraction and transportability testing of the test canister was not considered, since the test canister lid was not welded to allow for internal heater repair, if necessary. However, the IMP [1] indicates that the test canister can be removed for precise inspections if warranted. Furthermore, MPC extraction capability was demonstrated in 2017 to the NRC using the MPC simulator as a license condition prior to the start of fuel transfer operations[4]. SCE indicated that testing will be performed before transferring a loaded MPC (containing spent nuclear fuel) into a transportation cask.

LPI also submitted on inquiry on whether the location of the test canister is representative of the population's susceptibility to SCC, and the dates for when the test canister and first MPC were installed at the SONGS ISFSI. SCE stated that the test canister was installed in December 2019 and its location is a conservative representation of the loaded MPC population because it is closest to the ocean and the test canister temperature is set lower than the coolest MPCs to increase its susceptibility to SCC initiation. The test canister heat load will be installed in July 2020. The first loaded MPC was installed at the SONGS ISFSI in January 2018. Per LPI's request, SCE agreed to include the test canister on the Holtec ISFSI Pad Location and Visual Assessment Scope Map (located on Page A-1 of Exhibit 4 of [1]).

LPI requested that SCE describe the thermal distribution of the electric heaters in the test MPC versus the heat distribution from a typical fuel bundle. Three heater banks, each comprised of 3 heaters stacked vertically, were installed inside the test canister to simulate the heat distribution of a loaded MPC. Only two of the three heaters from each bank are energized, and the heat load can be adjusted by varying the current to attain

[4] Detailed information is provided in the NRC Report ML18200A400, https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18200A400.

the target temperature. SCE compared the temperature profile of the test canister to the spent fuel loaded MPCs and verified that the test canister temperature profile is similar to, and cooler than, the temperatures of the lowest heat-load MPCs that will be loaded in the ISFSI.

In summary, LPI reviewed the documentation provided for the inspection and monitoring of the test canister and LPI's inquiries on this subject were adequately addressed. The inclusion of a test canister program is an effective strategy for early detection of possible degradation of the MPCs at SONGS.

5.3 Multi-Purpose Canisters

The SONGS IMP provides the inspection schedule for the MPCs, which began in 2019 and included 8 MPCs. Going forward, the test canister will be inspected every 2.5 years, and multiple MPCs every 5 years. This inspection frequency is considered to be very conservative, since current NRC requirements consider initial MPC inspections after 20 years of service [6, 9, 31].

SONGS will inspect two MPCs; one of the two MPCs will be the MPC with the highest susceptibility to SCC – this canister will be inspected every five years. The second MPC to be inspected will be selected based on guidance provided in EPRI Report [9]. As mentioned previously in Section 4.2, SCE will perform susceptibility assessments per EPRI guidance [36] to determine the MPCs considered most susceptible to degradation. These susceptibility assessments will take into account storage time, canister shell material, canister decay heat load (surface temperature), and other considerations to prioritize MPCs inspections. Supplemental inspections will be performed if the observed degradation exceeds flaw depth acceptance criteria and/or degradation is not consistent with previous inspection results. The supplemental inspections will employ current industry standards and technology available at the time of inspection. Inspection methods under consideration include supplemental visual inspections (VT-1 resolution), which could presently be implemented, or Eddy-Current Testing (ECT) or Ultrasonic Testing (UT). The flowchart given in Exhibit 5 of the SONGS IMP illustrates the process for performing MPC inspections and subsequent tasks [1].

SCE's inspections plan is based on ASME Draft Code Case N-860 [6]. This Code Case provides guidance for the inspection and maintenance of spent fuel canisters for managing the most credible degradation mechanism (SCC) that may compromise the integrity of the MPCs. Code Case N-860 provides guidance on the frequency, number, and type of inspections that should be performed on spent fuel canisters and assumes that canister inspections begin after approximately 20 years of service.

LPI also inquired about the expected degradation rate of the MPCs and whether more frequent inspections may inadvertently accelerate (by exposure) the degradation rate. SCE reports that the anticipated degradation rates for the MPC weld regions are conservatively based on the SCC degradation rates of 0.0036 to 0.0261 in./yr as reported in NUREG-2214 [31]. The inspection of the MPCs does not change the daily environment, as such, no acceleration effects are expected to occur due to inspections. If degradation is observed, SCE stated that the degradation would be measured and evaluated in accordance with criteria reported in the SONGS IMP [1], and the results would be communicated to the nuclear industry for information and evaluation, as appropriate.

In summary, LPI reviewed the documentation provided for the inspection and monitoring of the MPCs at SONGS, and LPI's inquiries on this subject were adequately addressed. The proposed inspection frequency of the MPCs is consistent with the current guidance and best practices available.

6. REPAIR AND REMEDIATION

As stated in Section 5, SCE will be inspecting the test canister every 2.5 years and the MPCs every 5 years during the initial 20 years of service. The SONGS IMP describes the response and remediation plans that will be implemented based on the inspection results as illustrated by Figure 6-1.

SCE is actively working with industry to develop repair techniques that can be used to repair damaged MPCs. SCE has selected a combination of grinding to remove a flaw and, if necessary, application of a metallic overlay to mitigate flaw propagation [1].

Subsequent sections describe the repair and remediation plans when observed degradation exceeds flaw depth acceptance criteria of 0.0625 in. (i.e., 10% of MPC wall thickness).

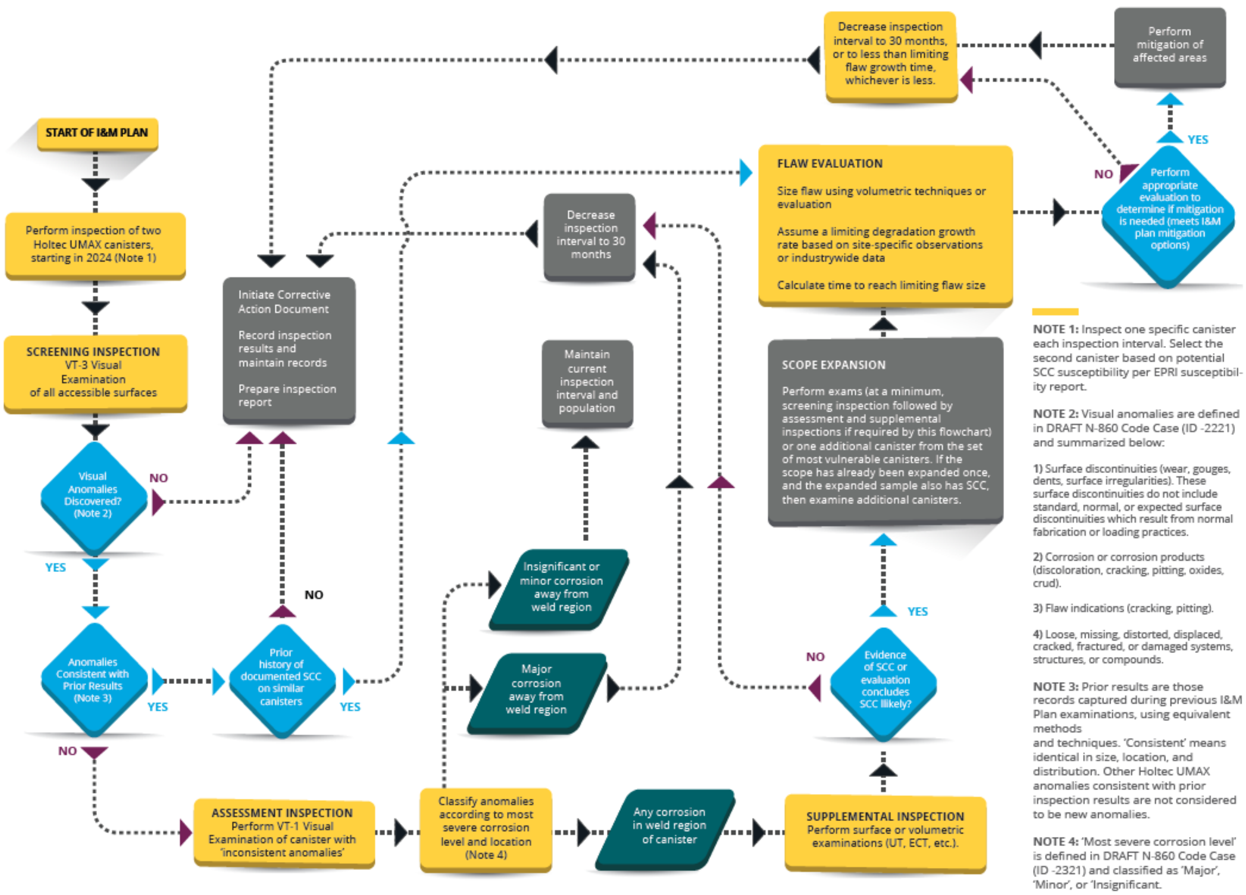

Figure 6-1 SONGS IMP Inspection and Remediation Plan [1]

6.1 Metallic Overlay

The metallic overlay process involves the application of a nickel coating to the damaged surface of an MPC. The metallic overlay process combines the capabilities of a robotic visual assessment with a high-energy solid-state coating and powder consolidation process involving an electrically heated high-pressure carrier gas (nitrogen or helium) to accelerate metallic powder through a supersonic nozzle above a critical velocity for particle adhesion (see Figure 6-2) [1, 25]. SCE and its partners developed and have demonstrated the capability to remotely apply a metallic overlay to mitigate a potential flaw in a canister. Remote inspection and canister mitigation procedures have been developed and approved by SCE [1].

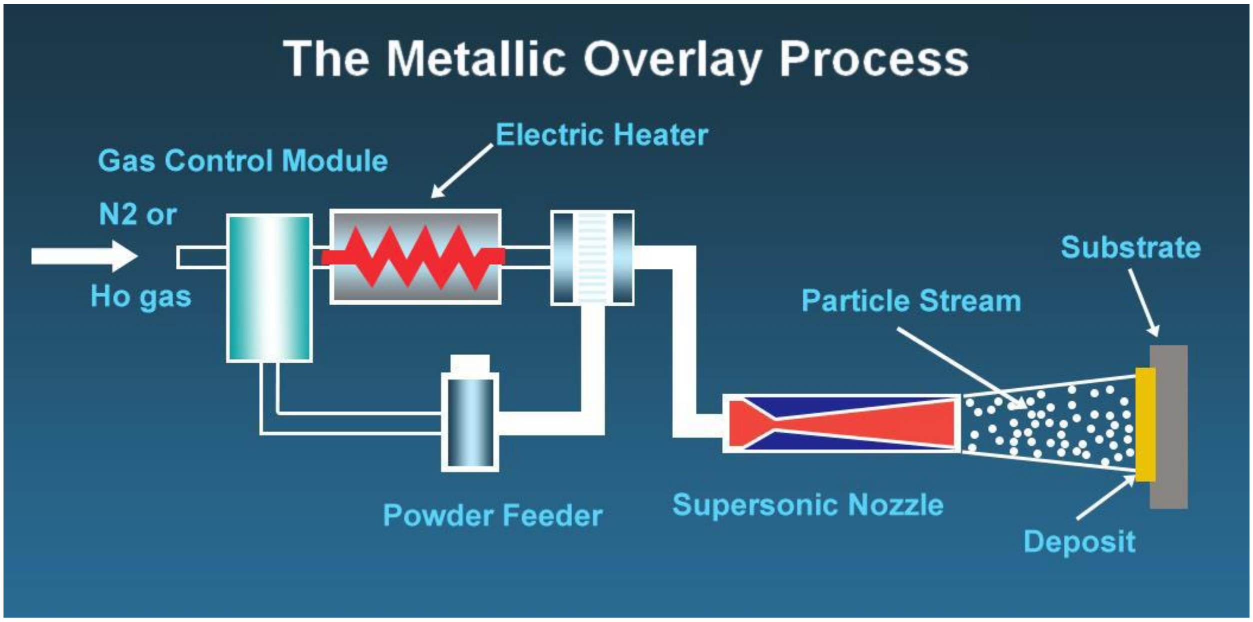

Figure 6-2 Metallic Overlay Process for Repairing MPCs at SONGS [1]

LPI requested clarification on the potential for any adverse effects that result from the metallic overlay methodology, and how the overlay may affect the desired fabrication stresses of the MPC. SCE stated that laboratory tests do not show any adverse effects resulting from application of the metallic overlay process. Instead, the metallic overlay process induces a compressive stress on the base material, which improves the resistance to SCC initiation.

6.2 Alternative Mitigation Methods

Besides grinding and the metallic overlay process, SCE considered encapsulating an MPC in an overpack, such as placing an MPC in a licensed transportation cask for storage. SCE is engaged with DOE, EPRI, industry, and academia investigating new methods to repair damaged MPCs, which will allow for the selection of modern repair and mitigation methods throughout the service life of the MPCs at SONGS.

Based on the documentation provided on the metallic overlay process, and SCE's efforts to employ the latest repair methods on degraded MPCs (if it should occur), the proposed repair and mitigation plan for the SONGS Holtec ISFSI canisters is reasonable.

7. DATA ANALYSIS AND REPORTING

The inspection results, condition trending reviews, and any corrective actions taken will be summarized in a report and provided to the CCC within 180 days of the completion of an MPC inspection (i.e., every five years). In addition, if mitigation is required to address any degradation on a loaded fuel canister, the CCC will be notified within 30 days of the decision to mitigate, followed by a plan detailing the actions SCE will undertake to assure future transportability of the MPCs. SCE's report to the CCC will provide the following:

- Summary of ISFSI inspections
- Inspection information for the selected location for the MPC
- ISFSI pad location,
- Test canister inspection location
- Inspection results and trending of data, and comparison with previous inspections
- Corrective actions that may have been taken based on the inspection results
- Assessment of whether the inspection frequency is adequate and revision of such, if necessary
- Assessment of degradation rate and impact to the structural integrity of MPCs and their transportability

7.1 Statistical Analysis Summary

SCE performed visual examinations (March and April of 2019) of the accessible surfaces of 8 out of the 29 Holtec MPCs installed (at the time) at this SONGS ISFSI. Visual assessments were performed to observe and characterize (width and depth) surface irregularities using a robotic crawler equipped with navigational cameras and a borescope, and a flexible camera with interchangeable lenses. This equipment is capable of measuring surface defects greater than 0.001 in. [27]. The majority of observed wear marks were caused from contact with the divider shell shield ring (maximum wear depth of 0.012 in.) and the MPC inner seismic restraints (0.026 in.). Surface irregularities were compared to post-fabrication photos to determine if the irregularities were present prior to MPC downloading. The 28 surface regularities have a mean depth of 0.0111 in. and standard deviation of 0.0075 in. [27]. A statistical assessment that was performed concluded that any wear mark that might occur during downloading operations has a 95 percent probability, with a 95 percent confidence level, of having an upper bound depth of 0.035 in. [1].

LPI requested that SCE provide details of the statistical evaluation that was performed to describe the technical basis for maximum depth projections, as well as an explanation of why only 8 MPCs were inspected, what data and trend analysis would be performed on wear depth data, and what is the acceptance criteria.

As shown in Attachment B, SCE provided responses to LPI's questions and provided additional documentation, an NRC report [34], and a May 2, 2019 report [27].
The May 2, 2019 report is summarized below:

- Based on wear depth data from 8 MPCs (out of 29), a statistical analysis was performed to determine the bounding depth at the 95/95 confidence level of a double scratch on the MPC wall resulting from insertion and then withdrawal from a VVM [27]. This analysis conservatively assumed a worst-case scenario that the insert and withdrawal scratches occur at the same location. It was further concluded that the deepest total scratch depth at one location resulting from insertion followed by withdrawal at the 95/95 confidence level is 0.0584 in. [27]. As a result, even under a worst-case scenario, potential scratches would reduce the SONGS canister wall thickness to 0.5666 in., which is above a minimum wall thickness of 0.5625 in. specified by ASME (i.e., 10% reduction in the nominal wall thickness) [4, 5, 34].

