SAN ONOFRE
COMMUNITY
ENGAGEMENT
PANEL

March 29, 2017

Honorable Scott Peters
Congressman, 52nd District of California
United States House of Representatives
San Diego District Office
4350 Executive Drive, Suite 105
San Diego, CA 92121

Dear Congressman Peters,

I write as a follow-on to our meeting on 21 February in your San Diego office, and with respect to the important matter of federal legislation necessary to open the door to offsite storage of used nuclear fuel from sites such as the retired San Onofre plant.

As chair of the San Onofre Community Engagement Panel (CEP), let me say your offer of support is greatly appreciated. If I may, here are the areas in which I believe you can have the greatest impact:

1. **Scope of legislation**
   My sense is that offsite storage has been elusive in part because the solution has been limited to a one-site virtual monopoly: Yucca Mountain. To maximize our chances for success in getting the spent fuel moved from San Onofre quickly, I believe we must be open to the important and distinct roles of both near-term consolidated interim storage (CIS) facilities as well as permanent geologic repositories like Yucca Mountain. Perhaps most importantly, once offsite storage becomes a reality, shutdown sites such as San Onofre should be first on the list for fuel pick-up, as such decommissioning sites – also known as "stranded" sites – no longer are producing used nuclear fuel. Operating nuclear plants should be lower on the list. At present, the Department of Energy (DOE) "Standard Contract" (10 CFR 961) states that priority *may* be given to shutdown sites but pickup also can be based on the oldest fuel regardless of whether that fuel is from an operating or a shutdown site. It would be strongly in our interest here in San Diego to press for a clearer and higher priority placed on early movement of fuel from shutdown sites.

2. **Broadening support for offsite storage**
   Pursuant to your request, attached is a list of states with shut down and soon-to-be shutdown nuclear plants in the U.S. that you may use to build a network of support through the House. Closer to home, we have Reps. Davis and Vargas, who also may be supportive of moving used fuel out of California. At the right time, we in the CEP are also keen to help engage Senator Harris to get her up to speed on this matter. If we can help share our experiences with delegations from other jurisdictions we would welcome your advice on where and how to do that.

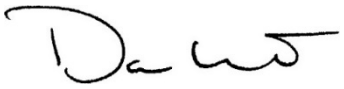
3. **Preparing a transportation strategy**
   The two CIS facilities—one in New Mexico and one in Texas—may be open for business in as few as five years. As we push to make CIS a reality, most attention has been focused on the sites themselves and on related issues such as how to manage liability for the fuel and how to pay for the modest cost of CIS. There has been much less attention to transportation. We in the CEP have learned that it is vitally important that we work now to ensure transportation planning advances at a pace such that we are prepared for the DOE to pick up and move used fuel. Reference the attached letter that the leadership of the CEP sent to the California Energy Commission (CEC) in December. The CEC is the state liaison to the Nuclear Regulatory Commission (NRC) and it is ideally suited to develop and execute a strategy for state-level transportation planning. At the federal level, I understand the DOE is working on other pieces of the transportation puzzle, such as a rail car to be used for shipments of used fuel. And I know Southern California Edison, decommissioning agent for San Onofre, is working hard to transfer its used fuel into canisters so that it is ready for DOE pickup. Information that Edison has shared with the CEP suggests that all of the fuel at San Onofre will be removed from the spent fuel pools by mid-2019. Some of that fuel is ready for shipment now; most of it will be ready by 2020. In short, the moment that CIS comes into focus as a real option, San Onofre will be ready.

4. **Funding**
   We are mindful that Washington is in the middle of broad efforts to realign federal budget priorities. It is probably crucial to our efforts to make CIS a reality that the budget cutting not undermine the DOE and NRC programs related to spent fuel (as well as federal programs on transportation).

Your efforts to support offsite storage of used fuel are greatly appreciated—through the House Energy & Commerce Committee, across Congress more generally, and in our community. In an environment of partisanship this may prove to be a good topic where bipartisan action is still possible.

Please let me know what we on the San Onofre Community Engagement Panel can do to support you.

All best,



David Victor

Attachments:

1. Letter from CEP to CEC Chair Robert B. Weisenmiller
2. List of decommissioning nuclear plants

cc: Brian Elliott, Field Representative
Jerry Kern, Oceanside City Council
Tim Brown, San Clemente City Council (CEP Vice Chairman)
Dan Stetson, Nicholas Endowment (CEP Secretary)
Tom Palmisano, Southern California Edison (San Onofre VP & Chief Nuclear Officer)
Manuel Camargo, Southern California Edison

December 12, 2016

SAN ONOFRE COMMUNITY ENGAGEMENT PANEL

Dr. Robert B. Weisenmiller
Chair
California Energy Commission
1516 Ninth Street, MS-33
Sacramento, CA 95814

Dear Chair Weisenmiller,

Thank you for your ongoing efforts to represent the interests of the State of California in favor of smart management of the state's nuclear power plants and policies. We lead the Community Engagement Panel (CEP) for the San Onofre Nuclear Generating Station (SONGS), a volunteer panel set up to help steward the process of decommissioning at SONGS. By far, the topic that has attracted the most attention at CEP meetings is how to accelerate movement of the spent nuclear fuel out of our communities into new consolidated interim storage (CIS) facilities in New Mexico, Texas, and perhaps other states. **It is in that respect that we write today and offer to work with the CEC to help sharpen a California strategy for accelerating the safe movement of spent nuclear fuel out of the state.**

We in the CEP have already benefitted enormously from the work of the CEC. We learned much when Executive Director Rob Oglesby presented at a SONGS CEP meeting in January 2015. We have also been engaged with the Department of Energy (DOE) process regarding consent for interim storage of spent fuel—a process that CEC has helped to shepherd, such as with the DOE public meeting in April 2016 in Sacramento. We think it would be useful for the CEP and the CEC to work together more closely.

Many of us in the communities around San Onofre are encouraged by the political window of opportunity that is opening for CIS. In addition to the two proposed CIS facilities that are at various stages of licensing we note that legislation was introduced in the current session of Congress to make the necessary changes in federal law, and co-sponsorship of that legislation has grown. It is quite possible that the upcoming session of Congress may see passage of that legislation as part of a larger legislative reform that would address permanent spent fuel storage (Yucca Mountain) as well as interim storage. And while the Presidential transition has created many uncertainties, DOE and the Nuclear Regulatory Commission (NRC) have been doing a lot to prepare the ground for consolidated interim storage.

It strikes us that now is the time for the State of California to accelerate planning and coordination among the appropriate state agencies in order to ensure that we are prepared to safely move the spent fuel from here—at SONGS, Diablo Canyon, Humboldt Bay, and Rancho Seco—as soon as practical. A California strategy would need to focus on how to advance our state's interests in the federal legislative and administrative processes to make CIS a reality. It would need to address questions such as how to ensure spent fuel from decommissioning nuclear sites is "first in line" when CIS becomes available, and how to ready our state, county, and local administrative bodies to work together on crucial topics such as coordination of transportation routes and safety.

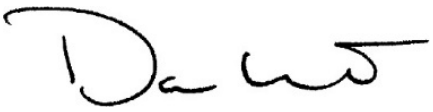
We understand that the CEC already participates in the California Nuclear Transport Working Group and, as such, coordinates with key parties such as the CHP, Cal OES, and California DPH. We appreciate that the CEC also is engaged with the Western Interstate Energy Board's High-Level Waste Committee, which offers another opportunity for the region to advance its interests. However, we are concerned that the state itself is not well enough organized to advance its interests in this debate, especially as the number of plants undergoing decommissioning in the U.S. is poised to rise—creating keen interest around the country in removing spent fuel from decommissioning sites. In the 2020s, when CIS could become available, all of the California nuclear reactors will be undergoing decommissioning—which puts our state in an almost unique position with distinct interest in making CIS a reality.

It is our hope that the CEC could help to focus and organize a statewide strategy on this important topic, and suggest ways the CEP can support such a strategy. We in the CEP have been working on many fronts—we attach a brief summary of our current strategy—but this question requires statewide and federal perspectives as well.

Those of us who serve on the San Onofre CEP would like to better understand the state-level strategy in advancing CIS while also preparing to manage the complexities of spent fuel transportation. On behalf of the CEP, we would appreciate the opportunity to discuss transportation planning with the appropriate representatives from the CEC.

We will follow-up via telephone to discuss the CEC's interest in such a discussion with the CEP or perhaps the undersigned CEP officers to start. In the meantime, thanks again for the important role you play on nuclear matters in California.

Sincerely,



David Victor
CEP Chair
Professor and Director, Laboratory on International Law & Regulation, UC San Diego



Tim Brown
CEP Vice Chair
City Council Member, San Clemente



Dan Stetson
CEP Secretary
Executive Director, Nicholas Endowment

Attachment: "San Onofre Community Engagement Panel Strategic Plan: Advocating for Federal Legislation to Enable Consolidated Interim Storage (CIS)"

cc: Members of the SONGS Community Engagement Panel
Mr. Robert P. Oglesby, California Energy Commission
Mr. Kevin Barker, Advisor, CEC
Mr. Justin Cochran, Nuclear Policy Advisor & Emergency Coordinator, CEC
Hon. Dianne Feinstein, U.S. Senator
Hon. Kamala Harris, U.S. Senator-elect
Mr. Bill Christiansen, District Director, Congressman Darrell Issa
Mr. Tom Palmisano, Vice President Decommissioning and Chief Nuclear Officer, SONGS
Mr. Manuel Camargo, Strategic Planning, SONGS
Concerned Coastal Communities Coalition

U.S. Nuclear Power Plants
Shut Down Facilities and Announced Shutdowns
March 2017

Shut Down Facilities	State
Big Rock Point Nuclear Power Plant	MI
Connecticut Yankee Nuclear Power Plant	CT
Crystal River Nuclear Plant	FL
Fort Calhoun Nuclear Generating Station	NB
Humboldt Bay Nuclear Power Plant	CA
Kewaunee Power Station	WI
La Crosse Boiling Water Reactor	WI
Maine Yankee Nuclear Power Plant	ME
Rancho Seco Nuclear Generating Station	CA
San Onofre Nuclear Generating Station	CA
Trojan Nuclear Power Plant	OR
Vermont Yankee Nuclear Power Plant	VT
Yankee Rowe Nuclear Power Station	MA
Zion Nuclear Power Station	IL

Announced Shutdowns	State
Indian Point Energy Center	NY
Oyster Creek Nuclear Generating Station	NJ
Pilgrim Nuclear Generating Station	MA
Diablo Canyon Power Plant	CA

List courtesy of Decommissioning Plant Coalition

GREG WALDEN, OREGON
CHAIRMAN

FRANK PALLONE, JR., NEW JERSEY
RANKING MEMBER

ONE HUNDRED FIFTEENTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON ENERGY AND COMMERCE
2125 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6115
Majority (202) 225–2927
Minority (202) 225–3641

March 20, 2017

The Honorable Rick Perry
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear Secretary Perry:

Congratulations on your confirmation as the 14th Secretary of Energy. As you made clear in your confirmation hearing, the Department of Energy (DOE) plays a critical role in our nation's national and energy security, environmental cleanup, and support for critical scientific research. We look forward to working collaboratively with you to advance DOE's critical missions.

One critical mission, and a long-standing, bipartisan priority of the Committee on Energy and Commerce, is to address our nation's challenges relating to nuclear waste management policy. Your testimony before the Senate Energy and Natural Resources Committee appropriately noted the "daunting task" of managing nuclear waste facilities and carefully disposing of nuclear waste.[1] More than three decades ago, Congress passed the Nuclear Waste Policy Act (NWPA) to formalize our nation's nuclear waste management policy, which included committing the Federal government to take title for permanent disposition of spent nuclear fuel (SNF) and high-level radioactive waste (HLW). In passing the NWPA, Congress designated DOE as the lead agency to manage this national priority.

Scientists and dedicated professionals at DOE and its national laboratories spent decades and some $15 billion to prepare the Yucca Mountain License Application (LA) for the Nuclear Regulatory Commission (NRC) to review. Since 2008, when the LA was filed with NRC, a number of decisions have been made that have impeded completion of the license review. While Congress considers legislation associated with managing SNF and HLW, we ask you take certain actions that could help facilitate implementation of the law.

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[1] The Honorable Rick Perry testimony to the Senate Energy and Natural Resources Committee, January 19, 2017.

We appreciate the inclusion of funding in the President's budget proposal to restart the Yucca Mountain licensing process. This is a critical step towards fixing the broken system and we applaud this action.

To begin with, we believe you should reconstitute the statutorily required Office of Civilian Radioactive Waste Management (OCWRM). The NWPA established OCRWM, led by a Director who is "directly responsible to the Secretary" to carry out NWPA authorized programs.[2] As you have previously noted, disposing of our nation's SNF and HLW is one of the largest challenges facing the Department. These challenges require the dedicated attention of the office specifically established in law to implement nuclear waste policy, not the current structure, in which the nuclear waste program competes with other important nuclear priorities within the Office of Nuclear Energy.