With regard to the trending and acceptance criteria of wear depth data, SCE reported that detailed photographs and videos were recorded during MPC inspections to allow long term comparison of canister conditions and to allow analysis (as needed) and predictions of future degradation based on past history. SCE indicated that additional visual examination and analysis will be performed as necessary, consistent with the guidance in ASME Draft Code Case N-860 [6]. All the inspection data will be entered into the SONGS inspection database for initial evaluation and will also allow for long-term analysis.

LPI provided additional questions on the statistical analyses relative to specific ASME Code flaw depth criteria, as well as why a Normal (Gaussian) distribution was assumed for the statistical analysis of wear depths since the Normal distribution includes negative flaw depths (based on the reported wear depth mean and standard deviation) – negative flaw depths do not make physical sense. SCE provided responses as shown in Attachment C and additional documentation showing that various statistical analyses had been performed on April 10, 2019 [28] and April 15, 2019 [29], as summarized below:

- A statistical analysis (April 10, 2019) was performed to determine the number of loaded canisters that need to be inspected to provide reasonable confidence that the deepest scratch in the entire population of canisters (29) that have been loaded to-date is less than an upper bound scratch depth [28]. By assuming that the deepest scratch on each of 3 MPCs can be treated as a Normally distributed random variable, it was concluded that there is 95 percent confidence that each of the 26 remaining canisters will not have a scratch deeper than 0.109 in. If 5 additional canisters are sampled and the measured depths are as expected (same mean and variance), the additional sample data would support conclusions that the bounding scratch depth at 95 percent and 99 percent confidence is 0.053 and 0.088 in., respectively. Likewise, if 10 additional canisters (total of 13) are sampled and the measured depths are as expected (same mean and variance), the additional sample data would support conclusions that the bounding scratch depth at 95 percent and 99 percent confidence is 0.046 and 0.070 in., respectively [28].

- A subsequent statistical evaluation (April 15, 2019) was performed on wear depth measurements from 8 MPCs. It was conservatively assumed that the probability of two scratches occurring at the exact same location, due to (inserting and extracting the MPC into the VVM), is unity [27]. The wear depths were assumed to be random variables, and, therefore, a Normal distribution was used for the analysis as random variables follow a Normal distribution. A simulation was conducted based on 1500 trials to produce a modified Normal distribution that forces all scratch depth measurements to be positive numbers (i.e., truncated Normal distribution) to assess whether using a standard Normal distribution was adequate. Results indicate that there is negligible difference in the confidence intervals between using a standard Normal distribution and a truncated Normal distribution [29, 40]. The statistical analysis also concluded that this sample size yields a 95 percent probability, with 95 percent confidence level, that wear marks would not be deeper than 0.035 in. [1, 29] – this conclusion applies for the remaining 21 canisters that had been installed at that time and future canisters (total of 75 MPCs) at the Holtec ISFSI at SONGS [34]. This scratch depth is below the ASME acceptable flaw depth of 0.0625 in.

SCE also reported that finite element (FE) modeling was performed on the unloading operations for MPCs. Results of this deterministic analysis suggested that wear depths will not exceed 0.030 in. (see Attachment D). Specifically, a finite element model was developed [41, 42] to determine the scratch depth and canister shell indentation resulting from downloading and uploading canister operations. Contact between the canister wall and an inner seismic support was modeled as a circular contact area on a flat canister surface. The resulting scratch depths calculated by the model are consistent with the results reported for actual simulated test data [41]. The analysis concluded the MPC wall thinning due to scratching will be less than a maximum of about 0.015 in. - even under contact loads of 30,000 lb [41]. LPI requested surface profiles of the wear marks to gain a better understanding on how the modeling implemented wear mark measurements and whether the modeling methods employed produce results that are consistent with measurements performed to-date (see Attachment E). SCE stated (see Attachment F), that the scratching modelled in the FEA model is a different phenomenon than what has been observed because of contact with the seismic restraint.

Regarding allowable flaw acceptance limit response by SCE in Attachment C, SCE indicated that instead of the ASME 10% depth tolerance (or 0.0625 in.) [5], a flaw depth limit of 0.175 in. is more appropriate per the local primary membrane stress limit of 1.1·Sm in ASME Code Section III [37] given that the MPC wall thickness is 0.125 in. thicker than the nominal wall thickness of 0.50 in.:

$$0.625 \text{ in.} – [0.50 \text{ in.} – (0.50 \text{ in} \times 10\%)] = 0.175 \text{ in.}$$

Consistent with NUREG-2214 [31] and the NRC Supplemental Inspection Report [34], LPI recommends that a 10% flaw allowable limit for preservice and in-service inspection requirements in ASME Code section XI (Table IWB-3514-1)) [6] be the acceptance criterion for determining maximum allowable flaw depths of MPC, and subsequent repair efforts. This conclusion is based on maintaining the benefit of the compressive residual stresses at the canister welds. Specifically, the NRC Supplemental Inspection Report [34] indicates that the protective layer over the welds and heat affected zones is approximately 0.080 in. Therefore, employing a 10% flaw depth acceptance limit of 0.0625 in. ensures that the compressive stresses in the outer surface of the Holtec MPCs (induced by over-rolling and laser peening) will not be compromised.

7.2 Recommendations for Statistical Analyses

LPI is of the opinion that the Normal distribution is not appropriate to model the maximum scratch depth per canister. In [29], the Normal distribution is based on the initial three measurements of 0.000, 0.012, and 0.026 in., with a corresponding mean and standard deviation (calculated by LPI) of 0.0127 in. and 0.013 in., respectively. In contrast, the Canister Inspection Plan [29] mistakenly reports the mean and standard deviation as 0.013 in. and 0.0125 in., respectively. This was clarified by SCE (as outlined in Attachment G) by conservatively replacing the reported 0.000 in. value with a 0.001 in. value to derive the mean and standard deviation values of 0.013 in. and 0.0125 in., respectively. An LPI plot of the data and fit are shown Figure 7-1.

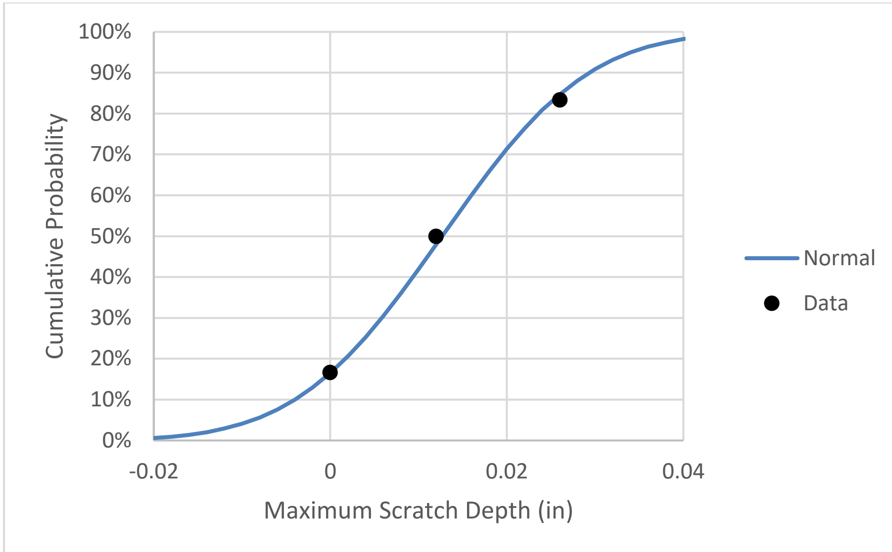

Figure 7-1 Normal Distribution, Three Wear Depth Measurements

For the initial three data points shown in Figure 7-1, it is evident that approximately 16.5 percent of the distribution extends into a region of negative or impossible values. If the mean and standard deviation for all 8 measurements had been used, approximately 7 percent of the distribution would still fall below zero. Both sets of data fail the typical “95% range check” [43] for considering the Normal distribution, whereby 95 percent of the fitted distribution needs to make physical sense. Although the primary region of concern is the upper tail of the distribution, specifically at 0.0625 in., having a significant amount of probability assigned to physically impossible negative values deprives the larger maximum scratch depths of probability, thereby underestimating the true risk to the canisters.

Of concern for the more significant (deeper) gouges identified on the MPC is the process of galling of the stainless steel canister with contact to the stainless steel seismic restraint within the VVM. The process of galling occurs when two materials, typically of similar hardness slide over each other. Galling is a different process to what was modelled in the previously identified finite element analysis. Galling is self-limiting in that material is typically removed from the surface in one region and redeposited in another region, the depth of the gall (trough), and height of the redeposited material as a prow, is limited by the contact stress between the materials and the hardness of the contact materials.

Galling, as a process, is well documented in the literature [44 - 48]. LPI utilized the existing data obtained from SCE inspection results [1] to perform a statistical evaluation and concluded, with a 95 percent probability and 95 percent confidence, that the deepest galled region for all 65 uninspected canisters would not be greater than 0.052 in. This damage depth is less than the 0.0625 in. ASME code 10% wall thickness limit, and within the depth of compressive stresses associated with the laser peening.

In summary, it was recommended the statistical analyses be updated at this time using a more appropriate distribution method, this was done by SCE, as outlined in Attachment G. Additionally, it is recommended that the statistical evaluation be reassessed after the scheduled 2024 MPC inspections, and every time MPCs inspections are performed thereafter to incorporate the additional wear depth data. The revised statistical analyses should include all wear depth data, and employ extreme value statistics to predict 95 percent probability bounding flaw depth, with 95 percent confidence level for the entire MPC population and not just a single canister. The number of canister inspections and inspection frequency should be revised (as appropriate) based on the revised statistical analyses. Scratch depth data from future inspections will likely reduce the probability in a meaningful way provided, of course, that the maximum scratch depths stay within the range of previous depth measurements.

In addition, it is not clear whether efforts have been made to minimize galling (gouging) and scratches during unloading operations based on the information provided for LPI's review. It is recommended to assess how unloading operations for future removal of MPCs can be improved to minimize wear depths.

8. CONCLUSIONS AND RECOMMENDATIONS

LPI performed an independent third-party review (ITPR) of SONGS' "Inspection and Maintenance Program" for the Holtec International (Holtec) independent spent fuel storage installation (ISFSI). The focus of the ITPR was to assess the methods for inspection and maintenance during storage and future retrieval for off-site transport of the MPCs for when future permanent storage becomes available. The SONGS IMP is comprised of inspection and remediation activities, and data management and reporting requirements.

LPI reviewed the draft SONGS IMP and supporting documents. The ITPR focused on design and structural stability of the MPCs given the materials of construction, fabrication methods, susceptibility and mitigation methods for potential degradation mechanisms, monitoring and inspections methods, number and frequency of canister inspections, data analysis and trending of inspections results, and the technical basis for proposed methods of the IMP. SCE was responsive in providing answers to LPI comments. In this regard, conference calls were also held to expedite comment resolution and provide clarification, as necessary.

In summary, based on the documents reviewed for this ITPR and extensive discussions with SCE, LPI is of the opinion that the canister fabrication methods (i.e., over-rolling and laser peening) will induce residual compressive stresses in the outer surface, which will effectively minimize susceptibility to stress corrosion cracking – the most credible degradation mechanism at the SONGS site. Furthermore, LPI believes that the Type 316L Stainless Steel Canisters combined with an additional 0.125 in. wall thickness (for an overall wall thickness of 0.625 in.), and the fabrication methods should effectively minimize susceptibility to stress corrosion cracking. The SCE IMP sets-out MPC inspection schedules, on an earlier and more frequent basis than mandated in the Certificate of Compliance (CoC) 72-1040 [49] for the spent fuel storage system canister design licensed by the United States Nuclear Regulatory Commission (NRC) for ISFSI temporary storage. LPI generally finds that the IMP satisfactorily establishes a plan to effectively observe any potential degradation mechanisms that may occur during the storage period through 2035. Additionally, the IMP presents credible maintenance actions, using best available current technology that could be implemented to address degradation mechanisms if they should occur.

However, an item of note was associated with the statistical evaluation that was performed to predict the maximum (bounding) depth of MPC scratches that may occur during insertion and extraction from the vertical ventilated modules (VVMs). These analyses employed a Normal distribution to predict a 95 percent probability bounding flaw depth, with 95 percent confidence level, that wear marks identified in future inspections would not be deeper than the bounding flaw depth of 0.035 in. for a single canister based on visual inspections of 8 MPCs (out of 29 MPCs). A Normal distribution is not appropriate for predicting maximum flaw depths as is done via extreme value statistics. The application of a Normal distribution underpredicts maximum flaw depth and probability of finding a flaw depth greater than the bounding flaw depth.

It was recommended the statistical analyses be updated at this time using a more appropriate distribution method. This was done by SCE, as outlined in Attachment G. Additionally, it is recommended that the statistical evaluation be reassessed after the scheduled 2024 MPC inspections, and every time MPCs inspections are performed thereafter to incorporate the additional wear depth data. The number of canister inspections and inspection frequency should be revised (as appropriate) based on the revised statistical analyses. The revised statistical analyses should include all wear depth data, end employ extreme value statistics to predict 95 percent probability bounding flaw depth, with 95 percent confidence level for the entire MPC population and not just a single canister. Furthermore, unloading operations employed for future removal of MPCs should be assessed and modified as appropriate to minimize gouge wear depths.

A second item of note was associated with the acceptable flaw limit for the Holtec MPCs at the SONGS ISFSI. LPI recommends that a 10% flaw allowable limit for preservice and in-service inspection requirements in ASME Code section XI (Table IWB-3514-1)) [6] be the acceptance criterion for determining maximum allowable flaw depths of MPCs, and subsequent repair efforts. This conclusion is based on maintaining the benefit of the compressive residual stresses at the canister welds. Specifically, the NRC Supplemental Inspection Report [34] indicates that the protective layer over the welds and heat affected zones is approximately 0.080 in. Therefore, employing a 10% flaw depth acceptance limit of 0.0625 in. ensures that the compressive stresses in the outer surface of the Holtec MPCs (induced by over-rolling and laser peening) will not be compromised.