You should also reassess the 2015 decision to pursue a defense-waste only policy. The NWPA required the President to make a determination whether HLW from atomic energy defense activities should be disposed of in a single common repository with commercial SNF. In 1985, President Reagan determined that a single common repository was required. In the ensuing years, American taxpayers contributed $3.7 billion from defense budget accounts to study and develop the Yucca Mountain LA.[3] In 2015, this policy was reversed with a decision to pursue a defense-only repository.[4] We are concerned about the fiscal implications of departing from the long-standing policy.[5] We believe you should reassess the cost and schedule estimates that served as a basis for the 2015 decision, which GAO recently identified as areas of concern.[6]

You should provide an initial level of funding to the State of Nevada, and the Nye County Commission. The NWPA authorized funding to assist Affected Units of Local Governments (AULG) with technical activities during the Yucca Mountain licensing process. We understand $20 million in unobligated funding from previous appropriations remains in DOE's nuclear waste disposal accounts.[7] We encourage you to provide targeted financial resources to AULGs, which would be a positive step towards building a constructive dialogue with Nevadan stakeholders.

As you are aware from your tenure as Governor of Texas, there are entities advocating to develop a centralized interim storage facility to temporarily store SNF until a repository is open for permanent disposal. If the Department determines that an interim storage facility is necessary, we expect you will work with us to amend the NWPA to allow a program to move

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[2] Sec. 304 of The Nuclear Waste Policy Act, as amended.
[3] Letter from the Honorable Ernest Moniz to Committee on Energy and Commerce Chairman Fred Upton, May 15, 2015.
[4] Department of Energy, *"Draft Plan for a Defense Waste Repository,"* December 2016.
[5] Letter from Committee on Energy and Commerce Chairman Fred Upton and Ranking Member Frank Pallone, Jr. to the Honorable Ernest Moniz, April 14, 2015.
[6] U.S. Government Accountability Office, *"Nuclear Waste: Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste,"* GAO-17-174. January 31, 2017.
[7] Letter from Acting Assistant Secretary for Nuclear Energy Raymond Furstenau to Subcommittee on Environment Chairman John Shimkus, January 11, 2017.

forward in a way that protects national interests, protects taxpayers, and does not interfere with the long-standing policy that SNF and HLW must be permanently disposed of in a repository.

Following the D.C. Court of Appeals ruling in *In Re: Aiken County*, our committee requested monthly reports on the balance in DOE's nuclear waste disposal accounts and detailed explanations of activities that are funded from those accounts. We request you continue sending the reports detailing expenditures from the Nuclear Waste Fund, as currently underway.[8]

You have a challenging task ahead as you constitute DOE's senior leadership team and develop your priorities and policies. We request that you work with us and committee staff to identify constructively a path forward to manage our nation's spent nuclear fuel as you fill out your leadership team and senior staff at the Department. In addition, the Committee would like to schedule a tour of the Yucca Mountain site with Members of Congress, and we invite you to participate on that tour.

We look forward to your response to this letter and your commitment to work with this committee to develop a sustainable solution to our nuclear waste management challenges. If you have any questions regarding this letter, please contact Andy Zach of the committee majority staff at (202) 225-2927.

Sincerely,

Greg Walden
Chairman
Committee on Energy and Commerce

John Shimkus
Chairman
Subcommittee on Environment

[8] See Furstenau letter to Shimkus.

High Burnup Dry Storage Cask Research and Development Project

Final Test Plan

Prepared by: the Electric Power Research Institute

REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	February 27, 2014		Final Test Plan

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TABLE OF CONTENTS

LIST OF FIGURES v

LIST OF TABLES vi

LIST OF ACRONYMS vii

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION AND PURPOSE 1-1

1.1 Purpose 1-1

1.2 Introduction 1-1

1.2.1 Inventories of Spent Nuclear Fuel 1-1

1.2.2 Development of SNF Dry Storage Technologies 1-2

1.2.3 Dry Storage System Safety Requirements 1-5

1.3 Early Dry Storage Demonstration Projects 1-5

2.0 BACKGROUND 2-1

3.0 TEST PLAN 3-1

3.1 Source of Spent Nuclear Fuel 3-3

3.2 Nature and Amount of Spent Nuclear Fuel to be Used 3-5

3.3 System Design and Data to be Collected 3-8

3.3.1 Cask Design and Operations 3-8

3.3.2 Data to be Collected and Instrumentation 3-12

3.3.3 Frequency of Measurements 3-19

3.4 Sister Rod Evaluation 3-20

3.5 Transportation Plan to Begin the High Burnup Dry Storage Research Project 3-23

3.6 Work to be Performed at the National Laboratories: Sister Rod Characterization 3-23

3.7 Applicable Codes, Standards, and Procedures 3-27

TABLE OF CONTENTS (cont.)

3.8 Unplanned Cask Opening 3-30

3.9 Fuel Examination Facility 3-31

3.10 Schedule for the Plan Implementation 3-33

4.0 VALUE OF THE HIGH BURNUP DRY STORAGE RESEARCH PROJECT 4-1

5.0 REFERENCES 5-1

LIST OF FIGURES

Figure 1-1 Projected SNF Inventory in Wet and Dry Storage in the U.S. 1-2
Figure 1-2 TN-32 Cask Cut-away View 1-3
Figure 1-3 Example of a Welded Metal SNF Storage Canister Inside a Concrete Overpack 1-4
Figure 3-1 Placing Dry Storage Casks on the ISFSI Concrete Pad at North Anna 3-4
Figure 3-2 View of Fuel Basket within a Typical TN-32 Cask 3-9
Figure 3-3 Lid Installation of a TN-32 Cask. 3-9
Figure 3-4 Example of Cask Lid Penetrations for Temperature Lances: CASTOR-V/21 Primary Test Lid 3-10
Figure 3-5 Example of Locations of Temperature Probes Within and Near the Assemblies: CASTOR-V/21 Thermocouple Lance Locations 3-11
Figure 3-6 Example of Potential Thermocouple Radial Locations within Fuel Assembly in Cask 3-16
Figure 3-7 Cross-sectional View of Typical Thermocouple Lance 3-16
Figure 3-8 Conceptual Instrumentation Guide 3-17
Figure 3-9 Cross-section of a Fuel Rod 3-25
Figure 3-10 Cross-section of a Fuel Rod with Significant Radial Hydride Orientation 3-25

LIST OF TABLES

Table 3-1 Available High Burnup Fuel Assembly Types for the High Burnup Dry Storage Research Project 3-6

Table 3-2 Schedule 3-34

Table 3-3 Key Milestones 3-35

LIST OF ACRONYMS

ALARA	As Low As Reasonably Achievable
AMP	Aging Management Plan
ANL	Argonne National Laboratory
BWR	Boiling Water Reactor
CoC	Certificate of Compliance
CWSR	Cold-Worked Stress-Relieved
DBTT	Ductile-to-brittle Transition Temperature
DCSS	Dry Cask Storage System
DHC	Delayed Hydride Cracking
DLBD	Design and Licensing Basis Document
DOE	Department of Energy
DOE-NE	Department of Energy - Office of Nuclear Energy
EPRI	Electric Power Research Institute
ESCP	Extended Storage Collaboration Program
FP	Fission Product
GWD	gigawatt-day
HDRP	High Burnup Dry Storage Research Project
HLW	High-level Radioactive Waste
INL	Idaho National Laboratory
ISFSI	Independent Spent Fuel Storage Installation
ISG	Interim Staff Guidance
ISI	In-service Inspection
LAR	License Amendment Request
MOX	Mixed Oxide (U/Pu) Fuel
MPC	Multi-purpose Canister
MTU	Metric Ton of Uranium
NDE	Non-destructive Examination
NRC	Nuclear Regulatory Commission
NWTRB	Nuclear Waste Technical Review Board
OD	Outer Diameter
OP	Overpressure
PWR	Pressurized Water Reactor

LIST OF ACRONYMS (cont.)

PRX	Partially Recrystallized
R&D	Research and Development
RAI	Request for Additional Information
RD&D	Research, Development, and Demonstration
RTN	Removable Top Nozzle
RX	Recrystallized
SCC	Stress Corrosion Cracking
SE	Safety Evaluation
SET	Separate Effects Test
SNF	Spent Nuclear Fuel
SSC	System, Structure, or Component
SST	Small-scale Test
UOX	Uranium Oxide Fuel
UQ	Uncertainty Quantification
U.S.	United States

EXECUTIVE SUMMARY

It is in the national interest to demonstrate the ability to safely store—for many decades—and then transport spent nuclear fuel (SNF). The potential need to store SNF for many decades will have a near-term and potentially significant impact on plant licensing and operations. While dry storage of lower burnup SNF [less than 45 gigawatt days per metric ton uranium (GWD/MTU)] has occurred in the United States (U.S.) since 1986, dry storage of high burnup SNF has been more recent. As of December 2012, approximately 200 dry storage casks have been loaded with at least some high burnup SNF. Furthermore, almost all SNF being loaded in the U.S. is now high burnup. Since high burnup SNF has different mechanical properties than lower burnup SNF, industry needs additional data on high burnup SNF under typical conditions.

This document describes a Test Plan for the High Burnup Dry Storage Cask Research and Development Project[1] (also referred to as the "High Burnup Dry Storage Research Project" (HDRP)) sponsored by the U.S. Department of Energy - Office of Nuclear Energy (DOE-NE) under contract DE-NE-0000593 to the Electric Power Research Institute (EPRI). In conjunction with U.S. national laboratories, EPRI is leading a project team[2] to develop and implement a Test Plan to collect data from an SNF dry storage system containing high burnup fuel.[3] The Test Plan for the HDRP outlines the data to be collected; the high burnup fuel to be included; and the storage system design, procedures, and licensing necessary to implement the Test Plan. The main goals of the proposed test are to provide confirmatory data[4] for model validation and potential improvement, provide input to future SNF dry storage cask design, support license renewals and new licenses for Independent Spent Fuel Storage Installations (ISFSIs), and support transportation licensing for high burnup SNF. To provide data that is most relevant to high burnup fuel in dry storage, the design of the test storage system must closely mimic real conditions high burnup SNF experiences during all stages of dry storage: loading, cask drying, inert gas backfilling, and transfer to the ISFSI for multi-year storage.[5] While the Test Plan described in this document is anticipated to provide confirmatory data to support license extensions of ISFSIs containing high burnup spent fuel, the data collected in this Test Plan can be used for other relevant—but optional—modeling, separate effects tests (SETs), and small-scale tests (SSTs) to extend the applicability of the data collected during the HDRP to evaluate

[1]The project is often called "the High Burnup Dry Storage Research Project" (HDRP) throughout this Test Plan.
[2]The EPRI team includes AREVA Federal Services, Transnuclear, Dominion Virginia Power, AREVA Fuels, and Westinghouse Fuels. A potential additional team member responsible for high burnup rod shipment will be identified in the future.
[3]'High burnup' fuel has a burnup level at or above approximately 45 gigawatt-days per metric ton of uranium (GWD/MTU).
[4]'Confirmatory' data means the data will be used to evaluate whether data from smaller-scale, accelerated test experiments are indicative of the actual state of the high burnup fuel and the storage systems in commercial use.
[5]This document will often use the word 'typical' to mean test conditions that closely simulate the actual conditions high burnup fuel experiences in commercial dry storage.

the integrity of dry storage systems and the high burnup fuel contained therein over many decades for a wider set of fuel parameters and environmental conditions.

The Department of Energy (DOE) has performed recent assessments focusing on long-term aging effects important to the performance of the structures, systems, and components (SSCs) of the dry cask storage systems for SNF. DOE has determined that a large-scale cask R&D project using various configurations of dry storage cask systems and experiments would be beneficial.

To aid the successful completion of the high burnup, large-scale, long-term dry storage cask R&D project to collect confirmatory data, DOE specified a set of activities the EPRI team would undertake. Among others, the activities to be performed through the initial storage period of this project include:

- Developing a Design and Licensing Basis Document (DLBD)
- Designing and modifying the lid
- Identifying candidate spent fuel
- Licensing
- Procuring the cask and lid
- Extracting sister rods from assemblies and shipping
- Characterizing the sister rods
- Loading spent fuel into a bolted lid cask
- Storing the loaded cask on a Nuclear Regulatory Commission (NRC)-licensed ISFSI in the U.S.
- Monitoring the spent fuel inside the cask during aging

Following the initial storage period, the anticipated activities to complete the project would include:

- Moving the loaded cask from the NRC-licensed ISFSI to an onsite prep area and preparing the cask for shipment
- Transporting the cask to an off-site fuel examination facility
- Opening the cask at the fuel examination facility and examining (if needed)

The Test Plan in Section 3 describes the EPRI team's planned approach. A TN-32 bolted lid cask (the Research Project Cask) will be loaded with intact, high burnup SNF with four different kinds of cladding at Dominion Virginia Power's North Anna Power Station (North Anna): standard Zircaloy-4, low-tin Zircaloy-4, Zirlo, and M5. All the SNF to be loaded into the cask is already present in the North Anna spent fuel pool.[6] The TN-32 lid will be modified to allow

[6]North Anna is a pressurized water reactor (PWR).

insertion of temperature probes inside the cask at various axial and radial locations, and cask cavity gas samples will be obtained while in a monitored area controlled for potential radiological release. Several TN-32 casks have already been loaded at North Anna. Hence, Dominion has both licensing and operational experience with TN-32 casks.

While other dry storage system types could be used in the HDRP, such as a modified, welded stainless steel canister design, the data to be collected is essentially independent of dry storage system type. The primary focus of the HDRP will be on obtaining confirmatory data on the long-term behavior of high burnup fuel rather than the behavior of the particular dry storage system (bolted lid versus welded stainless steel). Both designs provide typical time/temperature environments for the stored spent fuel.

Prior to loading the Research Project Cask with high burnup assemblies, up to 25 fuel rods will be removed, prepared for shipment using normal, approved vacuum-drying procedures, and shipped to a national laboratory for detailed non-destructive and destructive examination.[7] These 'sister rods' have very similar characteristics to those that will be stored in the Research Project Cask and will be taken from either assemblies having similar operating histories (symmetric partners) to those that are selected for storage in the Research Project Cask or actual fuel assemblies to be included in the Research Project Cask. The detailed examination at the national laboratory will provide essential information on the physical state of the high burnup rods and the fuel contained in the rods prior to the loading, drying, and long-term dry storage process. Similar tests are to be performed at the end of the long-term storage period to identify any changes in the properties of the fuel rods during the dry storage period.

The Research Project Cask will be loaded with high burnup SNF in the North Anna spent fuel pool, and the modified lid will be emplaced. The cask will then be removed from the spent fuel pool. The temperature probes will be inserted through the modified lid and the cask will be dewatered and dried using approved vacuum drying procedures.[8] Monitoring of the vent gases during the drying process will be performed to determine if any fuel rods fail during this time. For the first two weeks after the completion of the drying process, periodic gas samples will be taken to determine the amount of fission gas, water vapor, oxygen, and hydrogen gas, if present.[9]

[7] The non-destructive and destructive exams at the national laboratory will be conducted under a separate program from the program that is part of the EPRI-DOE contract.

[8] The design and analysis will ensure peak rod temperatures always remain below 400°C. No attempt will be made to achieve this peak temperature, although it is anticipated that the calculated temperature will be close to 400°C. This approach will likely cause the peak temperatures in the Research Project Cask to be somewhat higher than is typical for spent fuel currently in storage. Thus, this approach will somewhat increase the proclivity of the high burnup cladding to undergo hydride reorientation, such that the Test Plan condition approaches a bounding case.

[9] The thermal transient period of two weeks after drying is considered to be a reasonable period for which to monitor the cask cavity atmosphere for fission products, oxidizing gas, hydrogen, and moisture. Nevertheless, the EPRI team will continue to investigate and evaluate methods for performing gas sampling during the storage period. If a sampling method can be licensed, funded, and deployed without creating undue risk to the project, it will be implemented.

Presence of one or more of these gases would indicate defects of one or more SNF rods during the drying process, incomplete removal of water during the drying process, presence of oxygen, or radiolysis or other hydrogen generation activity due to any remaining water, respectively. Temperature data will be recorded no less frequently than hourly during the first two weeks to provide data during the thermal transient from spent fuel pool temperature to the peak assembly temperatures that will occur during the vacuum drying process, and then to the steady-state temperatures with the helium backfill gas for the initial storage period.

Approximately two weeks after completion of the drying process, the cask will be moved to the ISFSI pad for long-term storage, during which periodic temperature measurements will be taken throughout the long-term storage process. If water vapor or Kr-85 gas is detected during drying, or the first two weeks after drying, it is anticipated that the license will allow the cask to be moved to the pad and the test would continue. This is because the presence of water vapor and Kr-85 in some of the dry storage systems could be typical if water or Kr-85 gas is found in the Research Project Cask.

At the end of the long-term storage process, which may be up to 10 years or longer, the cask will be returned from the ISFSI pad to the cask preparation area at North Anna and prepared for transportation to an off-site Fuel Examination Facility.[10] At the Fuel Examination Facility, the cask will be reopened and the fuel visually examined for changes that occurred during drying and storage. Rods will be extracted from the high burnup assemblies and the same detailed non-destructive and destructive examinations will be performed as those performed on the sister rods extracted prior to loading into the Research Project Cask at the beginning of the test.

The test schedule by calendar year in this Test Plan (Section 3.10) is as follows:

2013:

- Prepare the Draft Test Plan
- Seek public comments on the Draft Test Plan

2014:

- Establish the Final Test Plan
- Complete the design of the modified bolted lid
- Begin preparation of the storage DLBD
- Complete title and liability transfer documents for sister rods
- Begin procurement for sister rod cask and fuel vendor extraction work; begin procedure development and site planning for sister rod cask, cask handling, rod handling, rod extraction, and cask testing at North Anna

[10] At this time the off-site Fuel Examination Facility exists but a location to open a large cask is still being evaluated.

- Extract sister rods from some of the high burnup assemblies (depending on the final schedule from Dominion, this may not happen until as late as 2016)

2015:

- Begin modifications to the cask lid
- Extract the remaining sister rods (may be delayed until 2016, depending on the final schedule from Dominion)
- Complete the DLBD
  - Include in the DLBD changes to the NRC approved TN-32 Safety Analysis Report to accompany the Dominion storage license application to NRC
- Submit the storage license application to the NRC; address requests for additional information

2016:

- Possibly extract sister rods from the high burnup assemblies and ship the extracted rods to a national laboratory for evaluation
- Continue to address NRC requests for additional information
- Perform fit-up testing of the modified lid, cask, and instrumentation
- Ship the Research Project Cask including the modified lid to North Anna

2017:

- Dominion will obtain storage license from NRC (tentative, pending NRC review)
- Perform dry runs
- Load the Research Project Cask and begin temperature and gas data collection during the drying process
- Move the loaded cask to the North Anna ISFSI

2018:

- Continue taking periodic temperature measurements and performing other gas cavity sampling tests if qualified during the development of the HDRP
- Complete a limited number of calculations to support a future transportation license submittal

2018 to the end of the storage period:[11]

[11]The DOE-EPRI contract includes execution of the test plan during the first five years, i.e., up to mid April 2018. Beyond that time, responsibilities will need to be determined.

- Subject to future agreements, periodic temperature measurements and gas cavity sampling will be continued using qualified procedures developed during the initial contract period

End of the storage period:

- Return the Research Project Cask from the ISFSI pad to the cask preparation area at North Anna
- Without opening the cask, prepare the cask for transport to an off-site Fuel Examination Facility
- Ship the cask to the Fuel Examination Facility
- Open the cask and visually examine the fuel
- Extract high burnup rods for subsequent examination
- Conduct non-destructive and destructive examinations of the rods at a national laboratory

It is important to note that a large amount of modeling and test data already exist related to the long-term storage of both low burnup and high burnup SNF. Existing data for several different fuel designs can be used to address questions from the NRC and the public about the ability of existing and future dry storage systems to safely store and transport low burnup and high burnup SNF for a prolonged period of time. Additional experiments are ongoing or in the planning stages. A full-scale, long-term confirmatory HDRP—as described in this Test Plan—would provide valuable information to support the technical bases for long-term storage followed by transportation. Furthermore, valuable data from the HDRP will be collected right from the start even though the proposed storage time may be more than a decade.

The HDRP will provide important, *confirmatory* data to be used in conjunction with the substantial modeling and experimental data that currently exist, along with additional modeling, separate effects testing, and small-scale testing that DOE is planning in the near future. With confirmatory data from the HDRP, the relevance of the present and future models and tests can be assessed. Assuming the validity of the relevant models, SETs, and SSTs are confirmed by the HDRP, a higher degree of confidence in these models and tests can be obtained. Optional, lower cost models, and accelerated SETs and SSTs can explore a wider range of conditions that may occur for the range of fuel types and storage conditions currently in storage and planned for future storage followed by transportation. Hence, the HDRP in this Test Plan will provide the platform for these models and tests to supply a large amount of data relevant to the assessment of the safety of long-term storage followed by transportation.

1.0 INTRODUCTION AND PURPOSE

1.1 Purpose

EPRI is leading a project team to develop and implement the first five years of a Test Plan to collect data from a SNF dry storage system containing high burnup fuel.[12] The Test Plan defined in this document outlines the data to be collected, and the storage system design, procedures, and licensing necessary to implement the Test Plan.[13] The main goals of the proposed test are to provide confirmatory data[14] for models, future SNF dry storage cask design, and to support license renewals and new licenses for ISFSIs. To provide data that is most relevant to high burnup fuel in dry storage, the design of the test storage system must mimic real conditions that high burnup SNF experiences during all stages of dry storage: loading, cask drying, inert gas backfilling, and transfer to the ISFSI for multi-year storage.[15] Along with other optional modeling, SETs, and SSTs, the data collected in this Test Plan can be used to evaluate the integrity of dry storage systems and the high burnup fuel contained therein over many decades.

It should be noted that the Test Plan described in this document discusses essential activities that go beyond the first five years of Test Plan implementation.[16] The first five years of the Test Plan include activities up through loading the cask, initiating the data collection, and beginning the long-term storage period at the ISFSI. The Test Plan encompasses the overall project that includes activities that may not be completed until 15 or more years from now, including continued data collection, shipment of the Research Project Cask to a Fuel Examination Facility, opening the cask at the Fuel Examination Facility, and examining the high burnup fuel after the initial storage period.

1.2 Introduction

1.2.1 Inventories of Spent Nuclear Fuel

Due to continued delays in the introduction of reprocessing or permanent disposal in most countries that operate nuclear power plants, the need for longer-term storage of SNF is increasing worldwide. Figure 1-1 is a forecast of the U.S. inventory of SNF. At present, none of the SNF or the high-level radioactive waste (HLW) generated from reprocessing of SNF has been disposed, as no SNF or HLW permanent disposal facility exists. Hence, 100 percent of the SNF and HLW remains in storage. The original assumption was that SNF would be transferred

[12] 'High burnup' fuel has a burnup level at or above approximately 45 gigawatt-days per metric ton of initial uranium (GWD/MTU). Throughout this report, burnup is expressed as assembly average unless otherwise stated.
[13] The detailed description of how the Test Plan will be implemented will be included in the Design and Licensing Basis Document (DLBD), which is described in more detail in Section 3.7.
[14] 'Confirmatory' data means the data will be used to evaluate whether data from smaller-scale, accelerated test experiments are indicative of the actual state of the high burnup fuel and the storage systems in commercial use.
[15] This document will often use the word 'typical' to mean test conditions that closely simulate the actual conditions high burnup fuel experiences in commercial dry storage.
[16] After the first five years of Test Plan implementation, some or all of the Test Plan may be implemented by others.

from the pools to a reprocessing facility before the pools reached their capacity. However, changes in the economics and national policies regarding reprocessing resulted in much more limited deployment of reprocessing worldwide. For countries without access to reprocessing or a centralized storage facility, such as the U.S., nuclear utilities have been forced to continue onsite storage of growing inventories of SNF. Most utilities facing loss of spent fuel storage pool capacity initially re-racked their pools to increase capacity. At present, the majority of the nuclear plants in the U.S. have re-racked their pools at least once.

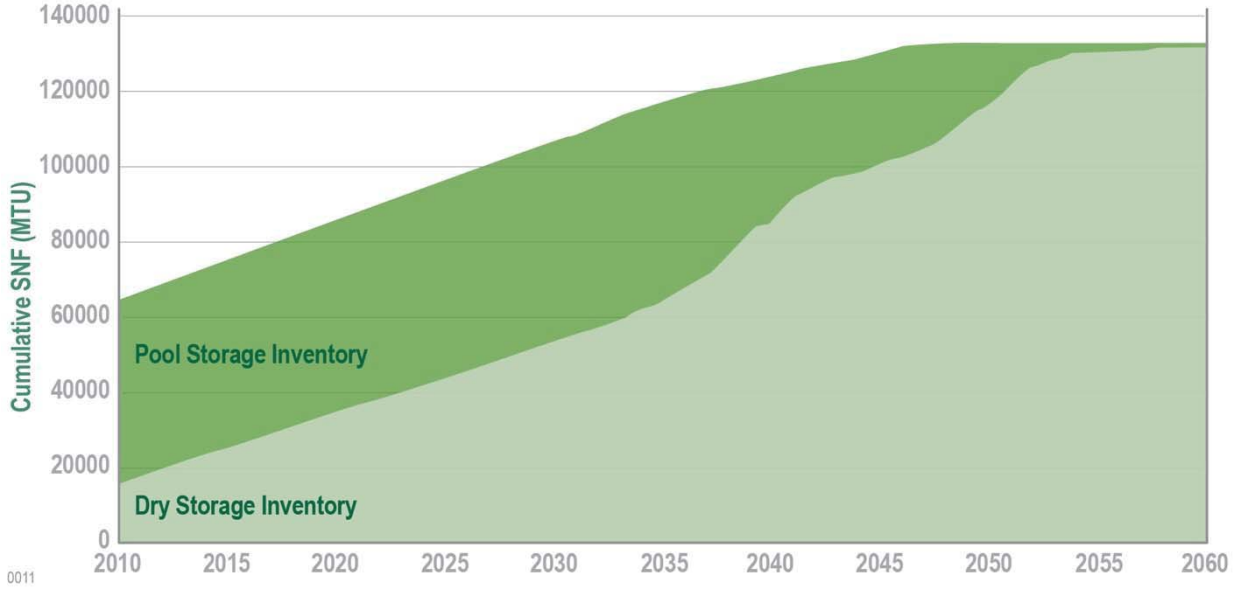


Figure 1-1: Projected SNF Inventory in Wet and Dry Storage in the U.S. [produced for EPRI by Energy Resources International, EPRI 2010].

1.2.2 Development of SNF Dry Storage Technologies

Even with re-racking, it was necessary to move SNF out of the pools into dry storage starting in the mid-1980s. In the U.S., the first SNF was placed into dry storage in 1986. Since then, the majority of U.S. nuclear plants include dry storage systems. Dry storage of SNF in other countries generally started later.