9. REFERENCES

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APPENDIX A. LPI REQUEST FORMS

Document:		Inspection and Maintenance Program		
Rev.:		DRAFT Dated 3/31/20		
Comment No:	Section No:	Page No:	Parg/Sent.	Comment:
1	--	--	--	Given the 8/3/2018 transfer incident that placed the MPC in a misaligned condition with lifting devices not supporting the MPC weight, what is the safety margin on the MPC lift cleat and attachment methods considering a dynamic load from a potential drop? Has a degradation mechansim been considered/evaluated for the attachment methods of the lift cleats to the MPC? What effect if any would degradation mechanisms have on the lift capacity of the cleat attachment points?
2	--	--	--	Are there any plans to test the extraction and transportability of the test canister prior to extraction of MPCs with SNF?
3	--	--	--	All figures need to be called out in the main body.
4	--	i	--	Table of contents should include the appendix (that is referenced on page 20) and the six exhibits. A reference section should also be included.
5	I.a.	1	--	8 MPCs were inspected out of how many canisters? Need to provide technical basis for the number of canisters selected and inspection frequency.
6	I.b.	2	--	Is the location of the test canister representative of the population for the susceptible degradation mechanism (i.e. SCC). When was the test canister implemented relative to loaded MPC - is the test canister as old as the first canister(s)? Provide dates for both.
7	I.b	2	--/2nd	Describe the thermal distribution of the electric heaters vs. the heat distribution from a typical fuel bundle, and the effect(s) if any.
8	I.c.	2	--	Was the ISFSI's vulnerability to flooding from storms, tsunamis, etc., considered? What is the inspection procedure (if any) following a major flooding event?
9	I.c	2	--/2nd	What is the flaw criteria for consideration/application of the metallic overlay?
10	I.c	2	--/2nd	Are there any adverse effects (e.g. residual stresses, etc.) as a result of the metallic overlay methodology? How does the overlay affect the desired fabrication stresses?
11	II.E.	7	4th/--	Specify how the five degradation mechanisms will be monitored, identify acceptance criteria, and parameter values that will be used to screen in/out susceptibility to each of the degradation mechanisms.
12	II.E	7	4th/last	Given SCC is considered the most likely long term degradation mechanism, are inspections targeted at high tensile stress regions (e.g. welds, etc.)? Are there pre-defined inspection checklists and acceptance criteria for targeted locations that may be more susceptible to SCC? Are there any plans to baseline, test on a periodic basis, and trend the halide concentration within the MPC environment?
13	III.A.1	13	4th/--	How will the inspection for ISFSI structure settlement be performed? Laser scanning, etc.? What is the acceptance criteria to affect MPC extraction?
14	III.A.2	13	--	Consider using automated photograph comparision technology such as Change Detection System (CDS) developed by DOE/INL. LPI is a commercialization partner/service provider of the CDS technology for the nuclear industry.
15	III.A.2.a	14	1st/1st	Need to clarify the following sentence: "The SONGS inspections were informed by previous inspections carried out by EPRI's Extended Storage Collaboration Program, which is discussed in more detail in section B.2 below." Should "...previous inspections" read "...previous inspectors"?
16	III.A.2.c	16	2nd/last	Regarding ".....SCE will conservatively begin inspecting canisters much sooner," reference to Table 1 should be included in this statement.
17	III.A.2.c	16	3rd/2nd	Table 1 is referenced here, is this the same Table 1 mentioned in the Executive Summary?
18	III.A.2.c	17	1st/1st	How will the canisters' relative susceptibility to degradation be determined for selection of the bounding MPC?
19	III.B.3	22	5th/1st	Is the "..miniaturized mitigation system.." mentioned here referring to the overlay system? If so, suggest rewording to be consistant elsewhere.
20	III.C	22	1st/1st	What is the basis of the 180-day reporting requirement from inspection completion?
21	III.C.2	23	--	What analysis and trending data is expected? What would be the acceptance criteria of that data?
22	III.C.5	23	--	What is the expected degradation rate considering industry OE (i.e. a slow-developing and well understood phenomenon that is not expected to occur within the first couple decades of the life of a canister)? Does more frequent inspection have the potential to accelerate (by exposure) industry established degradation rates?

Document:		SONGS Draft IMP Exhibits		
Rev.:		DRAFT Dated 3/31/20		

Comment No:	Section No:	Page No:	Parg/Sent.	Comment:
1	Exhibit 4	3	--	Provide details of the statistical evaluation that was performed, as it provides the technical basis for maximum depth projections, 95 percent confidence levels/probability, as well as the number of MPCs that were inspected (why are 8 MPCs adequate...out of how many?).
2	Exhibit 4	A-1	--	Would be helpful to provide the test canister on the map.
3	Exhibit 5	--	--	How is SCC distinguished from other corrosion mechanisms? Are there plans to test for halide concentration?

4/23/20 update

IMP Document Request Tracker

	Item	Date requested	Proprietary?	Status
1.	EPRI, Multi-Purpose Canister System Design Synopsis Report (Report TR-106962)	4/6/20		SCE provided via email 4/8/20
2.	EPRI, Aging Management Guidance to Address Potential Chloride-Induced Stress Corrosion Cracking of Welded Stainless Steel Canisters (Report 3002008193) (March 2017)	4/6/20		SCE provided via email 4/8/20
3.	EPRI report, Welding and Repair Technology Center: Extended Storage Collaboration Program Canister Mitigation and Repair Subcommittee – Industry Progress Report (Report 3002013130) (December 2018)	4/6/20		SCE provided via email 4/8/20
4.	Report that summarizes/describes the miniaturized mitigation system	4/6/20	VRC	SCE will provide this document via SharePoint soon – reviewing status of NDA with VRC.
5.	Design documents, especially those associated with risk analysis	4/6/20	Holtec – 4/23 NDA	SCE uploaded licensing drawing 6505R21 to SharePoint 4/23/20.
6.	Canister plate rolling procedures	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there's not a specific procedure for canister plate rolling, so SCE provided drawings that are responsive to this request. SCE uploaded licensing drawing 6505R21 4/23/20.
7.	Plate Mill Certs	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there are a large number of these certs, so SCE has provided some samples. SCE uploaded plate mill certs from five MPCs 4/23/20.

1

4/23/20 update

	Item	Date requested	Proprietary?	Status
8.	Welding Procedure Specifications (WPSs)	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, this item is especially sensitive/proprietary. Therefore, Holtec made a welding expert available by phone for an interview about the procedures. As discussed on 4/23 call, Holtec is also preparing a summary document, expected COB 4/28/20.
9.	Surface Peening Procedures	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, this item is especially sensitive/proprietary. Therefore, Holtec will provide publicity documents and Holtec and Curtiss-Wright will make experts available for a phone interview or to answer any specific questions LPI has about peening procedures. SCE uploaded HPP-2464-003 and sample figures from the peening sourcebook 4/23/20. SCE will provide peening results summary table discussed on 4/23 call.
10.	Grinding procedures	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there's not a specific procedure for grinding, but SCE can provide excerpts of documents that are responsive to this request. SCE uploaded licensing drawing 6505R21 4/23/20.
11.	ASME Code Case N-860	4/6/20		N/A – LPI has access to draft

4/23/20 update

	Item	Date requested	Proprietary?	Status
12.	Canister Welding Inspection Reports – including radiographs if RT was performed	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there are a large number of these reports, so SCE will provide some sample reports. SCE uploaded canister welding inspection reports from fabrication from five MPCs 4/23/20.
13.	The basis document for the dynamic evaluation of the lift cleats attachments	4/10/20	Holtec – 4/23 NDA	Holtec is making an expert on this topic available by phone to answer any questions.

3

5/1/20 update

IMP Document Request Tracker

	Item	Date requested	Proprietary?	Status
1.	EPRI, Multi-Purpose Canister System Design Synopsis Report (Report TR-106962)	4/6/20		SCE provided via email 4/8/20
2.	EPRI, Aging Management Guidance to Address Potential Chloride-Induced Stress Corrosion Cracking of Welded Stainless Steel Canisters (Report 3002008193) (March 2017)	4/6/20		SCE provided via email 4/8/20
3.	EPRI report, Welding and Repair Technology Center: Extended Storage Collaboration Program Canister Mitigation and Repair Subcommittee – Industry Progress Report (Report 3002013130) (December 2018)	4/6/20		SCE provided via email 4/8/20
4.	Report that summarizes/describes the miniaturized mitigation system	4/6/20	VRC	SCE uploaded proprietary VRC metallic overlay report to SharePoint 4/28/20.
5.	Design documents, especially those associated with risk analysis	4/6/20	Holtec – 4/23 NDA	SCE uploaded licensing drawing 6505R21 to SharePoint 4/23/20 and provided two MPR analyses via email 5/1/20.
6.	Canister plate rolling procedures	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there's not a specific procedure for canister plate rolling, so SCE provided drawings that are responsive to this request. SCE uploaded licensing drawing 6505R21 4/23/20.
7.	Plate Mill Certs	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there are a large number of these certs, so SCE has provided some samples. SCE uploaded plate mill certs from five MPCs 4/23/20.

1

5/1/20 update

	Item	Date requested	Proprietary?	Status
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9.	Surface Peening Procedures	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, this item is especially sensitive/proprietary. Therefore, Holtec will provide publicity documents and Holtec and Curtiss-Wright will make experts available for a phone interview or to answer any specific questions LPI has about peening procedures. SCE uploaded HPP-2464-003 and sample figures from the peening sourcebook 4/23/20. SCE will provide peening results summary table discussed on 4/23 call.
10.	Grinding procedures	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there's not a specific procedure for grinding, but SCE can provide excerpts of documents that are responsive to this request. SCE uploaded licensing drawing 6505R21 4/23/20.
11.	ASME Code Case N-860	4/6/20		N/A – LPI has access to draft

2

5/1/20 update

	Item	Date requested	Proprietary?	Status
12.	Canister Welding Inspection Reports – including radiographs if RT was performed	4/6/20	Holtec – 4/23 NDA	As discussed 4/10, there are a large number of these reports, so SCE will provide some sample reports. SCE uploaded canister welding inspection reports from fabrication from five MPCs 4/23/20.
13.	The basis document for the dynamic evaluation of the lift cleats attachments	4/10/20	Holtec – 4/23 NDA	Holtec made an expert on this topic available by phone to answer any questions.

3

APPENDIX B. SCE COMMENT RESPONSES 04/16/2020

SCE Responses to LPI's IMP Questions and Comments

April 16, 2020

Southern California Edison Company (SCE) provides the following responses to Lucius Pitkin, Inc.'s (LPI) April 8 questions and comments regarding SCE's Draft Inspection and Maintenance Program (IMP).

1. **Given the 8/3/2018 transfer incident that placed the MPC in a misaligned condition with lifting devices not supporting the MPC weight, [a] what is the safety margin on the MPC lift cleat and attachment methods considering a dynamic load from a potential drop? [b] Has a degradation mechanism been considered/ evaluated for the attachment methods of the lift cleats to the MPC? [c] What effect if any would degradation mechanisms have on the lift capacity of the cleat attachment points?**

   a. ***What is the safety margin on the MPC lift cleat and attachment methods considering a dynamic load from a potential drop?***

   The safety margin is (588,265 lbs/137,600 lbs – 1.0), or 3.275 (327.5%).

   After the 8/3/2018 downloading event, Holtec performed an analysis to evaluate the ability of the MPC downloader slings to withstand a sudden load application resulting from momentary contact between the MPC and the divider shell shield ring during MPC transfer operations. Two cases were analyzed:

   - Case 1: MPC comes to rest on the shield ring assembly resulting in a complete loss of tension in the MPC downloader slings, but the <u>slings remain taut</u> (i.e., no slack in slings).
   - Case 2: MPC comes to rest on the shield ring assembly resulting in a complete loss of tension and the <u>slings are slack</u> by 1.25 inches (i.e., slings must be raised 1.25 inches to become taut and restore tension in slings).

   Case 2 is bounding for dynamic loads, and the computed values for Case 2 are used to determine safety margin for the MPC lift cleats. This condition is considered reasonably representative for the scenario where the MPC is removed from resting on the shield ring. Therefore, the peak load is computed using Case 2.

   Per the Holtec analysis for Case 2, the calculated peak load on the set of 2 slings (static and dynamic) due to sudden application of load is 275,200 lbs, or 137,600 lbs applied to each sling. 137,600 lbs is the peak load that would also be applied to each MPC lift cleat.

   Per the design calculation for the MPC lift cleats, the ultimate capacity of a lift cleat is 588,265 lbs. The safety margin is (588,265 lbs/137,600 lbs – 1.0), or 3.275 (327.5%). In other words, there is over 300% safety margin between the ultimate capacity of an MPC lift cleat and the peak applied load (static and dynamic) resulting from a hypothetical drop.

   b. ***Has a degradation mechanism been considered/evaluated for the attachment methods of the lift cleats to the MPC?***

   Yes, potential degradation has been considered in the analysis. The lift cleats are attached by special purpose ACME threaded bolts. Through its proprietary report, *Structural Analysis of the Lift Cleats at SONGS*, Report HI-2188161, Holtec calculates a minimum safety factor for the bolted joint between the lid and the lift cleats as 1.263 times the code requirements. This calculation assumes the minimum (conservative) dimensions for each thread parameter. At the time the MPC is withdrawn, the threads in the lid will be checked to ensure they meet the specified tolerances. We do not expect any degradation of the threads during storage, but if degradation does occur, it will be evaluated and appropriately repaired.

c. ***What effect if any would degradation mechanisms have on the lift capacity of the cleat attachment points?***

We expect no significant degradation of the female threads in the lid where the lift cleats will be attached prior to future installation of the lift cleats for shipping. The holes will be warm and dry for the duration of storage and thus an environment that supports stress corrosion cracking or other forms of degradation will be avoided. However, at the time of withdrawal, the threaded attachment points will be cleaned and inspected. If any repair is needed, it will be addressed at that time. Repair of a threaded connection is not a difficult operation and can be performed remotely if required for dose conditions.

2. **Are there any plans to test the extraction and transportability of the test canister prior to extraction of MPCs with SNF?**

No, the test canister design does not accommodate testing for MPC extraction or transportation capability. To allow for the possibility of test canister heater work in the future, the test canister lid was not welded on.

The MPCs' extraction capability was demonstrated to the NRC using the MPC simulator as a license condition prior to the start of fuel transfer operations in September 2017. See NRC's August 24, 2018 SONGS Inspection Report, available at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18200A400. Similar testing will be required prior to loading an MPC containing spent nuclear fuel into a transportation cask.

With respect to transportability, once an MPC is loaded into a licensed transport cask, the NRC would consider it to be transportable.

3. **All figures need to be called out in the main body.**

SCE will incorporate this edit into the final IMP.

4. **Table of contents should include the appendix (that is referenced on page 20) and the six exhibits. A reference section should also be included.**

SCE will incorporate this edit into the final IMP.

5. **[a] 8 MPCs were inspected out of how many canisters? [b] Need to provide technical basis for the number of canisters selected and inspection frequency.**

a. ***8 MPCs were inspected out of how many canisters?***

Eight MPCs were selected out of 29 total MPCs loaded at the time of the 2019 inspection. The decision to inspect eight of the 29 MPCs was based on a statistical analysis performed by MPR Associates, Inc. (MPR), in its May 2019 SONGS report, *Canister Installation and Removal Effects on Wall Thickness*, which is attached as Exhibit A. MPR's analysis looked at a population of marks on the canisters rather than at individual canisters and concluded that inspecting eight MPCs provided predictive results for all 73 MPCs that would eventually be loaded.

Additionally, the NRC did an independent statistical analysis of the 2019 inspection as documented in its July 9, 2019 Supplemental Inspection Report, which is available at the following link: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19190A217.

b. ***Need to provide technical basis for the number of canisters selected and inspection frequency.***

SCE understands this question to be asking about the inspection frequency for the entire IMP.

The standard inspection frequency based on NUREG-2214 Aging Management guidance is to inspect one canister every 5 years.

The Electric Power Research Institute's (EPRI) 2015 report 3002005371, *Susceptibility Assessment Criteria for Chloride-Induced Stress Corrosion Cracking (CISCC) of Welded Stainless Steel Canisters for Dry Cask Storage Systems*, available at https://www.epri.com/#/pages/product/000000003002005371/?lang=en-US, recommends inspecting two canisters every 5 years based on the SONGS ISFSI location. Normally, the inspections would begin at the start of the license extension period, which is approximately 20 years after an ISFSI initial loading.

As part of the IMP, SCE proposes to do inspections starting 5 years after the initial 2019 ISFSI inspections (i.e., in 2024). Due to the long-term, slow developing nature of the known potential degradation mechanisms for stainless steel canisters, it is considered very unlikely that these additional inspections will discover any degradation.

6. **[a] Is the location of the test canister representative of the population for the susceptible degradation mechanism (i.e. SCC). [b] When was the test canister implemented relative to loaded MPC - is the test canister as old as the first canister(s)? Provide dates for both.**

    a. ***Is the location of the test canister representative of the population for the susceptible degradation mechanism (i.e. SCC).***

Yes, the location of the test canister is a conservative representative of the loaded MPC population. The test canister is loaded in location #62, which is the northwestern-most location on the ISFSI pad. It is in the row of canisters closest to the ocean.

As noted in the IMP, chloride-induced stress corrosion cracking (SCC) is the result of a combination of three factors: (1) a susceptible material, (2) exposure to a corrosive (wet) environment, and (3) tensile stresses. SCC initiation and growth on MPCs is very dependent on temperature. Higher canister temperature leads to less or no water on the canister; as a result, lower temperature canisters are more susceptible to SCC.