Dry storage systems are predominately two types: a metal 'cask' using a bolted lid (Figure 1-2) or a welded steel 'canister' inside a concrete overpack (Figure 1-3). The metal casks were massive enough to provide sufficient gamma shielding; neutron shielding was accomplished via incorporation of various high-hydrogen-content materials encapsulated in the metal cask body. There are other dry storage system designs including storage vaults.[17] At present, dozens of variants of the bolted lid and welded metal dry storage system designs exist that cover a wide range of storage system sizes, assembly types, and burnup and decay heat levels. The cask type

[17] A more detailed description of SNF dry storage systems in the U.S., including design, regulatory, and operational considerations, can be found in EPRI [2010].

included in this Test Plan is a TN-32 bolted lid cask (Figure 1-2). This cask is designed to hold 32 pressurized water reactor (PWR) assemblies.

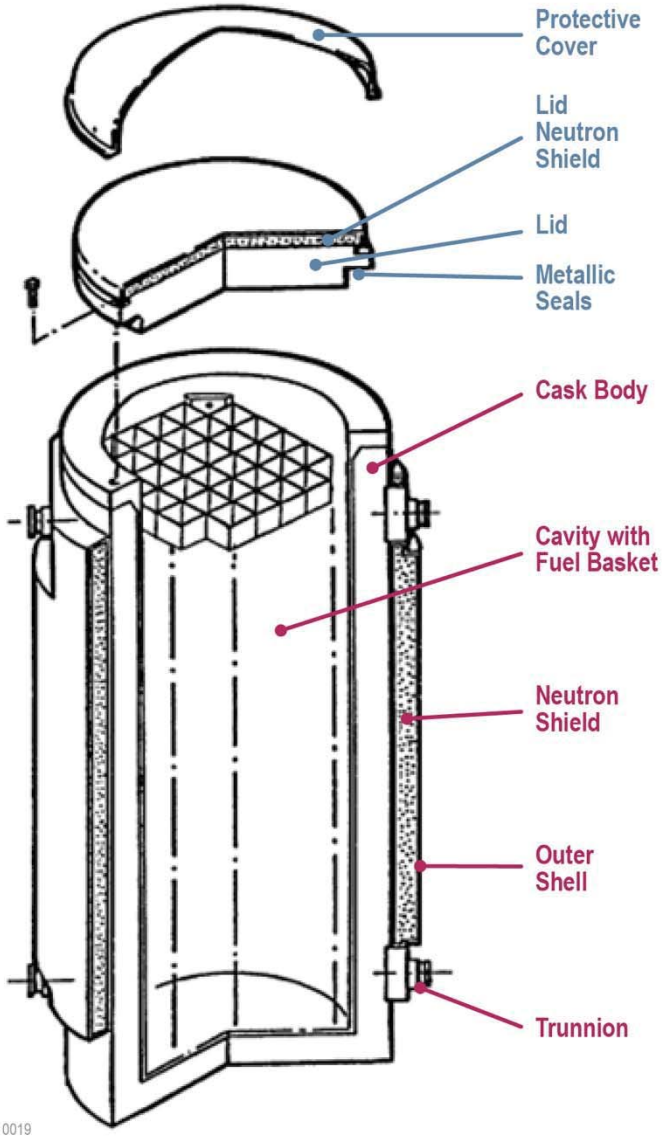


Figure 1-2: TN-32 Cask Cut-away View.

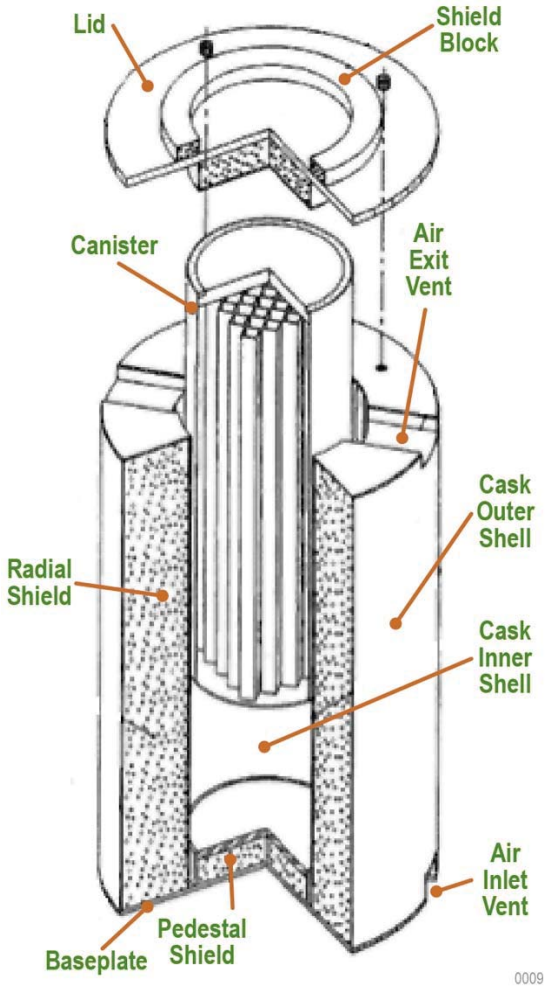


Figure 1-3: Example of a Welded Metal SNF Storage Canister Inside a Concrete Overpack (Cross Section of the HI-STORM 100 Overpack with MPC [NRC 2001]).

In the late 1980s, the U.S. utility industry began to explore the concept of 'dual-purpose' dry storage systems—that is, dry storage systems that are licensed by the NRC for both storage and transport without the need to re-handle individual SNF assemblies prior to shipment off site. The development of dual-purpose dry storage technologies has been particularly important for shutdown nuclear power plants that have off-loaded SNF to dry storage. Because the SNF at shutdown plants is stored in dual-purpose dry storage technologies, licensees have been able to dismantle and decommission their nuclear power plants, including the SNF storage pools, allowing decreased long-term operation and maintenance costs associated with storing the SNF until it is ultimately removed from the sites. The majority of ISFSIs that have been commissioned since 2000 have loaded SNF into dual-purpose dry storage technologies. Even most of those companies that began ISFSI operation in the 1980s and 1990s have transitioned from storage-only technologies to dual-purpose technologies.

1.2.3 Dry Storage System Safety Requirements

The NRC first developed a separate regulatory framework for storage of SNF outside of the reactor SNF storage pools in November 1980 with the issuance of U.S. Code of Federal Regulations (CFR), Title 10, Part 72, "*Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste*" (10 CFR 72). Similar regulations have been instituted in other countries as well. For storage, the main safety requirements are:

- **Thermal performance:** the storage system shall be designed to ensure peak temperature limits are not exceeded.
- **Radiological protection:** peak dose limits shall not be exceeded.
- **Confinement:** SNF and HLW shall be confined such that radioactive gases and particulates shall not be released to the environment.
- **Sub-criticality** shall be maintained under all normal and off-normal conditions of storage.
- **Retrievability:** the SNF in storage shall be able to be retrieved by normal means (i.e., crane and grapple).

1.3 Early Dry Storage Demonstration Projects

In the U.S., Section 218 of the Nuclear Waste Policy Act [NWPA 1983] required the Secretary of Energy to establish a Demonstration Program, in cooperation with the private sector, for dry storage of SNF at civilian nuclear power reactor sites. The objective of this Demonstration Program was to establish storage technologies that the NRC could approve by rulemaking for use at reactor sites without the need for additional site-specific NRC approvals.

In 1984, the Virginia Electric and Power Company (previously VEPCO, referred to now as Dominion Virginia Power) initiated a research program to provide additional SNF storage at its Surry station using dry storage technologies. DOE and EPRI signed cooperative agreements with VEPCO to demonstrate dry storage technologies at a federal site; selection and shipping of SNF to the federal site for storage; and the design, licensing, and initial operation of an ISFSI at the Surry station. The cooperative agreement program called for more than one cask design to be demonstrated at the Surry ISFSI and at the Idaho National Laboratory (INL), (at that time, the Idaho National Engineering Laboratory). The cask designs tested at INL included the CASTOR V/21, Westinghouse MC-10, and the TN-24P metal storage casks. EPRI published the results of the testing of these cask designs at INL in several EPRI reports [EPRI 1986; 1987a; 1987b]. Following receipt of a site-specific license from the NRC for an ISFSI at the Surry station, VEPCO loaded three separate metal cask designs with SNF and placed these casks in storage at the ISFSI as part of the cooperative agreement. The cask designs loaded under the cooperative agreement included the CASTOR V/21, Westinghouse MC-10, and NAC I28. VEPCO and EPRI documented this full-scale application of metal cask fuel storage technologies at the Surry station [EPRI 1989]. The HDRP described in this Test Plan is based largely on these previous tests.

Section 2 provides additional background that sets the stage for the Test Plan. The Test Plan itself is found in Section 3. Sections 4 and 5 provide a summary of the value of the data to be collected in the HDRP and references, respectively.

2.0 BACKGROUND

The technical bases for dry storage of low burnup SNF (burnups lower than approximately 45 GWD/MTU) have now been established, as evidenced by NRC granting license renewals for a total storage period of 60 years. The technical bases included: a large amount of hot cell data; the demonstrations at INL in the mid-1980s through early 1990s; and the CASTOR-V/21 Demonstration Cask that was reopened at INL in 2000. Due to the expanded use of high burnup fuel in dry storage and its different characteristics compared to low burnup fuel, similar data is desirable on high burnup fuel to support ISFSI license renewals as well as transportation licenses.

Since the 1990s, almost all SNF being removed from the reactors have burnups in excess of 45 GWD/MTU. While dry storage of lower burnup SNF (<45 GWD/MTU) has occurred in the U.S. since 1986, dry storage of high burnup SNF has been more recent:

- 9 years: Maine Yankee (up to 49.5 GWD/MTU)
- 7 years: HB Robinson (up to 56.9 GWD/MTU)
- 6 years: Oconee (up to 55 GWD/MTU)
- Less than 4 years for several other plants (up to 53.8 GWD/MTU)

As of December 2012, approximately 200 dry storage casks have been loaded with at least some high burnup SNF. Furthermore, almost all SNF being loaded in the U.S. is now high burnup. Hence, the need for license renewals for ISFSIs containing high burnup SNF for intermediate time periods (e.g., up to about 60 years) is growing. High burnup fuel mechanical properties are somewhat different than low burnup fuel. Two areas of particular interest for long-term dry storage where the mechanical properties of high burnup fuel, specifically the cladding, compared to low burnup fuel are different are hydride reorientation and ductile-to-brittle-transition temperature (DBTT).

At present, based on existing data, it is believed that long-term safe storage of SNF is possible, however the information to be gained through this project will help validate and solidify the technical bases for very long-term (beyond 60 years) wet and dry storage of both low and high burnup SNF. DOE, EPRI, NRC, and other U.S. and international organizations have been collecting data on low burnup fuel for many decades, and on high burnup fuel for over a decade, such that a database of low and high burnup SNF properties already exists. Furthermore, DOE, EPRI, and several organizations outside the U.S. are continuing to collect high burnup SNF data. Nevertheless, the NRC has begun asking applicants for dry storage system license renewals for information on the condition of high burnup SNF after the initial licensing period (20 years). NRC has recommended a high burnup demonstration program to address these questions and has suggested some considerations for such a program [NRC 2013]. NRC has also asked the applicants for information on the transportability of high burnup SNF after extended storage.

In combination with the growing database on high burnup SNF properties, a HDRP using high burnup SNF—like that done using low burnup SNF—could provide considerable information to address NRC's questions. The existing and future data and the results of the HDRP could:

- Form part of the basis for the development of aging management plans (AMPs) after the initial storage periods
- Provide data for multiple high burnup license renewal applications expected in the next decade, such as:
  - 2012: Prairie Island TN-40; Calvert Cliffs NUHOMS
  - 2015: Transnuclear NUHOMS 1004 design
  - 2020: NAC-UMS; Holtec HI-STORM designs
- Provide confidence in the ability to transport SNF prior to shipment to a consolidated storage, reprocessing, or permanent disposal facility

In 2012, DOE made the decision to solicit proposals from industry to develop a Research and Development Project using the science-based, engineering-driven approach outlined here. The result of that solicitation process was the award of a contract to an industry team, led by EPRI, to develop a HDRP using high burnup SNF. The Test Plan for the HDRP is the subject of this document.

3.0 TEST PLAN

This section provides the Test Plan. The main purpose of the HDRP is to collect information from an instrumented cask under 'typical' conditions—conditions that closely emulate the actual loading, drying, and storage conditions experienced by high burnup SNF. The typical conditions the HDRP will maintain are roughly as follows:

- The SNF will be loaded into the cask in the spent fuel pool.
- The cask will be dewatered and dried using an approved drying method.[18]
- Peak SNF cladding temperatures will not exceed 400°C.[19] Peak cladding temperatures typically occur during the drying process. The design and analysis will ensure peak rod temperatures always remain below 400°C. No attempt will be made to achieve a particular target peak temperature during drying or subsequent storage. However, the planned use of high burnup fuel and cask decay heat near the upper limit of the TN-32 design (Section 3.2) will likely cause the peak temperatures in the Research Project Cask to be near the 400°C limit and somewhat higher than is typical for spent fuel currently in storage. Thus, this approach will somewhat increase the proclivity of the high burnup cladding to undergo hydride reorientation, such that the proposed method approaches a bounding case.
- Vent gases will be monitored during the drying process to determine if any fuel rods fail during this time.
- After drying, the cask will be backfilled with helium gas to maintain a chemically inert environment and to enhance heat transfer.
- During the first two weeks after the cask is backfilled with helium, the cask will remain inside the North Anna decontamination building in which any unplanned release of fission gas from the cask can be monitored. Periodic gas samples will be taken during this period to determine if fission gas, water vapor, oxygen, or hydrogen are present. The two-week thermal transient period after drying is considered to be a reasonable period for which to monitor the cask cavity atmosphere for evidence of fuel failure during or immediately after cask drying (fission products), oxidizing gas, and evidence of residual moisture. It is assumed that this is the period of time whereby the cask reaches thermal equilibrium. Calculations are in progress to validate this assumption. Nevertheless, the EPRI team will continue to investigate and evaluate methods for performing gas sampling at the ISFSI during the longer-term storage period. If a sampling method can be licensed, funded, and deployed without creating undue risk to the project (i.e., qualified), it will be implemented.

[18] Two examples of drying methods currently approved by NRC are: maintaining a vacuum of less than 3 Torr for 30 minutes; and use of hot, recirculating helium. For the Research Project Cask the standard vacuum drying process (<3 Torr for 30 minutes) will be employed using existing Dominion procedures from previous TN-32 cask loading operations.

[19] Typically, conservative thermal models are used in cask design and licensing and casks are loaded at less than the design heat load, so peak cladding temperatures are well below 400°C.

- The cask will be transferred to the ISFSI pad using a special transfer hauler. The cask will be moved to the pad and the test will continue. If water vapor or Kr-85 gas is detected during drying or the first two weeks after drying, it is anticipated that the license will allow the cask to be moved to the pad and the test would continue. This is because the presence of water vapor and Kr-85 in some of the dry storage systems could be typical if water or Kr-85 gas is found in the Research Project Cask.
- The cask will be stored at the North Anna ISFSI pad for a number of years—perhaps on the order of a decade. The exact amount of time the cask will remain in storage at North Anna will depend on several factors:
  - If an unplanned cask opening occurs (Section 3.8) the test may be terminated or re-initiated with the same fuel assemblies or different assemblies;
  - When a Fuel Examination Facility (Section 3.9) becomes available and the Research Project Cask has been licensed for transportation. At such time, it is anticipated the Research Project Cask would be prepared for shipment and then shipped to the Fuel Examination Facility, pending an approved transportation license for the Research Project Cask. If a transportation license is not obtained, then continued storage at North Anna may occur.
  - It would be desirable for the cask to remain in storage long enough such that temperatures in at least part of the cask internals descend low enough for some of the high burnup cladding temperatures to be under the DBTT range based on laboratory data existing at the time. Existing DBTT data suggests this temperature is between below room temperature and approximately 150°C. Once the fuel assemblies to be used in the Research Project Cask are selected, thermal modeling will be conducted to determine at what time in the future some cladding temperatures will descend into this range.
- As the Research Project Cask is prepared for transportation in the North Anna decontamination building, a final gas sample will be taken, if possible, for the presence of fission products, water vapor, oxygen, and hydrogen.[20]
- The Research Project Cask will be designed with eventual transportation to an off-site location in mind. Hence, the SNF in the Research Project Cask will experience forces typical of 'normal conditions of transport' when the Research Project Cask is transported.

The need to instrument the Research Project Cask along with the desire to include multiple, high burnup SNF types will likely mean the HDRP will not be perfectly typical. The following are examples of the needs and practicalities for the HDRP that could result in a small degree of departure from being perfectly typical:

- *The HDRP will include SNF with as high a burnup as possible.* In reality, in-service casks and welded canister designs are all limited in burnup by regulatory Technical

[20] Taking a gas sample in the decontamination building requires breaking the double O-ring seal on the vent port. Once the sample is taken, the seal on the vent port will need to replaced, and leak tightness will need to be demonstrated. A gas sample will be taken only if Dominion can demonstrate compliance with any leak tightness testing criterion in effect at the time of shipment.

Specifications, or the number of assemblies with higher decay heat (due to either storage of lower burnup SNF with shorter decay times or higher burnup SNF with shorter-to-moderate decay times) is limited ('zoned' loading). Loading the Research Project Cask with some higher burnup SNF may cause higher peak temperatures and different temperature distributions and histories than SNF under more typical storage conditions.

- *The cooling rate versus time may be different for the SNF in the HDRP than for that in actual storage conditions.* This departure from being perfectly typical is a deliberate design feature of the HDRP. The somewhat higher temperatures the assemblies in the Research Project Cask will experience compared to the majority of the SNF in actual storage will provide more challenging conditions for the high burnup SNF in the HDRP.
- *Some assemblies used in this HDRP may be driven to higher burnups than might be typical for that particular design.* Test results must be interpreted based on the characteristics of the final fuel assemblies that are included in the test.
- *The Research Project Cask will include instrumentation penetrating to the inside of the cask.* This will require a special lid rather than the standard lid. The special lid will only minimally perturb the spatial and temporal temperatures inside the cask.
- *Some 'sister' rods will be shipped to a national laboratory for pre-test examination.* This will involve pulling rods and transportation. The reduction in decay heat due to removal of a handful of rods will have a negligible effect on internal cask temperatures.
- *The Research Project Cask may not be loaded with fuel in every cell location.* Typical practice is to load fuel in every location due to economics; however some instances do require loading a cask with empty cells due to limited availability of qualifying fuel or to meet overall cask decay heat limits. It is a primary goal of the HDRP to load fuel in every cell location, but it may be necessary to leave some cells empty to meet the heat load and criticality requirements for licensing. The conditions for the fuel would be driven largely by the local conditions within a particular cell, especially for the high decay heat, high burnup assemblies to be loaded, however the contributing effects from neighboring cells would be compromised somewhat if not all cells contained fuel.

The HDRP Test Plan included in this section therefore minimizes departures from typical conditions while still accomplishing the main objective: obtaining data on the near- and long-term behavior of high burnup SNF in dry storage.

3.1 Source of Spent Nuclear Fuel

Dominion's North Anna Power Station will be the source of the SNF used for the HDRP. There are two units at North Anna, each unit being a Westinghouse 3-loop PWR. The fuel is all 17x17 design for both units, and several different varieties of this design (i.e., different cladding materials) exist in discharged high burnup fuel. The fact that North Anna has high burnup fuel with different cladding materials makes it particularly attractive as a host site for this type of HDRP.

The fuel for the Research Project Cask is currently stored at North Anna in the spent fuel pool shared between both units. Access to the fuel is provided through normal fuel-handling practices

and procedures using the fuel building's handling crane under the site's reactor operating licenses (License Numbers DPR-32/37, NPF-4/7; Docket Numbers 50-280/281, 50-338/339).

Shown in Figure 3-1, the ISFSI at North Anna consists of storage systems used under the General License provisions of 10 CFR 72 co-located with systems stored under the site-specific provisions of Part 72 (the original Part 72 licensing framework). An existing TN-32 cask, fabricated but never used, will be used as the Research Project Cask following suitable modifications. North Anna has extensive experience with TN-32 cask technology having loaded 27 TN-32 casks under the site-specific license between 1998 and 2007 (License SNM-2507, Docket 72-16). This site-specific ISFSI license will need to be amended to address the characteristics of the Research Project Cask, cask performance with the selected high burnup fuel, and particular data and testing attributes of the cask. The NRC must approve the license amendment, but no other state or local approvals are required.



Figure 3-1: Placing Dry Storage Casks on the ISFSI Concrete Pad at North Anna.

The loaded Research Project Cask will reside at North Anna for the duration of the host-facility testing period. Security will be provided using the existing site security for the ISFSI. Other than normal onsite cask transfer from the plant to the ISFSI, no transportation modes will be necessary. The only state or local public interactions associated with the HDRP will be routine public outreach meetings or via the license amendment processes. Spent fuel management at North Anna is typically addressed at the routine public outreach meetings.

3.2 Nature and Amount of Spent Nuclear Fuel to be Used

All SNF assemblies to be used for the HDRP currently exist at North Anna Power Station in the spent fuel pool and can be loaded into the Research Project Cask using normal cask-loading procedures. The process for loading a cask includes developing a fuel certification that documents that the fuel planned for loading meets the license requirements. The cask is lowered into the cask-loading area of the spent fuel pool. Using the fuel-handling crane and the fuel-handling tool, fuel assemblies are placed into the cask locations designated by the fuel certification document. After the cask is loaded and before the lid is placed onto the cask, the unique fuel assembly identification numbers are verified by video to reside in the proper cask location as designated by the fuel certification document.

The fuel assemblies to be used in the HDRP will have various cladding types including standard Zircaloy-4, low-tin Zircaloy-4, Zirlo™, and M5™ (Table 3-1). The value of using different cladding types is that the types vary in the relative amounts of alloying elements, as well as final metallurgical treatment (e.g., cold-worked stress-relieved, partially recrystallized, fully recrystallized). Two high burnup fuel assemblies (approximately 58 GWD/MTU) with standard Zircaloy-4 cladding, that were previously characterized during poolside fuel examinations, are to be included in the Research Project Cask [EPRI 1992]. An additional Zircaloy-4 assembly (approximately 53 GWD/MTU) with low-tin composition will also be stored in the Research Project Cask. Acquisition of sister rods[21] from the two standard Zircaloy-4 fuel assemblies (burnup of approximately 58 GWD/MTU) is not possible in this HDRP, as the assemblies do not have removable top nozzles to gain access to the fuel rods. However, sister rod extraction from the low tin Zircaloy-4 assembly (burnup of approximately 53 GWD/MTU) is possible and is included as a sister rod donor candidate assembly.

[21] A 'sister rod' is a rod that has been determined to have very similar characteristics to those that will be stored in the Research Project Cask. There are two potential donor fuel assembly sources for sister rods: assemblies having similar operating histories to those assemblies that are chosen for storage in the Research Project Cask or actual fuel assemblies selected for storage. Properties that must be similar in order to be considered a 'sister' are: same fuel type (e.g., Zircaloy-4, Zirlo, M5), same initial enrichment, same relative reactor core location, and the same reactor operating history. See Section 3.4 for additional discussion on Sister Rods.

Table 3-1: Available High Burnup Fuel Assembly Types for the High Burnup Dry Storage Research Project

Cladding Material	Burnup Range (GWD/MTU)	Number of Assemblies Available	Last Irradiation	Manufacturer	Assembly Type
Standard and Low-tin Zircaloy-4	53-58	3	1989	Westinghouse	Lo-Par[22]
Zirlo	51 – 55	20	2004 – 2007	Westinghouse	V5H[23]
M5	52 – 67	11	2001-2010	AREVA	AMBW[24]
Low-tin Zircaloy-4	49 – 50	3	1994	Westinghouse	V5H

Not all of the fuel assemblies in Table 3-1 will be used in the HDRP. Design analyses will be performed to include most of the assemblies, and in particular, the assemblies with the greatest intrinsic value (e.g., limited amount of existing data on fuel/cladding type for burnup > 45 GWD/MTU). However, the thermal, criticality, and shielding analyses performed for the DLBD will govern how many of the above assemblies can be loaded into the Research Project Cask. The final design, including fuel selection and placement, is not part of the Test Plan. It is not practical, at this point, to define absolute criteria that must be met for fuel selection until the analyses are completed. In the fuel selection many tradeoffs may need to be made between the need for research data and the necessity to meet licensing requirements. Furthermore, while the analyses will evaluate the specific payload proposed for loading in the cask, a limited amount of flexibility in final fuel selection will be included in the licensing, should last-minute substitutions be required for some unforeseen reason. By performing the analysis for a narrow population of allowable fuel assemblies, excess design margin to account for a wider range of fuel assembly parameters does not need to be included. However, if the analysis evaluated only 32 specific assemblies and one of the assemblies could not be loaded for some unforeseen reason, loading would have to be delayed until a license amendment could be prepared, reviewed, and approved; thus including some flexibility is prudent.

The high burnup assemblies planned for use will range in average assembly burnup between 50 GWD/MTU and 67 GWD/MTU. Bear in mind that individual rod average burnups will be higher. The capability to load a full complement of 32 high burnup fuel assemblies in accordance with the cask thermal analysis, criticality analysis, and regulatory requirements must still be determined. It may be necessary to load a minimal number of fuel assemblies of lower burnup, or to leave certain cask storage locations vacant, as a last alternative, to accommodate the design heat-load limits. It may also be necessary to add poison rods to meet the regulatory criticality limits. Assuming a total of 32 assemblies are loaded, the estimated nominal MTU in the

[22] Low neutron parasitic materials used in fabrication.
[23] Vantage 5H design.
[24] Advanced Mark BW design.

Research Project Cask is expected to range from 14.56 to 15.04, or less if some cells have to be left vacant.

The following bounding criteria will be used to select fuel assemblies to be used in the Research Project Cask. The final selection and location of fuel assemblies within the Research Project Cask will be based primarily on the analyses established in the DLBD:

- All fuel shall be intact—no structural defects or open holes
- Assemblies susceptible to bulge joint corrosion will have been repaired
- Assemblies will be free of envelope violations that prevent the fuel assembly from being inserted into the cask cell (e.g., torn grid straps, debris, or assembly distortion), and unusual corrosion or crud
- The combination of assemblies to be used in the Research Project Cask will not result in any cladding temperatures exceeding 400°C

The fuel and cask will reside at North Anna Power Station's ISFSI during the life of the storage project. Security will be provided using the existing site security for the ISFSI, which will continue to meet all regulatory and licensing requirements.

The proposed Research Project Cask is a TN-32 bolted metal design. While other dry storage system types could be used in the HDRP, such as a modified, welded stainless steel canister design, the data to be collected is essentially independent of dry storage system type. The primary focus of the HDRP will be on obtaining confirmatory data on the long-term behavior of high burnup fuel rather than the behavior of the particular dry storage system (bolted lid versus welded stainless steel). Both designs provide typical time/temperature environments for the stored spent fuel.