The test canister heat load will conservatively be set slightly lower than the coolest MPCs, which are anticipated to be installed in or about July 2020. Since the test canister is already in service, and the lowest heat load canisters are not yet loaded, the test canister will have more service time, and is expected to be a leading indicator of any SCC development.

    b. ***When was the test canister implemented relative to loaded MPC - is the test canister as old as the first canister(s)? Provide dates for both.***

The first loaded MPC was placed on the SONGS ISFSI pad in January 2018, and the test canister was placed on the ISFSI pad in December 2019. While it is recognized that the test canister has not been in service as long as the first loaded MPCs, the first loaded MPCs had a high heat load and will be warm much longer than the later loaded MPCs. As a result, even though the first loaded MPCs have been in service longer, they will be less susceptible to degradation than the later, cooler MPCs. Additionally, the time between the placement of the first MPCs and the placement of the test canister is a relatively short period of time given the very slow-developing nature of SCC of stainless steel materials.

7. **Describe the thermal distribution of the electric heaters vs. the heat distribution from a typical fuel bundle, and the effect(s) if any.**

In order to mimic the heat distribution of a loaded MPC, SONGS placed a Unistrut frame inside the test canister, holding nine heaters mounted in three banks of three. The heater banks are arranged vertically: an upper bank, a middle bank, and a lower bank. Two heaters from each bank are energized, with the third heater in each bank as a spare. Thus, the heat is distributed longitudinally, similar to what is expected to occur in a loaded MPC. The heater load is controlled by adjusting the current to achieve the desired temperature. The temperature is chosen to match the temperature of the lowest heat load MPC (which is an MPC that will be loaded into the ISFSI in or about July 2020), since that coolest canister will be most susceptible to an environment that would allow initiation of SCC.

This heating configuration allows for thermal convection heat transfer within the test canister that approximates a loaded MPC convection heat transfer profile. SCE has compared the temperature profile of the test canister to the other MPCs and verified that the test canister temperature profile is similar to, and cooler than, the temperatures of the lowest heat-load MPCs that will be loaded in the ISFSI.

8. **[a] Was the ISFSI's vulnerability to flooding from storms, tsunamis, etc., considered? [b] What is the inspection procedure (if any) following a major flooding event?**

   a. Was the ISFSI's vulnerability to flooding from storms, tsunamis, etc., considered?

   The ISFSI's susceptibility to geologic hazards, including seismic ground shaking, slope failure, tsunamis, and coastal erosion were considered by the Coastal Commission in its approval of the 2015 Coastal Development Permit (CDP) for the SONGS Holtec ISFSI, CDP No. 9-15-0228 (the 2015 ISFSI CDP). The Staff Report supporting the 2015 ISFSI CDP is available at https://documents.coastal.ca.gov/reports/2015/10/Tu14a-10-2015.pdf.

   b. What is the inspection procedure (if any) following a major flooding event?

   Corrective actions in the event of a flooding event are described in Section 12.2.4.3 of the final safety analysis report (FSAR) for Holtec's ISFSI, which is available at https://www.nrc.gov/docs/ML1619/ML16193A339.pdf. SCE follows these corrective actions in its SONGS site-specific procedures.

9. **What is the flaw criteria for consideration/application of the metallic overlay?**

   The IMP's section on Metallic Overlay, Section III.B.1 at page 21 of the IMP, describes the implementation criteria required for use of the metallic overlay process. That section states: "If the existing degradation either (a) currently exceeds the maximum allowable degradation depth, or (b) analysis performed after the degradation is discovered determines that the degradation will exceed maximum allowable degradation depth prior to the next scheduled inspection interval, or (c) a through-wall degradation (such as a crack due to SCC) is discovered, or (d) SCE management conservatively decides to proactively implement canister mitigation and repair, then SCE will use the metallic overlay process to mitigate the degradation."

10. **Are there any adverse effects (e.g. residual stresses, etc.) as a result of the metallic overlay methodology? How does the overlay affect the desired fabrication stresses?**

    No – based on laboratory testing, there are no known adverse effects resulting from the metallic overlay.

    The metallic overlay process applies a compressive stress on the base material, which has a positive effect on the desired fabrication stresses. Since SCC requires tensile stresses to propagate through the canister material, addition of compressive stress prevents initiation of SCC and could arrest an existing crack, including a through-wall crack.

11. **Specify how the five degradation mechanisms will be monitored, identify acceptance criteria, and parameter values that will be used to screen in/out susceptibility to each of the degradation mechanisms.**

    The IMP supports maintaining the MPCs in a physical condition sufficient to allow on-site transfer and off-site transport. As such, the primary focus of the IMP is to ensure physical confinement of the spent fuel contained within the MPCs, which can be verified through visual inspections. Different corrosion and wear mechanisms are considered potential items to monitor and inspect, but the process to identify, evaluate, and mitigate are the same in all instances.

The five degradation mechanisms that are mentioned in NUREG-2214 that could credibly affect the MPCs during the first 60 years after initial licensing are (1) pitting and crevice corrosion, (2) galvanic corrosion, (3) chloride-induced stress corrosion cracking (SCC), (4) fatigue and (5) wear. Each of these mechanisms are addressed below.

1) Pitting and crevice corrosion

Pitting corrosion is a localized form of corrosion that is confined to a point or small area of a metal surface. Crevice corrosion occurs in a wetted environment when a crevice exists that allows a corrosive environment to develop in a component.

Both of these corrosion mechanisms would be visible on the surface of the canister, and would be monitored and visible to the currently available inspection techniques employed by SCE. If found, additional volumetric inspections would be performed as appropriate to characterize the corroded area, and mitigation would be performed based on the acceptance criteria noted in the Response and Remediation Section (III.B) of the IMP.

Since this degradation mechanism is considered credible per NUREG 2214, it would not be screened out, and visual inspections would be used to monitor and take action as appropriate.

2) Galvanic corrosion

Galvanic corrosion occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution.

This corrosion mechanism would be visible on the surface of the canister, and would be monitored and visible to the currently available inspection techniques employed by SCE. If found, additional volumetric inspections would be performed as appropriate to characterize the corroded area, and mitigation would be performed based on the acceptance criteria noted in the Response and Remediation Section (III.B) of the IMP.

This degradation mechanism is seen as extremely unlikely (there are no dissimilar metals in contact for the UMAX canister system). It is considered credible by NUREG 2214 and would not be screened out, and visual inspections would be used to monitor and take action as appropriate.

3) Chloride-induced stress corrosion cracking (SCC)

SCC is the cracking of a metal produced by the combined action of corrosion and tensile stress and requires a corrosive chemical environment. All austenitic grades of stainless steel (including the material used for construction of the MPCs) have long been reported to be susceptible to be SCC.

This corrosion mechanism would be visible on the surface of the canister, and would be monitored and visible to the currently available inspection techniques employed by SCE. If found, additional volumetric inspections would be performed as appropriate to characterize the corroded area, and mitigation would be performed based on the acceptance criteria noted in the Response and Remediation Section (III.B) of the IMP.

Since this degradation mechanism is considered credible per NUREG 2214, it would not be screened out, and visual inspections would be used to monitor and take action as appropriate.

4) Fatigue

Since spent fuel storage is a static operation, cyclic loading by a purely mechanical means is largely limited to the transfer cask lifting trunnions, which are loaded each time a canister is moved from the spent fuel pool to the ISFSI pad. Cyclic loads could also be experienced due to thermal effects, such as those caused by daily and seasonal fluctuations in the temperature of the external environment.

The UMAX system has performed an analysis performed which shows that thermal fatigue will not cause any impacts to the system during the initial license period. This analysis is described in the Holtec Non-Proprietary FSAR, Section 3.1.2.5.

However, since the effects of fatigue would likely be present on the canister surface, and deformation or cracking due to fatigue would be visible on the surface of the canister, and would be monitored and visible to the currently available inspection techniques employed by SCE. If found, additional volumetric inspections would be performed as appropriate to characterize the corroded area, and mitigation would be performed based on the acceptance criteria noted in the Response and Remediation Section (III.B) of the IMP.

Since this degradation mechanism is considered credible per NUREG 2214, it would not be screened out even though an analysis has been performed, and visual inspections would be used to monitor and take action as appropriate.

5) <u>Wear</u>

Adhesive wear, also known as galling, occurs when susceptible metal components such as austenitic stainless steel, slide against each other under an applied load. This mechanism has been observed previously in the inspection of the 8 MPCs in 2019. Since the canisters are now in a static condition, no further wear is expected until the canisters are removed in preparation for transport, and the wear that occurs then is expected to be similar to what occurred during loading.

The effects of wear would be visible on the surface of the canister, and would be monitored and visible to the currently available inspection techniques employed by SCE. If found, additional volumetric inspections would be performed as appropriate to characterize the worn area, and mitigation would be performed based on the acceptance criteria noted in the Response and Remediation Section (III.B) of the IMP.

Since this degradation mechanism is considered credible per NUREG 2214, it would not be screened out, and visual inspections would be used to monitor and take action as appropriate.

12. **[a] Given SCC is considered the most likely long-term degradation mechanism, are inspections targeted at high tensile stress regions (e.g. welds, etc.)? [b] Are there pre-defined inspection checklists and acceptance criteria for targeted locations that may be more susceptible to SCC? [c] Are there any plans to baseline, test on a periodic basis, and trend the halide concentration within the MPC environment?**

    a. ***Given SCC is considered the most likely long-term degradation mechanism, are inspections targeted at high tensile stress regions (e.g. welds, etc.)?***

Inspections will be undertaken broadly, covering more than 95% of the canister vertical surfaces and include, but are not limited to, specific regions such as the welds.

As discussed in Section II.F at pages 9-10 of the March 31 Draft IMP, SCE has gone above and beyond NRC requirements for the design and fabrication of the Holtec UMAX system. In response to feedback from the SONGS Community Engagement Panel and members of the public, SCE has made a number of improvements to the SONGS MPCs which make them especially robust, more readily inspectable and further reduces the risk of SCC.

The current inspection capabilities SCE can employ via remote robotics can observe greater than 95% of the canister vertical surfaces where SCC would be most likely to occur. The weld areas were clearly visible and could be inspected to a visual acuity to observe SCC if it were present. However, the inspection process evaluates the entire visible surface of the MPC to the same visual acuity level as mentioned above, so that any indications of degradation (no matter the reason) can be discovered and assessed as necessary to ensure the canisters remain acceptable for both on-site storage and off-site transport.

b. Are there pre-defined inspection checklists and acceptance criteria for targeted locations that may be more susceptible to SCC?

See SCE's responses to questions 9, 11 and 12.a, above. Inspections and criteria that trigger remediation are applied to the MPCs as a whole and include, but are not limited to, those specific regions which may be more susceptible to SCC.

c. Are there any plans to baseline, test on a periodic basis, and trend the halide concentration within the MPC environment?

Yes, baseline activities for the SONGS MPCs have been performed in two ways. First, high-resolution photographs of the entire surface of each MPC including the test canister (a total of 68 photos per MPC) were taken prior to canister loading at SONGS. These are available to compare to any future inspection results.

Second, SCE robotically inspected eight loaded MPCs in 2019. Video and photographic records were taken and entered into the SONGS system to allow any future inspections to be compared to these previous inspection results.

Two MPCs chosen to be inspected in each inspection period will be based on an evaluation, prior to the inspection, of the canisters' relative susceptibility to degradation. At the outset, SCE will identify one MPC that is determined to be bounding based on its relatively higher susceptibility to degradation, and that same MPC will be one of the two canisters inspected every five years. The second canister will be selected per the EPRI criteria.

The test canister will be inspected via the same methods approximately every 2.5 years, and inspection results will be compared to previous results to evaluate for long term degradation.

With respect to halide concentration, SCE does not test for halide concentration because SONGS is a seaside environment, and a high halide concentration is therefore a base assumption.

13. **[a] How will the inspection for ISFSI structure settlement be performed? Laser scanning, etc.? [b] What is the acceptance criteria to affect MPC extraction?**

a. How will the inspection for ISFSI structure settlement be performed? Laser scanning, etc.?

The initial baseline survey will be performed after fuel transfer operations to the ISFSI are complete. The survey work will be performed by a licensed professional approved land surveyor. They will use standard survey methods accepted by the profession. The work will be performed under the SCE Quality Assurance (QA) program.

Subsequent periodic surveys of the ISFSI for settlement will be conducted every five (5) years. Advances in the methods and techniques will always be considered.

b. What is the acceptance criteria to affect MPC extraction?

Allowable settlement has been established at 0.2 inches. However, settlement of 0.2 inches will not adversely impact MPC extraction even if applied at only one corner or one side of the ISFSI structure resulting in differential settlement. Differential settlement of 0.2 inches applied at one corner or side of the ISFSI would result in negligible tilt, not greater than 0.02 degrees.

14. **Consider using automated photograph comparison technology such as Change Detection System (CDS) developed by DOE/INL. LPI is a commercialization partner/service provider of the CDS technology for the nuclear industry.**

    Thank you for the information.

15. **Need to clarify the following sentence: "The SONGS inspections were informed by previous inspections carried out by EPRI's Extended Storage Collaboration Program, which is discussed in more detail in section B.2 below." Should "...previous inspections" read "...previous inspectors"?**

    "Inspections" is correct. For clarity, the words "informed by" should be changed to "based in part on." SCE will incorporate this edit into the final IMP.

16. **Regarding ".... SCE will conservatively begin inspecting canisters much sooner," reference to Table 1 should be included in this statement.**

    SCE will incorporate this edit into the final IMP.

17. **Table 1 is referenced here, is this the same Table 1 mentioned in the Executive Summary?**

    SCE will incorporate this edit into the final IMP.

18. **How will the canisters' relative susceptibility to degradation be determined for selection of the bounding MPC?**

    SCE will perform the susceptibility assessment described in EPRI report 3002005371, *Susceptibility Assessment Criteria for CISCC of Welded Stainless Steel Canisters for Dry Cask Storage Systems*, 2015, available at https://www.epri.com/#/pages/product/000000003002005371/?lang=en-US.

19. **Is the "...miniaturized mitigation system..." mentioned here referring to the overlay system? If so, suggest rewording to be consistent elsewhere.**

    Yes, miniaturized mitigation system refers to the metallic overlay system. SCE will incorporate this edit into the final IMP.

20. **What is the basis of the 180-day reporting requirement from inspection completion?**

    180 days was selected as a reasonable timeframe for completing the periodic report. In addition to this report, SCE will notify the Coastal Commission promptly if anything significant is found.

21. **[a] What analysis and trending data is expected? [b] What would be the acceptance criteria of that data?**

    a. ***What analysis and trending data is expected?***

    During each canister visual inspection, detailed photographs and videos are recorded to allow long term comparison of canister conditions and to allow analysis (as needed) and predictions of future degradation based on past history. In this case, the test canister is particularly important, since several data points over the 20-year period of the IMP will be obtained and should provide a detailed evaluation of canister conditions over the long-term.

b. What would be the acceptance criteria of that data?

Should canister inspections discover degradation which requires further analysis (consistent with the guidance in the ASME Draft Code Case N-860), additional data including visual characterization data (which can evaluate the size and depth of the degradation to an accuracy of 0.001") will be taken and analyzed.

All of the inspection data will be entered into the SONGS inspection database for initial evaluation, and will also allow for long term analysis.

The acceptance criteria (failure of which would require mitigation) are stated in IMP Section III.B, Response and Mitigation.

22. **[a] What is the expected degradation rate considering industry OE (i.e. a slow-developing and well understood phenomenon that is not expected to occur within the first couple decades of the life of a canister)? [b] Does more frequent inspection have the potential to accelerate (by exposure) industry established degradation rates?**

a. What is the expected degradation rate considering industry?

The degradation rates used by SCE for SCC cracking are provided in NUREG 2214 (Managing Aging Processes in Storage (MAPS) Report). Note that, under conservative conditions, crack growth rates of 3.6 mils/yr to 26.1 mils/yr could occur at weld regions. No data is available that would indicate that through wall cracking could occur in the first 20 years of operation.

b. Does more frequent inspection have the potential to accelerate (by exposure) industry established degradation rates?