The TN-32 Research Project Cask currently exists and was fabricated for general license use with NRC CoC 1021. However, Dominion does not use TN-32 casks under the general license provisions of 10 CFR 72. TN-32 casks are used at North Anna using the site-specific license provisions of 10 CFR 72. Therefore, Dominion will need to generate a license amendment request (LAR) for use of the cask at North Anna and submit it to the NRC for review and approval. The LAR would include all the basic design features of a TN-32 cask as well as the planned fuel payload, the analyses supporting the fuel payload, and the instrumentation and test features unique to the Research Project Cask. The site-specific license is a significant benefit for this type of application, as these particular research project features do not need to be addressed on a generic basis as with a license under the General License provisions of 10 CFR 72.

The planned design and licensing approach is described as follows:

(1) Develop the Research Project Cask DLBD for storage including:

(a) Proposed fuel payload including contingency measures if substitutions are required
(b) Testing and data acquisition methods
(c) Expected heat loads from fuel
(d) Effects of high burnup

(2) Develop site-specific ISFSI LAR for storage of TN-32 Research Project Cask:

(a) Base LAR on the DLBD
(b) Include separate Technical Specifications for the Research Project Cask
(c) Include need for periodic tests
(d) Schedule/attend pre-application meetings with NRC
(e) Submit LAR
(f) Respond to requests for additional information

(3) Develop the foundation and framework for a future Part 71 transportation license application:

(a) Perform all bounding calculations for transportation to identify areas needing additional analysis
(b) Perform sufficient detailed calculations to provide a reasonable expectation that a transport license could be obtained at some point in the future
(c) Obtain NRC feedback on design for future transport license

3.3 System Design and Data to be Collected

This section describes the design of the cask and data collection activities that will provide the confirmatory data desired.

3.3.1 Cask Design and Operations

The proposed Research Project Cask will use an existing TN-32 cask that was fabricated using an approved 10 CFR 72 Quality Assurance Program to be used with NRC CoC 1021. The codes and standards used for fabrication are identified in the TN-32 Final Safety Analysis Report (FSAR), [Transnuclear 2012]. The existing cask will be modified to include the special instrumentation for the Research Project Cask. Transnuclear will transfer ownership of the cask to Dominion using Dominion's applicable Quality Assurance requirements. The TN-32 cask is designed to use a single lid with a double-seal system. The helium pressure between the seals is monitored for seal integrity during storage. Figures 3-2 and 3-3 show the TN-32 cask without the lid and with the lid being installed, respectively.

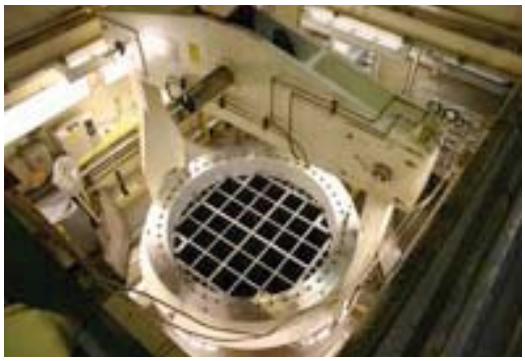


Figure 3-2: View of Fuel Basket within a Typical TN-32 Cask.



Figure 3-3: Lid Installation of a TN-32 Cask.

The instrumentation considered for the Research Project Cask includes several thermocouple lances through the lid using a modified lid design that would meet applicable storage regulations. The instrumentation penetrations seals would need to be monitored much like the other penetrations on the cask lid. Other instrumentation may be considered in the Test Plan development.

In principle, the design and locations for the temperature lances will be similar to those used in a series of demonstrations using full-scale casks containing low burnup fuel in the 1980s and 1990s. For illustrative purposes only, an example of the positions of the thermocouple lances used in those early tests with low burnup fuel is shown in Figures 3-4 and 3-5. The exact locations for the thermocouple lances for the high burnup Research Project Cask will be somewhat different than the examples provided, and will depend on the exact locations of the high burnup assemblies of interest in the Research Project Cask. Note also that the assembly guide tube pattern shown on Figure 3-5 is representative of a 15x15 fuel assembly, which will

differ slightly from the 17x17 fuel assemblies used in the Research Project Cask. The exact number and position of lances and the exact number and vertical position of the thermocouples inside each lance will be provided as part of the publicly available documentation supporting the LAR to NRC for storage of the Research Project Cask.

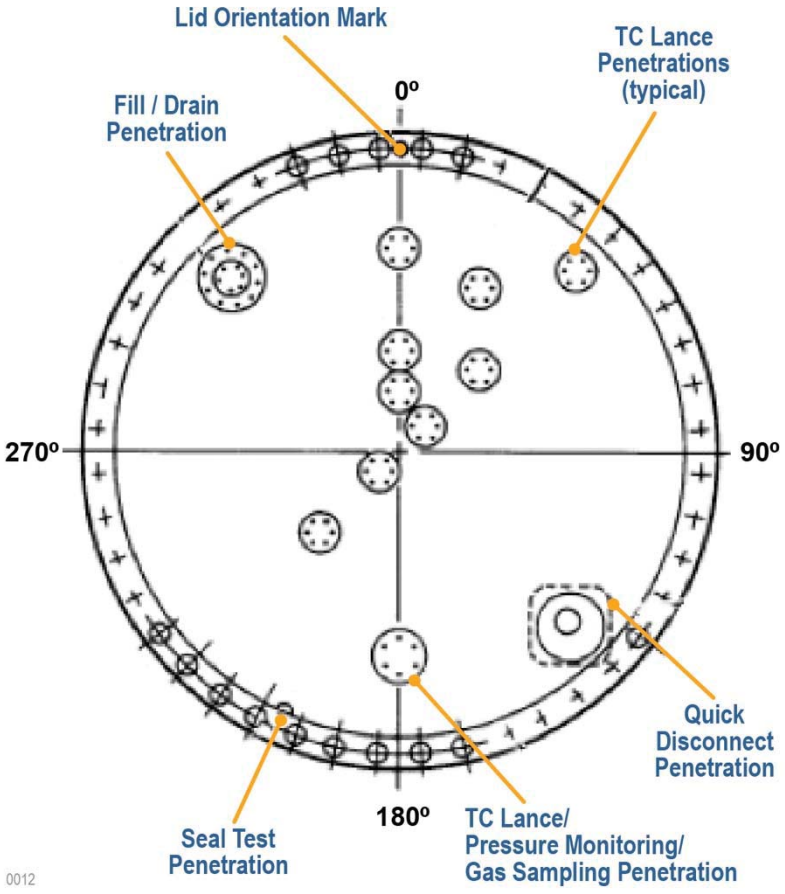


Figure 3-4: Example of Cask Lid Penetrations for Temperature Lances: CASTOR-V/21 Primary Test Lid [Figure 3-3 from EPRI 1986, for illustrative purposes only].

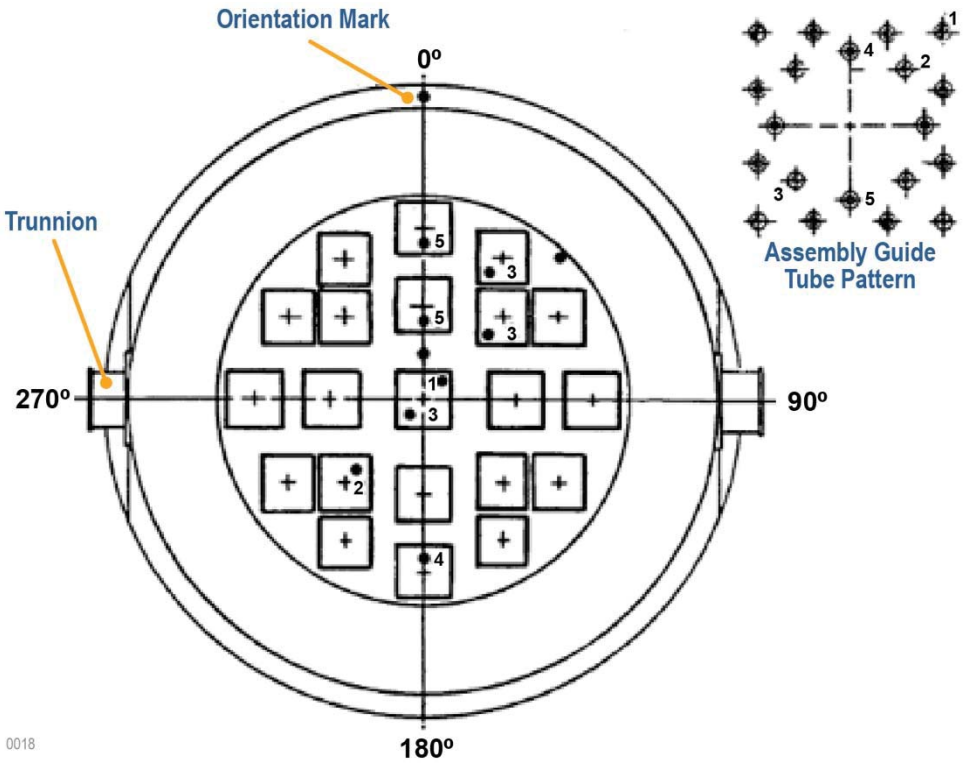


Figure 3-5: Example of Locations of Temperature Probes Within and Near the Assemblies: CASTOR-V/21 Thermocouple Lance Locations [Figure S-3, EPRI 1986, for illustrative purposes only].

The tests and instrumentation for the project will be obtained using approved site procedures with the appropriate Quality Assurance requirements. The data will be reported on a regular basis over the duration of the testing interval (see Section 3.3.3) and made available on a website by DOE.

One of the primary objectives of the HDRP is to monitor the internal temperatures during the loading evolution. The following sequence will be used during the loading process, however changes may be necessary to accommodate unforeseen limitations.

- The lid will be placed onto the cask under water following the fuel loading as with all TN-32 loadings.
- The cask will then be lifted from the spent fuel pool and out of the fuel building into the cask-loading bay.
- There, while the cask cavity is filled with water, the thermocouples will be inserted through the lid and sealed. This will save personnel exposure compared to inserting them into a dewatered cavity, and it allows recording of initial wet fuel temperatures.
- Thermocouple connections will then be made to a data logger to begin collecting temperature data.

- The cask would then be drained while backfilling with helium to prevent exposing the fuel to an oxidizing environment.
- The drying process then begins by reducing the cask cavity to under 3 Torr and then it is secured. It is assumed that the same drying Technical Specifications surveillance requirement (that currently exists for Dominion's TN-32 casks at North Anna) will be approved for use with the Research Project Cask. Monitoring of the vent gases during the drying process will be performed to determine if any fuel rods fail during this time.
- If the cask pressure passes the Technical Specifications surveillance requirement, it is considered dry, and the cavity is backfilled with helium to a pressure established in the Technical Specifications.
- The pressure in the cask will be monitored for a period of two weeks while the cask resides in the cask-loading bay.
- Cavity gas sampling will also be performed for a period of two weeks while the cask resides in the cask-loading bay. The periodic gas samples of the cask cavity will be obtained and analyzed for fission gas, hydrogen, oxygen, and moisture. This is assumed to be the period of time whereby the cask reaches thermal equilibrium. All cavity gas samples need to be taken prior to establishing the overpressure monitoring system with helium to allow an acceptable leak-rate test to be performed. Cavity gas samples obtained while this temperature transient is occurring are viewed to be the most valuable gas composition data. The thermal transient period of two weeks after drying is considered to be a reasonable period for which to monitor the cask cavity atmosphere for fission products, oxidizing gas, hydrogen, and moisture. Nevertheless, the EPRI team will continue to investigate and evaluate methods for performing gas sampling during the storage period. If a sampling method can be licensed, funded, and deployed without creating undue risk to the project, it will be implemented.

The instrumentation requirements, lid design, and instrumentation will be included in the cask's DBLD used to form the basis for Dominion's LAR, which will be submitted to the NRC for approval.

3.3.2 Data to be Collected and Instrumentation

The purpose of this high burnup R&D project is to collect data needed to confirm the behavior of high burnup fuel for storage and transportation. The data to be collected was identified as that data that could be obtained from such a Research Project Cask, which would provide the maximum amount of confirmatory data. Hence, the data to be collected, and the purpose for that data, are described as follows:

- Detailed half-face visual exams of each assembly to be loaded into the cask
  - Purpose:
    - Provide baseline detailed visual for comparison after storage period
    - Confirm no defects are visible

- Temperatures at 'key' locations inside and outside the cask[25]
  - Purpose:
    - Confirm/benchmark 'best-estimate' temperature models
    - Assess safety margins to actual limits (i.e., measured vs. predicted peak temperatures during vacuum drying and subsequent dry storage)
    - Support the determination of the cladding stress; also governing the amount of hydride reorientation is the cladding stress, which is a function of the internal rod pressure and remaining cladding thickness
    - Understand what fraction of the cladding, if any, will be prone to hydride reorientation (currently we assume 100 percent will be prone to reorientation). This will be determined by considering the combination of cladding type, temperature distribution, sister rod internal gas pressure, sister rod hydride content/distribution/orientation, and sister rod cladding oxide thickness data. Together, these data can be compared to laboratory experiments under specific cladding type, temperature, hydride concentration/distribution/orientation, and cladding stress conditions to predict the degree of hydride reorientation occurring in the cladding in the Research Project Cask.
    - Determine how much cladding, if any, will have temperatures descending into the ductile-to-brittle transition range and timeframe the cladding will enter that range
- Internal gas sampling: gas pressure
  - Purpose: Monitor the cover gas, and also provide a gas pressure profile during the two-week thermal soak transient
- Internal gas sampling: water content in atmosphere
  - Purpose:
    - At very early times (during the drying operation and over the next two weeks) the water vapor content in the gas will determine how much residual water is left in the cask; any increase in water vapor content during the first two weeks after drying will be observed
    - As the system ages, it is likely the water vapor concentration in the helium atmosphere will decrease as the water reacts with the cask internals; in the case of water hydrolysis into hydrogen and oxygen gas, it is anticipated that any oxygen produced will react with the cask internal cladding and other surfaces
- Internal gas sampling: oxygen content
  - Purpose: ensure oxygen is removed during the initial vacuum drying and helium backfilling process
- Internal gas sampling: hydrogen content

[25] These considerations will govern the final decision on the exact number and locations of the thermocouples.

  - Purpose: identify the amount of hydrogen that may be present after completion of the drying process and due to radiolysis of water left in the cask

- Internal gas sampling: fission product (FP) gas content
  - Purpose:
    - FP gases emerging during or immediately after the drying process would indicate that one or more cladding defects existed prior to loading or a defect occurred during drying[26]
    - FP gases found in the gas sample taken shortly before the cask is reopened (i.e., after the long-term storage period) will indicate cladding defects occurred during storage

Regarding the period of gas sampling, the thermal transient period of two weeks after drying is considered to be a reasonable period for which to monitor the cask cavity atmosphere for FPs, oxidizing gas, and moisture. Nevertheless, the EPRI team will continue to investigate and evaluate methods for performing gas sampling during the storage period. If a sampling method can be licensed, funded, and deployed without creating undue risk to the project, it will be implemented.

DOE will make the data available via a website accessible to the public.

The quality objectives for the data need to be considered in the data collection process for the data to be of maximum use in future dry storage system licensing. The quality objectives are governed by a number of factors: ability to provide adequate benchmarking data for computer codes and analytical models; ability to adequately quantify long-term degradation processes, which require data on initial conditions; applicable Quality Assurance requirements; and to some degree, the limitations in the ability to collect and the accuracy of the particular data.

In general, the data collected will likely be used to support future licensing decisions. As such, the data will be collected under a Quality Assurance Program using approved procedures. Also, to improve the value of the data collected, it is desired to minimize the overall uncertainty of the data to the extent practicable through appropriate selection, calibration, and insertion of the instruments and design of the system for measuring and recording the data. For example, by reducing the number of electrical connections in series from the recording instrument to the data recorder, the overall system uncertainty will be reduced.

The temperature data to be collected will be used to improve the parameters used in licensing to allow the thermal modeler to substitute more ‘best-estimate’ (rather than ‘conservative’/ bounding) parameters. The temperature data quality will also be affected by the location of the instrumentation. Ideally, the temperature measurements will be taken directly on the surface of the cladding. Since this is not possible, it is proposed to insert the instrumentation in very close

[26] Cladding defects during vacuum drying and subsequent storage leading to fission gas release to the cask interior are not expected because only intact fuel assemblies will be used in the Research Project Cask.

proximity of the fuel cladding, (i.e., the guide tubes). The temperature lances used to insert the temperature instrumentation into the guide tubes will be similar in concept to those used in the 1985-1999 low burnup CASTOR/V21 cask demonstration at INL [EPRI 1986].

The thermocouples are anticipated to continue to function during the entire storage period. However, if the thermocouples fail to function for the entire storage period, the temperature data up to the time of failure will still provide important benchmarking data for thermal models. Furthermore, the extent of any hydride reorientation (and the concomitant DBTT) during the drying and storage period will still be obtained at the end of the storage period when the cask is reopened and rods are extracted for destructive examination.

The data to be collected from characterization testing of individual high burnup rods is an important aspect of this project. Hence, it is essential that all handling, transportation, transfer, cladding preparation, instrumentation calibration, and data collection procedures maintain traceability through the application of appropriate Quality Assurance requirements.

To collect the desired data, the Research Project Cask lid will be modified to accommodate approximately seven thermocouple lance instrument penetrations. See Figure 3-6 for an example (for illustration purposes only) showing various radial locations that may be chosen. It is anticipated that up to seven radial locations will be in the final design. The thermocouple lances will be inserted into the guide tubes of several fuel assemblies. It is anticipated that the lances will be located at various radial locations within the cask (aligning with key assemblies), and each lance will contain approximately nine individual thermocouples at defined axial locations (Figure 3-7). The EPRI team further anticipates inserting a lance in a non-fueled region of the cask toward the radial extremity to further provide benchmark reference data for cask thermal performance evaluations. Additional consideration will be given for thermocouples to be placed on the cask exterior. The host station’s meteorological system data will supply the environment measurements needed for conditions at the pad used to correlate with the data collected inside the cask.

At the top of the thermocouple lance, the thermocouple wires will be sealed and terminated into a multi-pin connector. The thermocouple lance will pass through and be sealed to a bolted flange containing a dual seal.

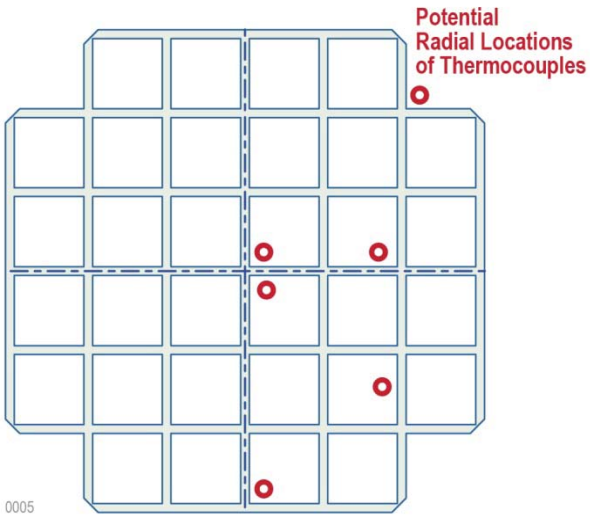


Figure 3-6: Example of Potential Thermocouple Radial Locations within Fuel Assembly in Cask.

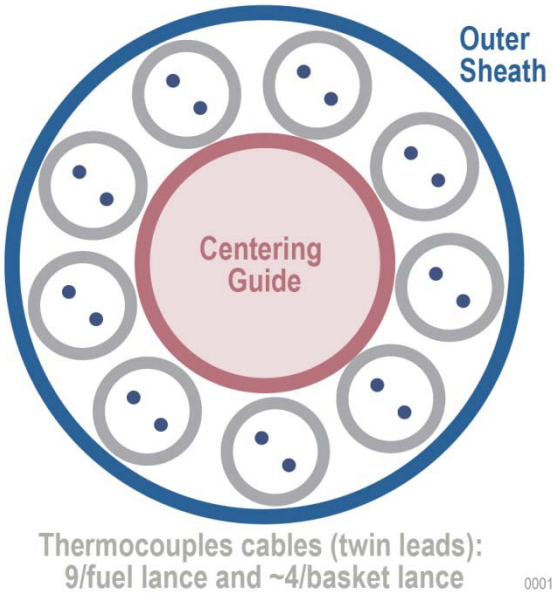


Figure 3-7: Cross-sectional View of Typical Thermocouple Lance.

A guide fixture will be used to ensure proper alignment and to avoid damage to either the fuel or the thermocouples. Figure 3-8 provides a conceptual means to aid in the insertion of the thermocouple lance into the guide tube. The guide will be designed for ease of installation using remote tooling. Prior to deployment at the North Anna Power Station, fit-up testing and training will be conducted to demonstrate that the equipment will function as designed and operators and technicians are proficient using the equipment. This evolution is very important to ensure the planned methodology, associated procedures, and training will result in a successful execution of this critical step. It is also important that the host site have confidence in the approach prior to deployment to their plant. As low as reasonably achievable (ALARA) considerations are also a

major factor in the equipment design and operational procedures used for the installation of the thermocouple into the assemblies. Careful design and fit-up testing using proven ALARA techniques will minimize worker dose.

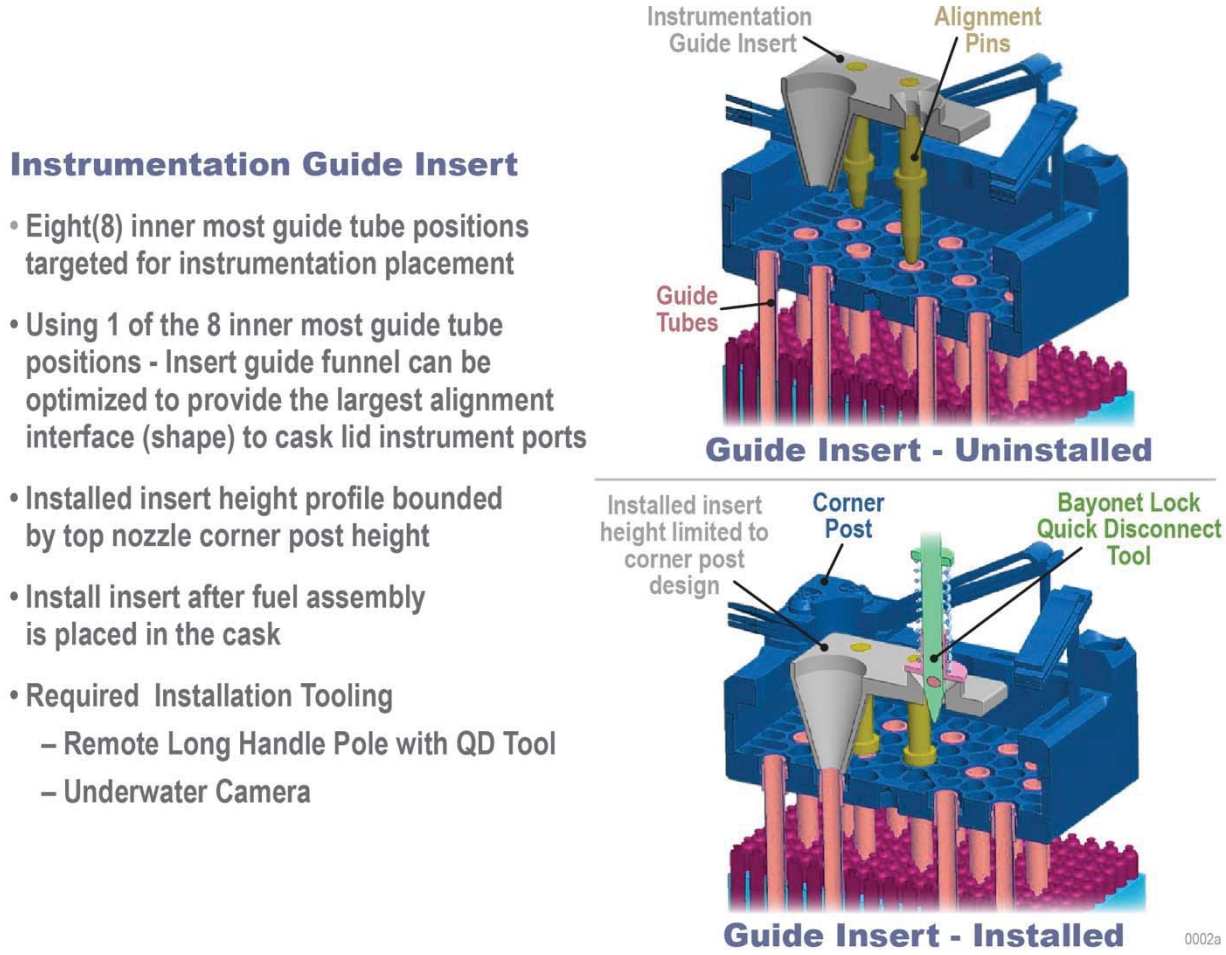


Figure 3-8: Conceptual Instrumentation Guide.

Additional instrumentation for consideration would include a pressure transducer installed on the overpressure (OP) tank. The OP tank provides the monitoring gas pressure to the inter-seal space. Recognize that the TN-32 is a single lid cask and does not have a direct monitored penetration to the cask cavity. Instead, the pressure is monitored between the required dual seals (much like any other bolted lid cask design). The inter-seal pressure on the TN-32 is maintained at a higher pressure than the cask cavity pressure such that if the inter-seal pressure (from the OP tank) decreases beyond a certain set point, an alarm is received indicating a potential problem with a seal. By Technical Specifications for the existing TN-32 casks at North Anna, the inter-seal pressure and the pressure switches undergo periodic surveillance at three-year intervals. This is expected to also be the case for the Research Project Cask.

A data logger will likely be contained in a weatherproof box mounted on the side of the Research Project Cask. The logger would digitally record temperature and inter-seal pressure data from all

instruments used on the Research Project Cask. The logger likely will be powered by battery with a solar collector to keep the battery charged. Temperature and pressure data would be recorded periodically, as discussed in Section 3.3.3.

The design and selection of the instrumentation and supporting equipment for the project is based on many years of performance data at operating nuclear power plants as part of the station's in-core instrumentation. The temperatures, pressures, radiation doses, and other environmental conditions encountered during reactor operations are easily greater than those that the instrumentation will be subjected to in the HDRP. Historical data from usage of similar equipment at numerous operating commercial nuclear power stations provides documented evidence indicating that a functional lifespan of at least 10 years is reasonable. After fabrication of the thermocouples, extensive testing and qualification of the instruments is performed to ensure it meets the required specifications. Testing and qualification of the instrumentation includes:

- Physical inspection
- Radiography
- Heat treatment (anneal)
- Hydrostatic testing
- Electrical testing

Additionally, routine radiation surveys at the cask and the ISFSI in general are performed quarterly. While it is not expected that this data will provide any important information, it would identify any anomalies.