While possible, SCE considers it unlikely that increased inspection frequencies would accelerate industry established degradation rates for SCC cracking.

Many canister inspections have been performed robotically as part of Aging Management Programs – not including the SCE's work, there more than 10 additional ISFSI site inspections. No significant degradation requiring more extensive inspections has been discovered during these industry inspections.

The SONGS inspections that will be performed within the IMP are unique to the nuclear industry, since they will be performed during the initial 20 year license period for the Holtec ISFSI. While unlikely, it is always possible that a previously unknown degradation mechanism could be discovered during the IMP inspections. If this were to happen, the degradation would be measured and evaluated using the criteria mentioned in the IMP, and the results would also be communicated to the nuclear industry for information and evaluation as appropriate.

Exhibit Questions

1. **Provide details of the statistical evaluation that was performed, as it provides the technical basis for maximum depth projections, 95 percent confidence levels/probability, as well as the number of MPCs that were inspected (why are 8 MPCs adequate…out of how many?).**

   See response to question 5 above.

2. **Would be helpful to provide the test canister on the map.**

   SCE will incorporate this edit into the final IMP.

3. **How is SCC distinguished from other corrosion mechanisms? Are there plans to test for halide concentration?**

   See response to questions 11 and 12(c) above.

Exhibit A - May 2019 MPR Report

MPR

0299-0042-MEMO-024
Revision 0

Canister Installation and Removal Effects on Wall Thickness

Prepared for: San Onofre 2 & 3

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QA Statement of Compliance

This document has been prepared, reviewed, and approved in accordance with the Quality Assurance requirements of the MPR Standard Quality Program.

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MPR

May 2, 2019

Canister Installation and Removal Effects on Wall Thickness

1.0 Purpose

Determine the bounding depth at the 95/95 confidence level of a double scratch on the MPC wall resulting from insertion and then withdrawal.

2.0 Background

On August 3, 2018, a SONGS multi-purpose canister (MPC) came to rest on the Vertical Ventilated Module (VVM) shield ring as it was being lowered into the UMAX canister storage cavity. This event raised concern that the canisters could have been scratched or gouged during downloading operations. A total of 29 canisters have been loaded to date. During March and April 2019, eight canisters were inspected using a robot and specialized camera equipment capable of measuring surface defects greater than 0.001 inch. The inspections revealed rub marks and scratches with measurable depths on seven of eight canisters. Several rub marks due to contact between the shield ring and canister were observed up to 0.012 inches deep. Several long scratches due to contact between an inner seismic restraint and the canister were observed with a maximum local depth of 0.026 inches on one canister.

3.0 Approach

The deepest scratch resulting from insertion and then withdrawal is assumed to result from two scratches occurring in the same location (axial and circumferential) during both an insertion and a subsequent withdrawal. The depth of the scratch resulting from contact between the MPC wall and a VVM component is treated as a random variable with the characteristics determined by the results from inspecting eight loaded canisters. The 95/95 confidence level was selected as the standard for reasonable confidence. To estimate the depth of the deepest "double scratch" at a 95/95 confidence level, the probability that a single scratch of a given depth occurring twice in the same spot will be determined. The depth of the scratch will be selected to achieve the 95/95 confidence level for the combined double scratch based on the eight canister sampling statistics.

4.0 Analysis Inputs and Assumptions

4.1. Random Variable

The depth of the deepest scratch on each canister resulting from insertion is assumed to be a normally distributed random variable with an estimated mean (0.0111 inches) and standard deviation (0.0075 inches) determined by the deepest scratch measurements performed on eight loaded canisters after insertion shown in Table 4.1. The basis for this assumption as well as the statistical evaluation are provided in Reference 1. The canister inspection results include the depth of any manufacturing anomalies on the surface that coincide with a scratched contact area as well as any instances where multiple overlapping scratches occurred on the same wall location due to multiple VVM components making contact during one insertion cycle.

4.2. Scratch Locations

Scratches caused by contact during withdrawal are assumed to occur in exactly the same spot as the deepest scratch resulting from insertion. This introduces significant conservatism as described in paragraph 5.2 below. Based on the visual inspection results, the size (length and width) of the deepest scratch created on each canister during insertion is very small compared with the area that could be scratched during withdrawal.

The depth of the scratches observed after insertion are shown in Table 4.1 below (Reference 3).

Table 4-1. Measured Scratch Size and Depth

Canister No.	Maximum Scratch Depth (in.)
64	0.012
67	0
72	0.026
94	0.012
55	0.012
65	0.011
68	0.004
61	0.012

Estimated maximum scratch mean depth = 0.0111 inches

Estimated standard deviation for depth = 0.0075 inches

5.0 Calculation

5.1. Assumption: Scratch Depth

The depth of the scratch resulting from contact between the MPC wall and a VVM component is treated as a random variable with the characteristics determined by the results from inspecting eight loaded canisters.

From Reference 1, the estimated depth of the deepest scratch and the probability/confidence intervals for scratches during canister insertion are summarized in Table 5-1.

Table 5-1. Summary Statistics for Deepest Scratch on Canisters

	Bounding Scratch Depth (in.)		
Sample Size	**90 / 90**	**95 / 95**	**99 / 99**
8	0.028	0.035	0.055

From Reference 2, based on a sample size of 8, the 95/95 confidence level is reached at 3.188 standard deviations from the mean.

Table 5-2. Tolerance Interval Coefficients (from Reference 2)

	Tolerance Interval Coefficient (*K*)*		
Sample Size	**90 / 90**	**95 / 95**	**99 / 99**
8	2.219	3.188	5.811

Based on Student T distribution, a t score value of 3.188 has a single tailed probability of 0.0077

5.2. Conservative Assumption 1: The same area will scratch during insertion and withdrawal.

1. The number of scratches was few and varied from one canister to the next.
2. There were no predominant locations for scratches around the circumference. There were 8 inner seismic restraints and 8 areas between them. Different segments would show wear marks on insertions of different canisters.
3. Sometimes, very few and in one instance no scratches occurred on a given canister.
4. Withdrawal of a canister that had been landed is not likely to "cock" and center the same on withdrawal due to different rigging and crews and different angles on withdrawal compared to insertion.
5. Despite the likely improbability of a scratch occurring at the same axial and circumferential location in a sequence of insertion and withdrawal, the probability that this will happen will be assumed to be 1.0. This is very conservative.

5.3. Conservative Assumption 2: Withdrawal scratches will be as deep as insertion scratches

While the same randomness exists for the scratches that might occur from the withdrawal of the MPC from the CEC, it is very likely that the depth of the scratches on withdrawal will be much less severe on average compared to insertion. The principal reasons for this are:

1. Insertions are done into a blind hole with the tightest clearances unseen at the bottom of a 200" long canister. The likelihood of rubbing against the shield ring and supports and the inner seismic restraints at some angle are very likely.
2. During withdrawal MPC starts already tightly aligned and level inside the CEC so that the very tight tolerances of the inner seismic restraints just 10-inches below the bottom of the shield ring will provide an excellent alignment to raise the top of the MPC through the shield ring.

3. The alignment of the top of the MPC as it is withdrawn is visible as to its being centered in the shield ring.

5.4. *Double Scratch Depth*

Let P_1 be the probability that a scratch of depth greater than d_1 occurs during insertion

d_1 is depth of deepest scratch during insertion

P_2 is probability that a scratch of depth greater than d_2 occurs during withdrawal

d_2 is depth of deepest scratch during withdrawal

P_3 is the probability that a combined scratch greater than d_1+d_2 occurs on canister after insertion and withdrawal

d_3 is depth of combined scratch due to insertion and withdrawal

The probability of the combined insertion and withdrawal scratch events $P_3 = P_1*P_2$

For conservatism, the probability that two scratches will occur in the exact same location is assumed to be 1.0. While this is very conservative as noted in paragraph 5.2, the statistics of hitting the same location is complex and will not be necessary if the resulting double scratch depth is acceptable. The occurrence of a scratch on insertion is considered independent of a scratch occurring on withdrawal for the reasons stated in paragraph 5.3.

The probability that two independent scratches occur would be equal to P_1*P_2. It was previously shown that a worst case scratch will be lower than a bounding limit of 0.035 inches with a probability of 95% with a confidence level of 95% (Reference 1). This was based on a tolerance interval coefficient of 3.188 (Table 5.2) multiplied times the standard deviation and added to the sample mean value. Using this coefficient and a Student T distribution, reveals the probability that a worst case scratch could be larger than 0.035 inches would be 0.0077. To maintain the 95/95 confidence level for the combination of two scratches, based on a sample of 8 canisters and the use of the Reference 2 methodology, the probability of the combined scratches being exceeded will also match the 0.0077 probability.

The probability of two scratches occurring would be $P_3 = P_1 * P_2$, or $P_3 = P_1^2$ with $P1 = P2$ for the same size scratch. For $P3 \leq 0.0077$, P1 would have to be $(0.0077)^{0.5}$. Scratches that are deeper than this will occur less frequently and when the probabilities for two of these deeper scratches are combined they will exceed the 95/95 confidence interval. Therefore, the probability for the deepest scratch that can occur at insertion while still maintaining the 95/95 confidence interval is $P_1 = (0.0077)^{0.5} = 0.08775$. This anticipates that a similar 0.08775 probability for scratching will exist during withdrawal.

Based on Table A-7 from Reference 2, a probability of 0.08775 is associated with a tolerance interval coefficient of 2.4128 standard deviations. The estimated standard deviation based on the sample of 8 canisters was 0.0075 inches and the estimated mean was 0.0111 inches (Table 4.1).

Based on the above, the probability of an insertion scratch with a depth greater than (0.0111) + 2.4128*(.0075) or d_3 = 0.0292 inches is 0.08775.

When two of these scratches occur at the same location, the deepest double scratch that can occur at the 95/95 confidence level (P_1*P_2 or 0.0077) will be less than (2*0.0292) or d_3=0.0584 inches deep.

6.0 Conclusion

The deepest total scratch depth at one location resulting from insertion followed by withdrawal at the 95/95 confidence level is 0.0584 inches. This results from very conservatively assuming two worst case scratches would occur at the exact same location axially and circumferentially during both an insertion and a withdrawal and that the withdrawal scratches would be as deep as the insertion scratches.

7.0 References

1. "Canister Inspection Plan", MPR 0299-0057-MEMO-001 Rev 1, April 15, 2019.

2. Natrella, M. G. (1963). Experimental Statistics. In M. G. Natrella, *National Bureau of Standards Handbook 91* (pp. 2-13-2-15, T14-T15). Washington DC: US Government Printing Office.

3. " San Onofre Nuclear Generating Station Downloading Effects on HI-STORM MPC Visual Assessment Report", SCE, April, 15, 2019

APPENDIX C. SCE COMMENT RESPONSES 04/22/2020

SCE Responses to LPI April 22 Questions

Follow-up questions re SCE's Response No. 5.a (statistical analysis):

1) Need to identify the specific ASME Code allowable depth value.

SCE Response:

Holtec's past commentary on this topic is in blue below. In short, based on ASME Code section XI, scratches as deep as 0.175 inches would satisfy minimum wall thickness requirements for in-service conditions on the SONGS MPCs without doing further analysis.

> The design basis for the CoC for the Holtec HI-STORM UMAX multipurpose canister is 0.500 inches. The size of an allowable local wall thinning due to wear scar, scratch or gouge would be covered by limits for wall thinning as discussed in IWB-3514 of the ASME Code Section XI. Table IWB-3514-1 provides an allowable surface flaw size equal to 10% of the vessel thickness for preservice and in-service inspections. IWB-3514 is also referenced in NUREG-1927 (Renewal of Spent Fuel Dry Cask Storage System Licensing and CoC) and NUREG-2214 (Managing Aging Processes in Storage Report) [Reference 4], for canister aging management plan inspections. Table IWB-3514-1 also comports with ASME Section III, Subsection NB if another 0.050 inches is locally removed per NB-3213.10, which specifies a local primary membrane stress limit of 1.1Sm (or 10% higher than the general primary membrane stress limit). By this measure, a scratch up to 0.050 inches or a depth of 0.450 inches would be acceptable in the wall of a nominal 0.500-inch design basis canister.
>
> Because SONGS ordered the canisters with a 25% thicker wall than the base thickness to permit an extra allowance for potential abrasion and (as allowed by ASME: Section III Division 1 - NB-3121), the thicker nominal wall of 0.625 inches would permit a scratch or gouge that was up to 0.125 inches to be acceptable just to reach the original CoC nominal wall thickness. That together with the 0.050 inch flaw permitted for the base wall thickness (10% of the CoC nominal wall) would indicate that 0.175 inches of scratch or gouge would be allowable.

Note that ASME Code section III, which relates to components during manufacture, discusses a 10% allowance with respect to the original specified design thickness. In this case, that would provide an allowance of 0.0625 (10% of the 0.625 original specified design thickness). While the NRC has cited ASME Code section III on this topic in the past, SCE believes Section XI (0.175) is more appropriate for the reasons discussed by Holtec above.

2) What is the probability of exceeding the ASME allowable depth for at least one canister? And for all 73 canisters?

SCE Response:

The probability of a scratch deep enough to breech the ASME Code minimum wall thickness of 0.175 inches (or the even smaller depth of 0.0625 inches) for even one canister is vanishingly small (~zero). Specifically,

i) based on the inspections performed, the probability of a single scratch exceeding a depth of 0.035 inches is estimated to be 0.7% (3.188 standard deviations, 95/95 confidence level). The probability of a scratch with a depth of 0.0625 inches is estimated to be 1E-4 (6.866 standard deviations). The probability of all 73 canisters having a scratch deeper than 0.0625 inches would be on the order of $(1E\text{-}4)^{73}$, and
ii) a deterministic elastic-plastic ANSYS finite element analysis indicated that scratch depth is limited to less than 0.030 inches for the SONGS MPCs since the canister wall begins to dent, which limits contact forces.

3) Why was a normal distribution assumed? Based on the mean and standard deviation values, ~8% percent of the cumulative distribution represent negative depths?

SCE Response

A normal distribution was selected based primarily on the inspection results (distribution of the measured deepest scratch data). Selecting a normal distribution rather that a lognormal distribution for example also makes more physical sense in that the individual parameters that combine to create the distribution of scratch depths are more likely additive. Selecting a lognormal distribution implies that the underlying variable parameters are multiplicative rather than additive. Examples of likely variable parameters affecting scratch depth are listed below:

a) Material properties, particularly the yield and tensile strengths of the canister wall and VVM component materials.

b) Variations in canister shell and VVM component geometry (shell diameter, roundness, seismic support and shield ring protrusion).

c) Centering and levelness of the canister as it pass through the shield ring.

d) Vertical alignment of the VCT on the pad and the VVM components.

e) Which crew performed the download.

f) Specific canister rotational orientation as it passes through the shield ring.

g) Environmental conditions like wind, temperature and light.

As described in the attached April 15, 2019 MPR white paper, *Canister Inspection Plan*, the concern that assuming a normal distribution would be non-conservative since a normal distribution would allow negative scratch depths, was previously addressed by performing a sensitivity analysis that showed the effect of the slight non-conservatism introduced by the negative values in the left tail of the normal distribution did not have a significant effect on the maximum scratch depth statistics.

Follow-up question re SCE's Response No. 9 (flaw acceptance criteria):

1) Need to specify the value of "the maximum allowable degradation depth" and the specific ASME Code section reference.

ASME Draft Code Case N-860 is currently the first and only ASME guidance concerning degradation and repair of welded stainless steel fuel canisters. Draft Code Case N-860 does not currently address weld repair of a canister.

SCE, by developing a mitigation method, is several years ahead of the industry. There are no other methods currently available to mitigate a canister. In SCE's case, the mitigation would be treated as a "patch" to seal any degraded area. No structural credit (as in a repair) would be taken for the mitigation that SCE would perform, as there is currently no ASME Code guidance.

It is expected that either a future revision to Draft Code Case N-860 or a new code case will consider the repair of canisters, and provide appropriate guidance.

Currently, if a degraded area was discovered during SCE's planned inspections, SCE would determine whether it was less than 0.175 in. If it was greater than 0.175 in., SCE would need to perform analyses to ensure that the degraded area would not have the potential to exceed any code limitations based on projected degradation through the next inspection.

MPR

April 15, 2019

Canister Inspection Plan

1.0 Purpose

Evaluate the wear mark inspection results from a sample of eight SONGS canisters and provide a statistical assessment of the potential for wear mark depths in the remaining canisters.

2.0 Background

On Aug. 3, 2018, a SONGS multi-purpose canister (MPC) came to rest on the Vertical Ventilated Module (VVM) shield ring as it was being lowered into the UMAX canister storage cavity. This event raised concern that the canisters could have been scratched or gouged during downloading operations. A total of 29 canisters have been loaded to date. During March and April 2019, eight canisters were inspected using a robot and specialized camera equipment capable of measuring surface defects greater than .001 inch. The inspections revealed rub marks and scratches with measurable depth on seven of eight canisters. Several rub marks due to contact between the shield ring and canister up to 0.012 inches deep were observed. Several long scratches due to contact between an inner seismic support an a canister were observed with a maximum depth of 0.026 inches. The observed scratches were deeper than expected.

3.0 Approach

The approach to providing a statistical assessment of the potential for maximum scratch depths in the remaining canisters involves defining the depth of the deepest scratch in each canister as a random variable, estimating the mean and standard deviation of the population by sampling and then determining an upper bound scratch depth for the remaining canisters.

4.0 Analysis Inputs and Assumptions

4.1. Random Variable

The parameter of interest for developing the sampling plan is the depth of the deepest scratch expected on each canister. In order to evaluate the inspection data, the known physical characteristics of the downloading operation need to be considered. The depth of the deepest scratch on each canister is defined as the random variable of interest since most of the variable parameters that can potentially affect scratching are associated with individual canister downloading operations. Random variables that follow a normal distribution are typically associated with processes that are influenced by a large number of independent parameters. Therefore a normally distributed random variable is a good choice for the deepest scratch on each downloaded SONGS canister since the following parameters can likely affect the depth of the deepest scratch.

1. Material properties, particularly the yield and tensile strengths of the canister wall and VVM component materials.
2. Variations in canister shell and VVM component geometry (shell diameter, roundness, seismic support and shield ring protrusion).

3. Centering and levelness of the canister as it pass through the shield ring.
4. Vertical alignment of the VCT on the pad and the VVM components.
5. Which crew performed the download.
6. Specific canister rotational orientation as it passes through the shield ring.
7. Environmental conditions like wind, temperature and light.

One concern with selecting a normal distribution for modeling the deepest scratch random variable is that measured scratch depth is always a positive number and the left tail of the normal distribution will include some negative numbers making the probabilities associated with a standard normal distribution non-conservative. To determine whether use of a standard normal distribution is acceptable considering the effect of the negative left tail values, a simulation was run using 1500 trials to produce a modified normal distribution that forces all scratch depth measurements to be positive numbers. In the simulation, every time a negative value for scratch depth occurs, the simulation selected another normally distributed random number to replace the negative value until a positive value appeared. The results of simulations for the standard normal distribution and the modified normal distribution for the mean scratch depth (13 mils) and standard deviation (12.5 mils) associated with the three measured canisters are compared below.

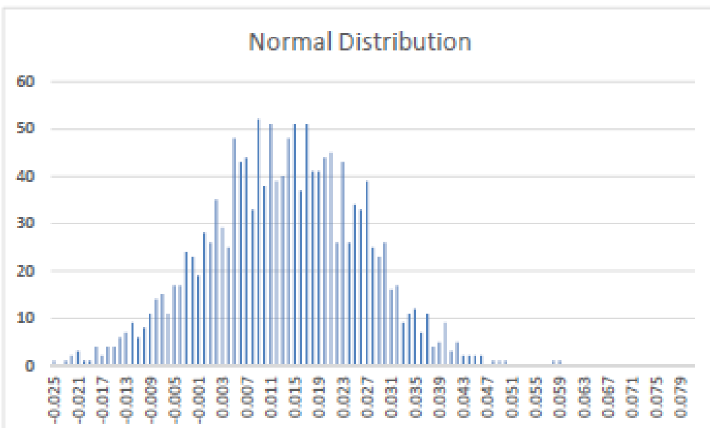


Figure 4-1.

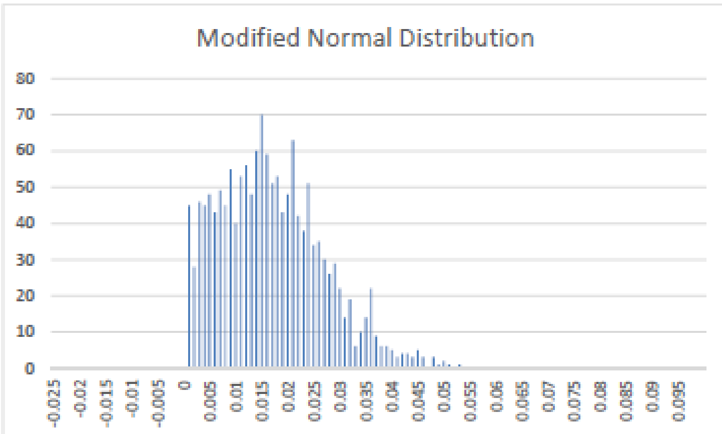


Figure 4-2.

Upper confidence intervals for the population mean can be calculated when the variance is not known and the sample size is relatively small (typically less than 30) using the Student t distribution as follows:

$$UCI = \mathrm{M} + \mathrm{t}\sqrt{\frac{S^2}{n}}$$

Where:

M is measured mean
t is t distribution statistic associated with the selected confidence level
S is measured standard deviation
n is sample size

Comparing the upper confidence intervals of the standard normal and modified normal distributions for the simulations shows very little difference in the confidence intervals for the means in the region of interest (above a 90% confidence level) as shown in Table 1.

Table 1. Upper Confidence Interval for Simulated Scratch Depth Distributions

Distribution	90% Upper Confidence Interval	95% Upper Confidence Interval	99% Upper Confidence Interval
Standard Normal	0.029	0.035	0.044
Modified Normal	0.030	0.036	0.046

Since these differences are small, a standard normal distribution is judged to be adequate to model the deepest scratch random variable.

3

5.0 Calculation

5.1. Eight Canister Inspection

The deepest scratches measured on eight canisters are shown in Table 2 below.

Table 2. Deepest Scratch on Each Canister

Canister No.	Maximum Value (in.)
64	0.012
67	0
72	0.026
94	0.012
55	0.012
65	0.011
68	0.004
61	0.012

5.2. Confidence Interval Coefficients

The confidence limits determined in Section 4.1 are limits within which we expect a given population parameter, such as the mean, to lie. Statistical tolerance limits are limits within which we expect a stated proportion of the population of scratch depths to lie. Therefore, the appropriate statistic to use for assessing the likelihood of having an unacceptable scratch depth in one of the canisters is a tolerance interval. One sided tolerance intervals for a normally distributed random variable were calculated using the method described in Reference 1 (Natrella, 1963). Table 3 summarizes the tolerance interval coefficient (K) for a sample of eight canisters selected from an infinite population as described in Reference 1.

Table 3. Tolerance Interval Coefficients (from Reference 1)

	Tolerance Interval Coefficient (K)*		
Sample Size	**90 / 90**	**95 / 95**	**99 / 99**
8	2.219	3.188	5.811

* The column headings indicate the probability and confidence level for the upper tolerance interval.

The equation to calculate a one-sided confidence interval is as follows:

$$UTL = \bar{X} + K \cdot S_e$$

Where,

UTL = Upper Tolerance Limit
$\bar{X}$ = Mean scratch depth from sample inspection, in.
K = Tolerance interval coefficient (from Reference 1)
S_e = Standard deviation of scratch depths from sample inspection, in.

Table 4 summarizes the deepest scratch depth estimates based on the upper tolerance limit for a sample size of 8 scratch depth measurements. The mean (.0111 inches) and standard deviation (.0075 inches) were obtained from the data given in Table 2.

Table 4. Summary Statistics for Deepest Scratch on Unmeasured Canisters

Sample Size	Bounding Scratch Depth (in.)		
	90 / 90	95 / 95	99 / 99
8	0.028	0.035	0.055

* The column headings indicate the probability and confidence level for the upper tolerance interval.

6.0 Conclusion

Using the reasonable assumption that the deepest scratch on each canister can be treated as a normally distributed random variable, the eight canister measurements performed at SONGS are sufficient to support a conclusion that there is 95% probability with 95% confidence that each of the remaining canisters will not have a scratch deeper than 0.035 inches.

7.0 Reference

1. Natrella, M. G. (1963). Experimental Statistics. In M. G. Natrella, *National Bureau of Standards Handbook 91* (pp. 2-13-2-15, T14-T15). Washington DC: US Government Printing Office.

APPENDIX D. SCE COMMENT RESPONSES 05/06/2020

SCE Responses to LPI's May 6 Questions

1) SCE's response to LPI Question #5a (see 041620 SCE Responses to LPI IMP Questions.pdf) indicates that EPRI Report No. 3002005371 recommends the inspection of two canisters every 5 years. However, this recommendation was not found within this EPRI report; please identify section and/or page number.

SCE Response:

In the IMP, SCE has proposed inspecting at the same number and frequency as it would under an aging management program (AMP). SCE relied on EPRI Report No. 3002005371 to perform a site assessment for the SONGS site. From this assessment, SCE relied on guidance from sources including NUREG 2214, ASME Draft Code Case N-860 and other ISFSIs' NRC-approved license renewals to develop a plan to inspect two MPCs every five years based on the SONGS ISFSI location.[1] Following this approach is very conservative on SCE's part because an AMP begins at the start of the *extended license period* (i.e., when the canisters have been in service for approximately 20 years) and the SONGS MPCs have been in service a much shorter time.

2) SCE's responses to LPI Questions 6a and 7 (see 041620 SCE Responses to LPI IMP Questions.pdf) suggest that higher susceptibility to SCC occurs at cooler temperatures. However, this response contradicts observations in the literature and discussion in the EPRI Report 3002005371 (see Section 2.4). Generally, higher temperatures increase susceptibility to SCC and increase crack growth rates.

SCE Response:

While it is true that in general higher temperatures increase growth rates of stress corrosion cracking (SCC) and increase crack growth rates, it is important to take into account the need/impact of deliquescence in the potential propagation of SCC. The impact of deliquescence is discussed in EPRI Report 3002005371's conclusions (pages 6-7) and in Appendix A to the report. By keeping the temperature above the threshold to prevent the onset of deliquescence, the conditions needed for onset of SCC cannot exist and the susceptibility is essentially zero.

---

[1] Based on the environment at the SONGS site, guidance in ASME Draft Code Case N-860 indicates that the recommended inspection frequency for an AMP during the extended license period would be to initially inspect two canisters every 10 years, and then modify the inspection number and frequency based on the inspection results.

The typical industry practice for inspecting an ISFSI under an AMP has been to perform canister inspections every five years. SCE's IMP follows the industry AMP practice of performing inspections every five years, and the Draft N-860 Code Case recommendation to initially inspect two canisters. Please also note that the test canister, which is a leading indicator of future degradation, will be visually inspected twice each five year period.

In addition, EPRI Report 3002008193, *Aging Management Guidance to Address Potential Chloride-Induced Stress Corrosion Cracking of Welded Stainless Steel Canisters*, section 2.2.1.3, provides further guidance. This section is provided below:

> **2.2.1.3 Effect of Environment on CISCC Susceptibility**
>
> For atmospheric CISCC, the three main environmental factors are: (1) presence of concentrated chlorides, (2) temperature, and (3) aqueous conditions. Locally concentrated chlorides break the protective oxide layer at the surface of the stainless steel, and aqueous conditions permit the electrochemical reaction of corrosion to occur. Elevated temperatures improve the kinetics of the electrochemical reactions, increasing the rate at which corrosion can occur.
>
> The most applicable chloride source for canisters is the deposition of chloride aerosols from marine or manmade (e.g., road salt) sources. The susceptibility assessment criteria for ISFSI locations (*ZISFSI* rank) [10] are designed to capture the effect of the most common sources of chloride aerosols. The *ZISFSI* rank is also designed to capture the likelihood that aqueous conditions are present on the canister surface. The overpack geometry shelters canisters from rain and other external sources of water, so the hygroscopic absorption by salts of water vapor from air (deliquescence) is expected to be the source of sustained aqueous conditions. Deliquescence is controlled by the relative humidity at the surface and the salt mixtures present on the canister surface. The relative humidity at the canister surface is, in turn, set by the canister surface temperature and the atmospheric absolute humidity (AH). <u>While higher surface temperatures accelerate the mechanism of CISCC, they also reduce the relative humidity at the surface so that conditions sufficient to cause deliquescence occur less frequently</u>. Additional discussion of the interplay between deliquescence and CISCC growth is found in the EPRI Flaw Growth and Flaw Tolerance Assessment report [9].[2]

Since deliquescence is necessary for SCC crack propagation, and the currently-loaded MPC surface temperatures are hotter than the temperature at which deliquescence would typically occur, the first canisters that could propagate an SCC crack are the canisters which currently are the coolest, and will decay into the deliquescence temperature range first. Thus, the statement made in the response to previous questions is correct for the IMP.

If temperature is kept high enough, deliquescence cannot occur, and probability of SCC approaches zero. Some references on this topic are below:

From NUREG-2214:

> In a sheltered environment, deliquescence of airborne salts below the dew point also could generate an aqueous electrolyte initiating general corrosion. These salts

[2] The document cited as EPRI's Flaw Growth and Flaw Tolerance Assessment Report [9], *Flaw Growth and Flaw Tolerance Assessment for Dry Cask Storage Canisters* (EPRI 2014), states the following in its Conclusions, section 5.1: "Flaw propagation is only expected to occur at positions on the canister which meet all of the following conditions: (1) a substantial accumulation of chlorides is present, and (2) <u>the surface temperature is cool enough to experience deliquescence for a meaningful fraction of the year (typically, less than 30°C above ambient)</u>, and (3) sufficient through-wall tensile stress is present; i.e., located within about four wall thicknesses of a weld."

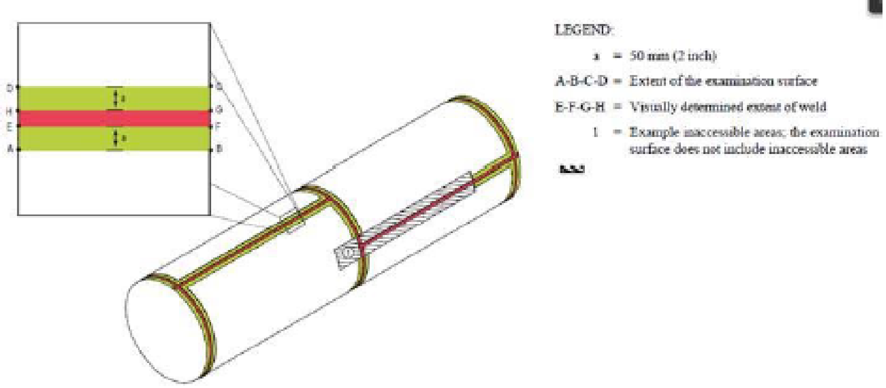
may be chloride rich and originate from marine environments, deicing salts, and condensed water from cooling towers, as well as a range of other nonchloride-rich species originating from industrial, agricultural, and commercial activities. Studies have shown that $MgCl_2$, a component of sea salt with a low deliquescence relative humidity, would deliquesce below 52 degrees C [126 degrees F] under realistic absolute humidities in nature (He et al., 2014). The heat generated by the radioactive decay of spent fuel decreases over time. Time-temperature profiles calculated for the stainless steel canister shell suggest that, while initial temperatures are high, the threshold temperature for deliquescence of some salts on the external surface of the shell could be reached during the 60-year timeframe (EPRI, 2006; Meyer et al., 2013).

From Table 6-2 of NUREG-2214:

Sample Size. For sites conducting a canister examination, there should be a minimum of one canister examined at each site. Preference should be given to the canisters with the greatest susceptibility for localized corrosion or SCC. Factors to be considered include older and colder canisters with the greatest potential for the accumulation and deliquescence of deposited salts that may promote localized corrosion and SCC, types of systems used at the site, canister location with respect to potential sources of atmospheric deposits, system design, and operational experience. Industry guidance on evaluating susceptibility has been published by the EPRI (Fuhr et al., 2015).

See Figure 4-4 of EPRI Report 3002008193:

Inspection Program Guidance (Detection of Aging Effects)



GENERAL NOTES:

(1) A general visual assessment (Exam 1-b examination) may be performed instead of VT-3 in areas of the shell which are not susceptible to deliquescence.

Figure 4-4
Examination Surface for Accessible Parts of Canister Shell

See Table 2-5 of EPRI Report 3002008193:

			as needed
Examination Coverage	Recommends focus on canister welds and HAZ, crevices, horizontal surfaces, cold surfaces; specific examination coverage not provided	Use surface temperature measurements to exclude areas not subject to deliquescence	General visual examination of accessible surfaces; VT-3 examination in vicinity of welds only

3) Please provide the estimated maximum temperature of the MPCs, and the maximum chloride concentration (ppm) and maximum humidity in the air that will cool the MPCs.

SCE Response:

i. Maximum temperature on the MPCs is approximately 225F (from temperature data collected during MPC inspections performed in March and April of 2019).
ii. Highest humidity for the SONGS site, for a typical year, is shown on Table B-1 of EPRI Report 3002008193.
iii. SCE has not performed chloride aerosol concentration monitoring for the SONGS site. SCE assumes chloride aerosol concentration at the SONGS site is high enough to support initiation and propagation of SCC (the industry has not recognized a threshold chloride concentration for SCC initiation). SCE is not taking the position chloride aerosol concentration at the SONGS site will not lead to SCC.

The above notwithstanding, EPRI report 3002005371 provides chloride aerosol concentration for various monitoring stations—e.g., reference Tables B-1 and B-2. In addition, the contractor who prepared the EPRI report was contacted, and provided the data in the attached table for two monitoring sites on the California coast (chloride aerosol in units of µg/m^3). The data is provided in Table 1 below.

<u>Table 1 – Data for Response to LPI Question 3(iii)</u>

Code	Lat	Long	Elev	Name	State	Max	Median	Avg	Start	Stop	Points
REDW1	41.5608	-124.084	243	Redwood NP	CA	2.58	0.375	0.588	1/2/10	5/31/13	189
PORE1	38.1224	-122.909	97	Point Reyes Nat Seashore	CA	7.81	0.921	1.371	1/2/10	5/31/13	356

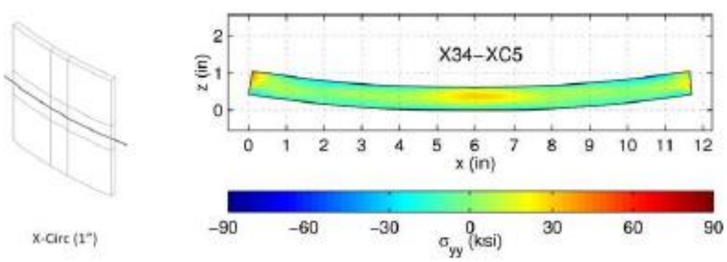
SCE Responses to LPI May 6 Questions

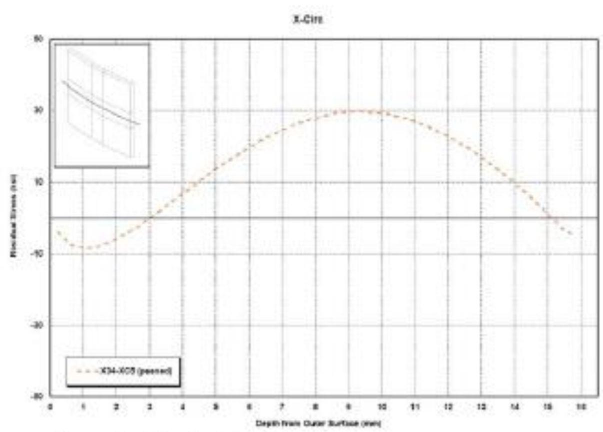
4) In the latest version of the file "Peening Coupon Test Results v2.pdf," the plots have been updated to show the x-axis as "Distance from Outer Surface;" however, it does not indicate where along the "Line" in the color contour plots the path from the Outer Surface was taken. That is, was the path taken through the weld centerline, the fusion line, HAZ into the base metal, etc.? Also, the global X-Y-Z directions should be indicated in the sketch on pg. 2, as well as with the contour plots.

SCE Response:

Values for residual stress for coupons are taken by performing an EDM cut through the weld centerline. The values for the plots are then taken from the center of the coupon contour profile. Coupon X34-XC5 will be used as an example. This coupon has an x-weld pattern which represents the longitudinal weld and circumferential weld at the middle of the canister. The EDM cut was performed along the weld centerline of the circumferential weld, shown as a bold line in the sketch to the left below. Data points used for the plot are taken starting from the outside surface of the coupon (Z of 0 in) and continue to the inside surface of the coupon (Z of 0.625 inches). Plots were converted to mm to demonstrate that the minimum required depth of compression referenced on the Table were achieved.

As for the request for stress profiles away from the centerline, SCE does not have that data. During the peening process development, SCE concluded that the centerline of the weld is the highest tensile stress and so stress profiles were only generated for that location.



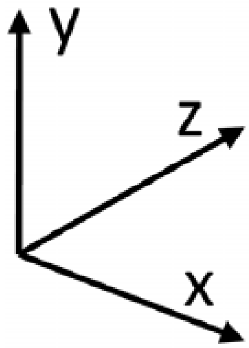


Notes: compressive residual stress has a negative value (-)
tensile residual stress has a positive value (+)

5

If more clarification is needed, we can arrange a phone call to walk through this item in more detail.

Regarding the second part of the question, Peening Coupon Test Results v3 includes the following figure to demonstrate the global X-Y-Z directions.



APPENDIX E. SCE COMMENT RESPONSES 05/18/2020

SCE Response to LPI May 15 Question

1) Please provide more information regarding the 2019 canister inspections, MPC scratch profiles, and number and location of scratches.

SCE Response:

Eight Holtec MPCs were inspected in March/April 2019 using a remote robotic vehicle and the GE Inspection Technologies borescope system.

As noted in SCE's April 16, 2020 response to LPI's Question #5(a) (seeking verification of the number of canisters inspected through the 2019 inspection):

> Eight MPCs were selected out of 29 total MPCs loaded at the time of the 2019 inspection. The decision to inspect eight of the 29 MPCs was based on a statistical analysis performed by MPR Associates, Inc. (MPR), in its May 2019 SONGS report, *Canister Installation and Removal Effects on Wall Thickness*, which is attached as Exhibit A. MPR's analysis looked at a population of marks on the canisters rather than at individual canisters and concluded that inspecting eight MPCs provided predictive results for all 73 MPCs that would eventually be loaded.
>
> Additionally, the NRC did an independent statistical analysis of the 2019 inspection as documented in its July 9, 2019 Supplemental Inspection Report, which is available at the following link: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19190A217.

The NRC's July 9, 2019 report explains that NRC inspectors "utilized the data obtained through the visual assessments to perform independent statistical assessments using several models that were appropriate for the sample size. The inspectors concluded, through the independent assessments, that the conclusion presented by SCE was conservative and reasonably bounded the maximum anticipated scratch or wear resulting from operational activities." July 9, 2019 Supplemental Inspection Report at p. 36.

The NRC also concluded that "[SCE]'s evaluation also demonstrated that American Society of Mechanical Engineers Section 111 code tolerances for wear were met and did not require a change to the storage system's technical specifications. <u>The NRC utilized the data obtained through the visual assessments to perform independent statistical assessments using several models that were appropriate for the sample size. The NRC concluded that the conclusion presented by the Southern California Edison Company was conservative and reasonably bounded the maximum anticipated scratch or wear depth resulting from routine operational activities.</u> The NRC concluded the licensee's 10 CFR 72.48 change did not require prior NRC review and approval through an amendment request." July 9, 2019 Supplemental Inspection Report at pp. 4-5, emphasis added.

<u>Analysis of Scratches on the MPCs</u>

GE Inspection Technologies visually assessed the majority of the vertical surface of the MPCs (>99%) through these inspections.

Scratches on the MPCs occurred due to an MPC interaction with the UMAX vault, also known as the vertical ventilated module (VVM), either at the VVM's (1) shield ring or (2) seismic restraints.

The shield ring is a circumferential ring near the top of the vault that is located above an inserted MPC, which functions to reduce radiation 'streaming' as the MPC is inserted and the shield lid installed. Interactions between the shield ring and the MPC resulted in scratches of up to 30" long, widths of <0.5" to 8" and very little depth (<0.013") because the similar diameters resulted in a broad contact area. Interactions with the shield ring were found in 7 of the 8 MPCs inspected.

The seismic restraints are 304 stainless steel curved restraints (radius 2") that are part of the VVM interior to restrict MPC movement in the event of a seismic event during storage. Two sets of seismic restraints (one set near the bottom of the installed MPC, and one set near the top) are part of the VVM design. Interactions between the seismic restraints and the MPC resulted in scratches of up to most of the length of the canister, widths of up to 0.25", and depth of up to 0.026". Interactions with the seismic restraints were identified in 4 of the 8 MPCs inspected. The upper seismic restraint and shield ring are shown in Figure 1 below.

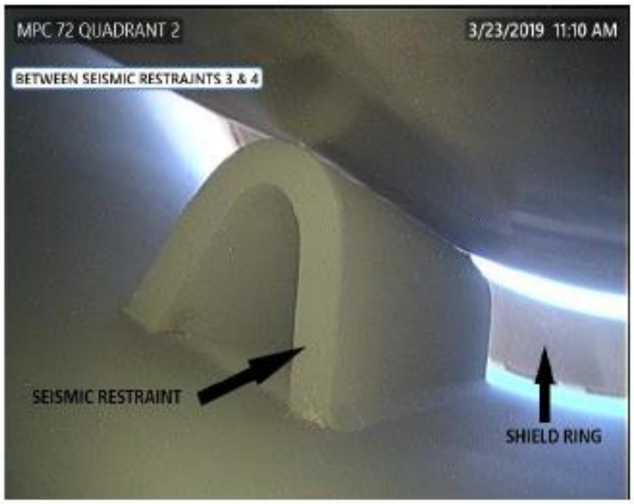


Figure 1. Robotic system photo taken from below the seismic restraint, looking up.

Table 1 below contains a summary of the scratches with measurable depth identified on the eight 2019 inspected canisters. (Only seven canisters are listed because one inspected canister had no scratches.)

Table 1 – Summary of Scratches Found During MPC Inspections
(the yellow-highlighted scratches are the two examples shown in photos below)

MPC No.	Scratch Type	Length (inches)	Width (inches)	Max Depth (inches)
064	Shield Ring	30	2	0.012
064	Shield Ring	6	1	0.009
064	Shield Ring	6	1	0.009
064	Shield Ring	8	1	0.009
064	Shield Ring	1	4	0.009
064	Shield Ring	15	5	0.011
064	Shield Ring	30	2	0.003
072	Shield Ring	4	8	<0.001
072	Seismic Restraint	>120	0.192	0.016
072	Seismic Restraint	>120	0.192	0.016
072	Seismic Restraint	12-24	0.192	0.026
072	Seismic Restraint	24-36	0.192	0.016
094	Shield Ring	4	8	0.012
055	Seismic Restraint	6	0.25	0.003
055	Shield Ring	6	4	0.004
055	Shield Ring	8	0.5	0.005
055	Shield Ring	6	0.125	0.003
055	Seismic Restraint	>130	0.25	0.012
055	Seismic Restraint	>120	0.25	0.004
065	Shield Ring	4	8	<0.001
065	Seismic Restraint	>130	<0.2	0.011
065	Seismic Restraint	12-24	<0.2	0.002
068	Shield Ring	3	6	<0.001
068	Shield Ring	>150	0.75	0.004
061	Shield Ring	4	8	<0.001
061	Seismic Restraint	>60	0.125	0.001
061	Seismic Restraint	>60	0.125	0.012

The far right column in Table 1 above contains the maximum depth observed for each scratch. During the inspection, detailed pictures and profilometry were made for the deepest area of each scratch. Most scratches were long and shallow and the deeper areas were generally localized.

As an example, representative photos of two scratches from canister #72, with associated profilometry, are shown in Figure 2 below. (These scratches are identified in the highlighted entries of Table 1 above.) Both of these scratches were caused by interaction with a seismic restraint.

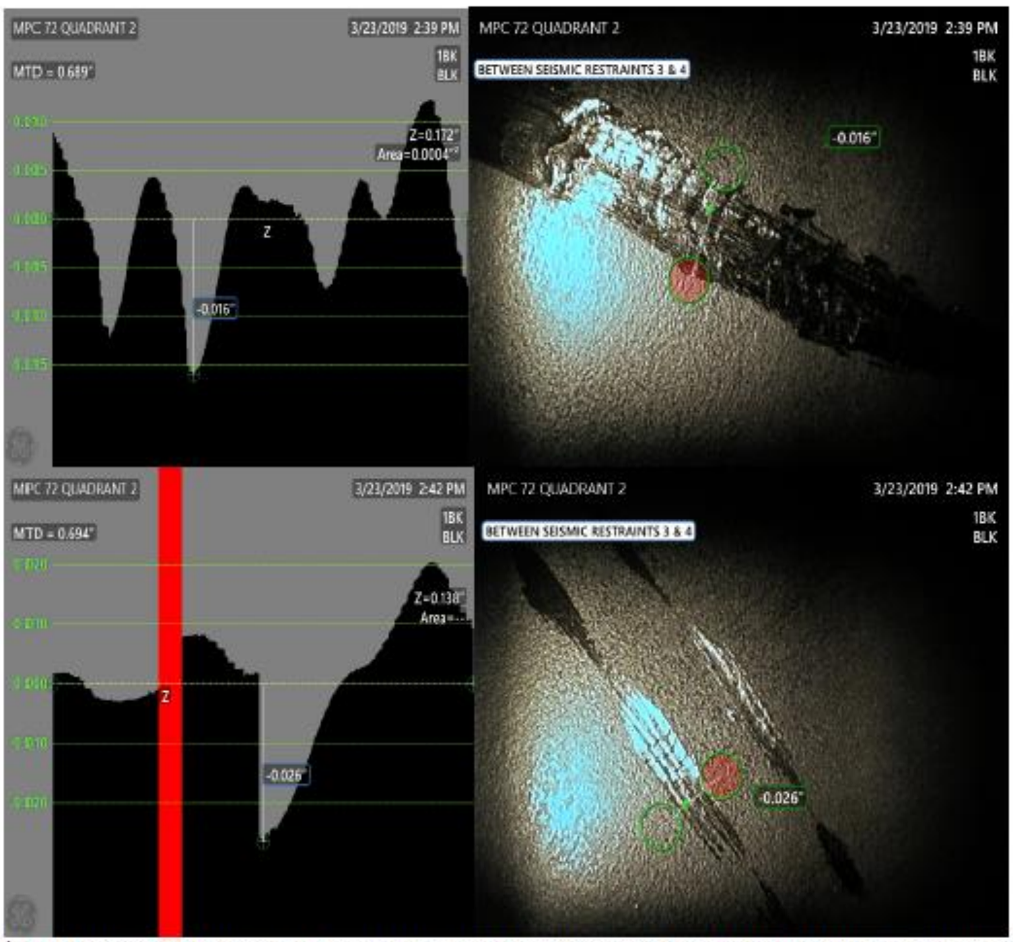
The profiles generally show raised metal adjacent to each depression consistent with galling of austenitic stainless steel. No metal removal was observed. No metal debris was found in the bottom of the VVM or at the contact points on top of the shield ring or seismic restraints.

A deterministic finite element analysis (FEA) of the interaction between the MPC and VVM predicted shallow scratching. Most of the actual scratches were long and shallow, sometimes consisting of a visible shiny mark with no measurable depth. The large majority of the scratches were less than .005" deep. The areas with deeper indications were generally very small and narrow.

The FEA included a conservative assumption of large forces in the interaction between the MPCs and VVM, which were much greater than possible given the geometry of the MPCs and the VVM. The tight clearances between the VVM and the MPC do not allow enough misalignment to generate large forces. There was no evidence of denting on the MPCs.

The deeper measurements were only observed in localized areas of galling. Galling occurs when two austenitic stainless steel surfaces wear, and is a different phenomenon than the scratching modeled by the FEA. Galling is self-arresting because the material is not removed, just rearranged.

Figure 2 – Canister #72 Detailed Pictures and Profilometry



(The red segment of the bottom left profilometry graph above represents 'noise' in the data that was not used for evaluation.)

Figure 3. Photo showing a view of MPC 72 seismic restraint scratches.

APPENDIX F. SCE COMMENT RESPONSES 05/20/2020

SCE Responses to LPI May 19 Questions

1. SCE indicated that the majority of scratches were not located on the MPC welds. LPI requests detailed information on the location of each scratch (as listed in the draft SONGS IMP: Table 1 of Exhibit 4) in order to quantify the number of scratches that occurred at welds (including surface profilometry photos if available).

SCE Response:

The only scratches located on MPC welds were the five items identified in Exhibit 4 to the IMP (see Note 4 of Table 1 in Exhibit 4). These scratches were less than 0.005" depth at the point where they crossed the welds.

The intent of SCE's 2019 inspections was to find the deepest scratches on the inspected MPCs. During the inspections, SCE and its contractor, GE Inspection Technologies, visually inspected all scratches and performed profilometry for the deepest scratches.

As SCE indicated in its Response to LPI's May 15 Questions, most of the scratches were long and shallow, sometimes consisting of a visible shiny mark with no measurable depth. The large majority of the scratches were less than 0.005" deep.

Five scratches crossed the welds of the inspected MPCs. Because these five scratches were less than 0.005" deep at the point where they crossed the welds, their depths in that area were not recorded. The portions of these five scratches that crossed the welds amounted to less than 1% of the total scratch length recorded.

Table 1a below contains the location information for the scratches from Table 1 of SCE's May 15 Responses that were 0.012" or deeper at any point of the scratch. As shown in Table 1a, three of these scratches crossed the weld, but again they were less than 0.005" deep at the point where they crossed weld.

2. SCE communicated that the MPC axial welds do not align with the VVM's seismic restraints, the deeper scratches result from contact with the seismic restraints, and that only the MPC beltline weld is potentially affected by scratching/galling from the seismic restraints. LPI requests SCE to provide detailed information on the deeper scratches (in particular those found on MPC #72) with respect to location/proximity to the beltline weld (including surface profilometry photos if available).

SCE Response:

The MPC longitudinal welds do not align with the seismic restraints. The longitudinal weld is located between seismic restraints 1 and 8 and cannot contact any seismic restraint. The vertical cask transporter (VCT) rigging is also attached in a manner that does not allow rotation of a loaded MPC. Thus, the longitudinal weld on the MPC cannot contact the seismic restraints.

While the exact location of each profilometry measurement was not recorded, a review of the inspection report and inspection videos confirms that no galling in excess of 0.012" (or even 0.005") occurred on the welds.

The table below provides the location of all scratches that had a maximum depth of 0.012" greater from Table 1 of SCE's Response to LPI's May 15 Question. Profilometry for the deepest portion of most of these scratches is provided in either SCE's May 15 response or below.

Table 1a – Information re location of May 15 "Table 1" scratches of 0.012" or greater
(the yellow-highlighted scratches are the three examples shown in profilometry below)

MPC No.	Scratch Circumferential Location	Scratch Type	Location of max scratch depth	Scratch Proximity to Circ Weld	Max Depth (in.)	Profilometry Available?
064	Between SR5-SR6	Shield Ring	Bottom ¼ of MPC	Does not contact circ weld	0.012	Provided below
072	Below SR1	Seismic Restraint	Bottom ½ of MPC	Scratch crosses circ weld; less than 0.005" depth at weld	0.016	Profilometry performed but not recorded
072	Below SR4	Seismic Restraint	Bottom ½ of MPC	Scratch crosses circ weld; less than 0.005" depth at weld	0.016	Provided in previous response
072	Below SR4	Seismic Restraint	Bottom ¼ of MPC	Does not contact circ weld	0.026	Provided in previous response
072	Below SR5	Seismic Restraint	Bottom ¼ of MPC	Does not contact circ weld	0.016	Profilometry performed but not recorded
094	Between SR1-SR8	Shield Ring	Above Circ Weld	Does not contact circ weld	0.012	Provided below
055	Below SR5	Seismic Restraint	Bottom ½ of MPC	Scratch crosses circ weld; less than 0.005" depth at weld	0.012	Provided below
061	Below SR3	Seismic Restraint	Bottom ½ of MPC	Does not contact circ weld	0.012	Profilometry performed but not recorded

Figure 4[1] – Canister #64 Profilometry

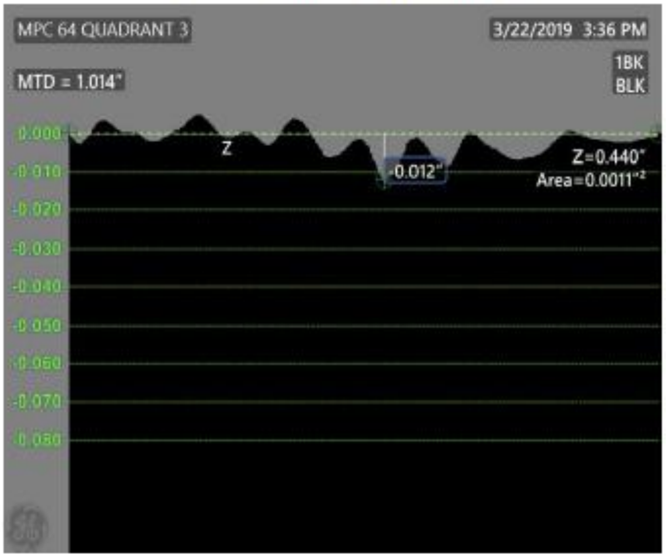
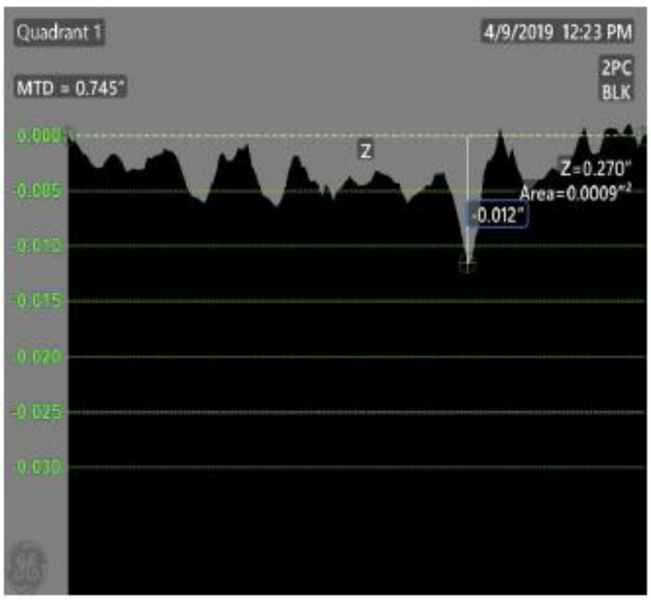
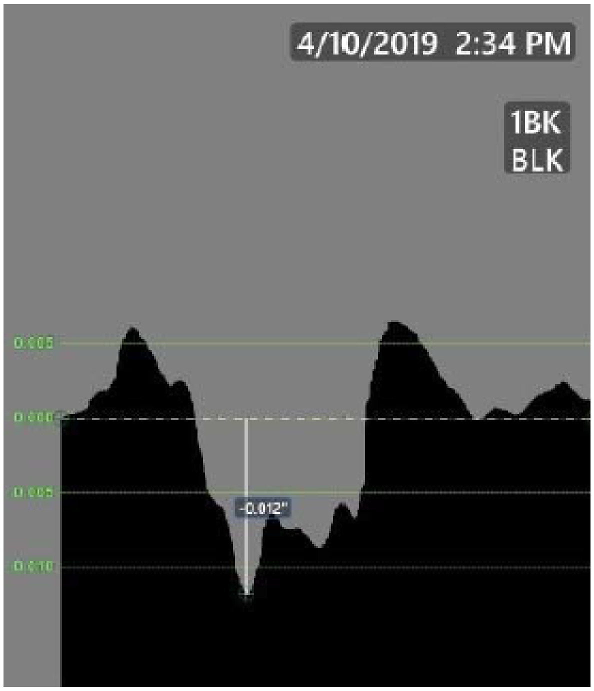


Figure 5 – Canister #94 Profilometry



[1] Figure numbers continue from the numbering in SCE's Response to LPI May 15 Question to avoid confusion.

Figure 6 – Canister #55 Profilometry



Note: This scratch is the most common shape for a seismic restraint scratch. The depth of 0.012" is larger than other scratches of similar profile.

APPENDIX G. SCE COMMENT RESPONSES 05/29/2020

SCE Response to LPI May 29 Questions

1) Please provide information regarding a probabilistic statistical assessment of the 2019 SONGS canister inspections.

SCE Response:

In response to earlier LPI information requests, SCE provided its April 2019 statistical analyses of the 2019 SONGS canister inspection data.[1] As requested by LPI, SCE is also providing an analysis using an extreme value statistical theory, which is the attached MPR analysis dated June 9, 2020.

Using extreme value statistical analysis for the 2019 canister inspection data would not result in any significant changes to the prior conclusions, which used a normal distribution. In practice and on an ongoing basis, SCE intends to perform the statistical analyses using both a normal distribution analysis and an extreme value distribution analysis.

2) Please review the data points shown in the April 10, 2019 and April 15, 2019 MPR documents for a possible typographical error.

SCE Response:

This question is clarified in the attached June 9, 2020 MPR analysis. SCE apologizes for the confusion.

The minimum measurable scratch depth for the equipment used in the 2019 inspection was .001 in. As a result, in Table 2 of the 2019 reports, the maximum scratch depth value of "0 in." shown for canister 67, which had no scratches, was conservatively replaced with .001 in. when the statistics were calculated. All three analyses (the April 10 and April 15, 2019 analyses and the attached June 9, 2020 analysis) used .001 for canister 67 to calculate the statistics instead of the rounded 0 shown in the 2019 tables.

[1] *See* MPR Canister Inspection Plan documents dated April 10, 2019 (with 3 canisters inspected) and April 15, 2019 (with 8 canisters inspected).

MPR

June 9, 2020

SONGS Canister Inspection - Extreme Value Statistics Scoping Analysis

1.0 Purpose

In May 2020, the California Coastal Commission conducted a review of SCE's Inspection and Maintenance Program for in-service inspections of spent fuel storage canisters at SONGS.

In the course of this review, the Coastal Commission recommended that the potential for canister scratching during installation be statistically evaluated using extreme value statistical theory. The Coastal Commission recommended that extreme value statistical theory be applied to canister inspection data collected in March-April 2019.

This document provides the extreme value statistical theory scoping calculation requested by the Coastal Commission. In summary, using extreme value statistical analysis for the 2019 inspection data would not result in any significant changes to the prior conclusions, which used a normal distribution.

2.0 Extreme Value Statistics

The effect of applying extreme value statistical theory to the SONGS canister data was evaluated by fitting the data available for the eight canister inspections to both a type 1 (Gumbel) and to the generalized extreme value family of distributions. The scratch depth values listed in the Table below were used for this analysis.

Table 2-1. Scratch Depth Data

Canister No.	Maximum Value (in.)
64	0.012
67	0.001*
72	0.026
94	0.012
55	0.012
65	0.011
68	0.004
61	0.012

*Since the minimum measurable scratch depth was .001 in. for the equipment used in the 2019 inspection, the maximum scratch depth value reported (0 in.) for canister 67, which had no scratches, was conservatively replaced with .001 in. to calculate statistics. (Note that the Coastal Commission identified this item as a potential typographical error in the April 2019 reports; however, the use of .001 instead of the rounded 0 shown in the 2019 tables accounts for the discrepancy.)

The canister scratch depth data was fit to the extreme value probability distributions using MATLAB 2018a functions. As requested by the Coastal Commission, both the best estimate fit parameters (50 confidence) and the 95 confidence values of the fit parameters were used to generate cumulative probability distribution plots. The results are shown in the figure below.

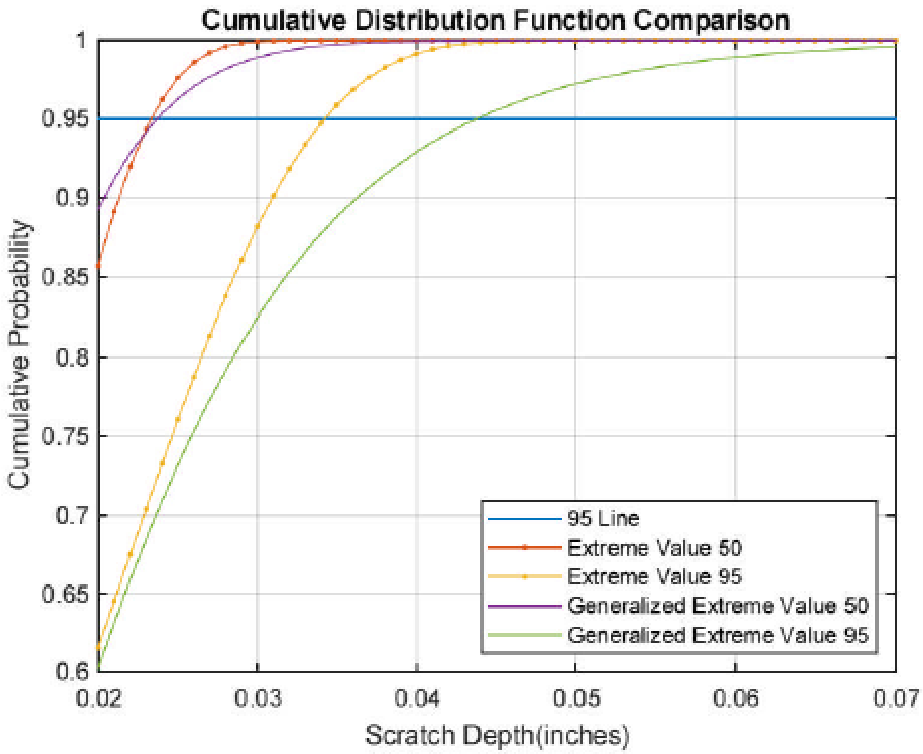


Figure 2-1. Extreme Value Cumulative Probability Distributions

2.1. Summary

The 95/95 deepest scratch assuming a type 1 extreme value probability distribution is very similar to the 95/95 deepest scratch value calculated using traditional statistical theory as shown in Table 1-2 below. Application of the generalized extreme value probability distribution calculates a larger 95/95 scratch depth (0.043 inches).

Table 2-2. 95/95 Deepest Scratch

Assumed Probability Distribution	95/95 Deepest Scratch (inches)
Normal	.035
Type 1 Extreme Value	.034
Generalized Extreme Value	.043