The modifications to the existing cask needed for the Research Project Cask are estimated to take about 18 months, which includes time for fit-up testing. The materials needed for the instrumentation would be the standard materials currently supplied for reactor thermocouples, with a flange design compatible with the modified cask lid.

Planned Measurements

- Approximately 63 thermocouples (e.g., 7 radial and 9 axial locations) – measurements will be recorded by the data logger system
- Site ambient conditions will be taken from the station's meteorological system
- A pressure transducer may be utilized to send OP tank pressure readings to the data logger for recording
- Cask external dose rates will be recorded as part of the normal site radiation protection program

- Gas sampling and analysis during the first two weeks after cask drying and helium backfilling will be accomplished via grab samples and analysis at an onsite laboratory prior to moving the cask to the pad.

3.3.3 Frequency of Measurements

It is important to collect data with a frequency sufficient to accomplish the HDRP objectives. While data collection frequency will vary depending on the rate of change of the variable during the period of the measurement, no need for continuous data collection is foreseen. The proposed data collection frequency, and the rationale for the proposed data collection frequency are as follows:

- Temperature measurements:
  - During the initial cask drying process: every minute. Rationale:
    - Provide data for thermal models during the larger temperature transients during the drying process.
    - Measure peak temperatures and time at peak temperature to support assessments of the degree of hydride reorientation.
  - During the long-term storage period: minimum of twice per day—preferably near the time of maximum and minimum daily ambient temperature.[27] Rationale:
    - Data collection at this frequency will also provide information on how cask gas temperatures are affected by daily and seasonal temperature fluctuations and other ambient conditions (rain, snow, and cloud cover).
    - Data collection at this frequency will provide information on high burnup cladding time at temperature that will provide input to hydride reorientation, ductility recovery, and creep behavior.
- Gas pressure and composition measurements:
  - First two weeks: two times per week.
    - Gas sampling in the first two weeks immediately following loading will provide the maximum data value as both potential rod failure and conversion of any residual water to the gas phase will likely occur either during or almost immediately after the cask drying process.
    - Gas pressure measurements during the first two weeks will provide an indication that all seals and gas-sampling procedures are functioning as predicted.
  - Long-term storage period: no cask cavity gas pressure or gas sampling is proposed.
    - Significant changes in gas composition, if they occur, will most likely occur during the first two weeks after drying. Furthermore, due to the design feature of maintaining a higher helium pressure between the inner

[27] Temperature measurement frequency may be more than twice per day. The exact temperature data collection frequency will be established by the amount of data that can be stored in the data logger, and the frequency with which the data is downloaded from the data logger.

and outer seals, no oxygen ingress into the cask cavity will be possible. There are license requirements to avoid unmonitored release of radionuclides to the atmosphere, so it will be difficult to obtain gas samples once the Research Project Cask has been moved out of the building onto the ISFSI pad. Additionally, it may not be possible to obtain a satisfactory leak test either on the ISFSI pad or in the facility once the seal has been broken. The final gas sample will be taken at the end of the prolonged storage period shortly before the cask is reopened. Nevertheless, the EPRI team will continue to investigate and evaluate methods for performing gas sampling during the storage period. If a sampling method can be licensed, funded, and deployed without creating undue risk to the project, it will be implemented.

Detailed system operational procedures and associated training will be developed and implemented in accordance with the host site's programmatic requirements. In addition, procedures and training requirements governing the inspection, maintenance, repair, and calibration requirements of the instrumentation and related equipment will also be developed and implemented. The calibration frequency and technical requirements will be established based on instrument vendor input and performance requirements.

The EPRI team has the ability to change the frequency of the temperature data collection throughout the course of the storage period.

3.4 Sister Rod Evaluation

To evaluate the effect of storage on the high burnup rods, it is necessary to test the fuel rods before and after storage in order to compare any differences in behavior induced by drying and long-term dry storage. Since the testing needed to properly characterize the rods' parameters requires destructive examination, it is not possible to test the same rods before and after storage. Hence, similar, or sister rods are used. Sister rods are fuel rods that have similar characteristics (e.g., same design and similar power histories) to fuel rods in assemblies that are planned for storage in the Research Project Cask. Also see footnote 21 in Section 3.2 for a description of sister rods.

Collecting data on typical high burnup fuel from three different cladding types (low-tin Zircaloy-4, Zirlo, and M5) subjected to vacuum drying and then placed into a dry, inert helium atmosphere (dry storage) for a long period of time is the primary goal of the proposed HDRP. While the plan is to load standard Zircaloy-4 assemblies and low-tin Zircaloy-4 assemblies into the Research Project Cask, only the low-tin Zircaloy-4 assemblies will be studied in detail as described later in this section. Note that for the purposes of this project, results for low-tin Zircaloy-4 and Zircaloy-4 are considered to be comparable. Several studies have been performed on a limited number of *empty*, unirradiated and irradiated cladding tubes to better understand and quantify the impact of the thermo-mechanical transients experienced by SNF during drying and dry storage. Based on early understanding of observed degradation phenomena, limitations on

peak cladding temperature and thermal cycling have been adopted in the U.S. and internationally. Regulatory criteria among different countries are not uniform, however. Therefore, the objectives are to verify that (1) the expected behavior of high burnup fuel, typically characterized by high decay heat and high cladding stress states, meets performance criteria stipulated in the regulations, and (2) there are no unidentified synergistic effects that would lead to unexpected fuel rod degradation.

Rod Selection

There are two potential donor fuel assembly sources for sister rods: assemblies having similar operating histories (symmetric partners) to those that are selected for storage in the Research Project Cask or actual fuel assemblies chosen for storage.

Symmetric partner assemblies have burnup characteristics that are nearly the same (i.e., there may be minor differences in relative power between the symmetric partners) and operating histories would be similar. Typically, symmetric partner assemblies come from the same reload batch of fuel assemblies fabricated for use in the reactor. Therefore, rods from an assembly that is a symmetric partner to a fuel assembly planned for storage in the Research Project Cask should provide good references for the fuel rods in the stored assembly.

The other potential source for sister rods is to remove particular fuel rods from an actual fuel assembly planned for storage. The void in the assembly where the removed rod existed will be replaced with a solid, non-fuel rod called a dummy rod.[28] Sister rods from the same fuel assembly planned for storage are ideal in that they truly share the same power and operating history. The sister rods will be removed prior to loading the Research Project Cask. The minor amount of decay heat removed with the sister rods will have a negligible effect on the overall decay heat of the individual assemblies such that the behavior of the rods in the Research Project Cask should remain typical.

In some instances no sister rod donor assembly exists. It is likely that some of the highest burnup fuel assembly storage candidates were used as center assemblies. Center assemblies are those assemblies located in the single center location in the reactor core, and have no symmetric partner donor assemblies to provide sister rods. Some of the high burnup assemblies were lead-test assemblies and may have been used in the center location of the core to drive the burnup to very high levels (i.e., beyond their normal design limit) for subsequent post-irradiation examinations.

The number of sister rods proposed for pre-test extraction is governed by the following factors:

[28] A dummy rod in this case is a solid stainless steel filler rod inserted in the rod location left by the extracted rod. It is desirable to insert such dummy rods as the cask criticality evaluation results may show more residual nuclear reactivity when moderator occupies the space left unoccupied.

- In order to manage costs of extraction and transportation of the high burnup rods to the national laboratory, the total number of rods will be limited to the capacity of existing high burnup rod shipping casks, which is approximately two dozen.
- The number of rods that can be accepted by the receiving national laboratory. The Test Plan assumes, however, the national laboratory can accept an entire shipment of high burnup rods.
- At least a few rods from all three types of fuel must be selected.
- The availability of sister fuel assemblies or sister rods. In some cases, the number of high burnup assemblies of a particular type may be limited such that rods from the assemblies to be used in the Research Project Cask may need to be extracted. As long as only a few such rods are extracted, there should be minimal impact on the particular assemblies' overall behavior during drying and subsequent long-term storage.

The exact rods to be extracted prior to the HDRP will be determined during the fuel selection process in consultation with DOE and the national laboratories.

Rod Extraction and Shipping

Extraction of fuel rods from an assembly requires the removal of the top nozzle, which is the structural component at the top of each assembly required to safely handle the assembly. The fuel vendors, AREVA Fuels and Westinghouse Fuels, have extensive poolside experience successfully removing and replacing top nozzles, as well as extracting fuel rods, transferring them into baskets, and replacing them with dummy rods.

All of the donor fuel assemblies have removable top nozzles[29] (RTNs) except the older vintage Zircaloy-4 assemblies. (The low-tin Zircaloy-4 fuel assemblies, however, do have removable top nozzle assemblies and sister rods which will be extracted from at least one of these assemblies). Extracting fuel rods from the older vintage assemblies without RTNs is much too labor intensive to be conducted at the host site and is considered to be beyond the scope of this HDRP, especially when comparable results can be obtained from similar fuel assemblies. Nevertheless, these candidate assemblies had fuel rods characterized in poolside examinations and were documented [EPRI 1992]. The older vintage Zircaloy-4 assemblies will remain as candidate storage assemblies, as there was significant poolside characterization performed. Similar post-storage tests could be performed on fuel rods in these assemblies for comparison of dry storage effects.

The fuel vendors will work on site at North Anna to remove the top nozzles from their donor assemblies and extract the specific rod to be used as a sister rod. Each fuel vendor has its own proprietary method for removing the RTNs, which is why two separate fuel vendors are required to extract sister rods. The vendor personnel, using their own equipment and tooling, will remove

[29] RTNs have a locking, but detachable, mechanical interface to remove the top nozzles to gain access to the fuel rods.

the RTN from the assembly. With the rods exposed from the top, the vendor will install an indexing plate so that individual rods can be specifically extracted from the array. A single rod-pulling tool with a collet grapple mates with the indexing plate, grapples the fuel rod, and withdraws it from the matrix. A video of the rod is recorded as the rod is extracted up into the rod puller enclosure to ensure proper rod location and verify extraction is complete prior to transferring the rod to the rod storage location. The extracted rod is then moved to its next storage location, which in this case, is anticipated to be the fuel rod shipping basket.[30] The process is reversed to insert a solid stainless steel dummy rod.

Once all the rods have been extracted and loaded into the fuel rod shipping basket, the basket will be loaded into the shipping cask in the spent fuel pool and prepared for shipment under the requirements of the NRC CoC for transportation. Assuming a total of 25 sister rods are extracted and loaded, the estimated nominal MTU in the sister rod shipping cask is expected to range from 0.043 to 0.045. Peak rod temperatures during cask drying and transportation are expected to remain at or below approximately 93°C, which is low enough such that little to no zirconium hydride dissolution will occur. This will avoid hydride reorientation of the sister rods such that the sister rods' properties will remain unchanged after arrival at the national laboratory. Once the sister rods and time of shipment have been determined, a thermal calculation will be performed to estimate peak sister rod temperatures during loading, drying, shipping, and unloading.

3.5 Transportation Plan to Begin the High Burnup Dry Storage Research Project

Given that no high burnup assemblies need to be shipped to North Anna to begin the HDRP, no transportation plan is needed to begin the HDRP. However, a transportation plan will be needed for shipment of the high burnup rods for pre-characterization testing of sister rods and for shipment of the loaded Research Project Cask to a Fuel Examination Facility. These transportation plans will be developed later, as needed, by the appropriate responsible organizations.

3.6 Work to be Performed at the National Laboratories: Sister Rod Characterization

The characterization activities proposed in this section are intended to be performed at the national laboratories. Though these activities are necessary for the completion of the long-term cask demonstration project, they are not required for EPRI's performance of the scope of work under contract DE-NE-0000593. This work will be funded directly by DOE through their work control processes and procedures. All activities proposed are subject to DOE's discretion and the availability of appropriated funds.

[30] A fuel rod shipping basket is a specially designed basket with about the same dimensions as a fuel assembly. It is designed to safely contain fuel rods during shipment in a shipping cask. The basket is placed in the spent fuel pool to allow fuel rod transfers to and from donor assemblies, and is handled in the fuel pool and inserted into the shipping cask in a similar fashion as a fuel assembly. A fuel rod shipping basket typically holds a complement of 20 to 25 fuel rods, depending upon the shipping cask's licensed Certificate of Compliance.

The fuel rod cladding property testing described in this section provides the initial conditions of the fuel that will be used as a basis for the comparison when the Research Project Cask is opened for fuel investigation. A combination of non-destructive and destructive exams is to be performed.

Non-destructive examination (NDE) of the cladding will start at the national laboratory with detailed visual examination of each rod for signs of crud or oxide layer spallation, local wear, or other indications of degradation. NDE also includes cladding profilometry to determine the cladding outer diameter (OD) prior to destructive exams. The amount of creep during storage can be determined by comparing the OD of rods removed after the storage period with the OD of the rods removed before HDRP initiation. To capture OD variability of each rod, profilometry measurements should be taken at various axial positions as well as at two circumferential positions at each axial position.

After the NDE is completed, a series of destructive exams are performed to obtain detailed data on the fuel and cladding. The following is the list of destructive exams to be conducted:

- *Rod internal gas pressure and content.* The rods will be punctured to determine internal rod pressure, internal rod free volume, and gas composition (FP gases, helium) to determine the amount of fission gas released into the rod inside the cladding. The majority of the fission gas during reactor operation remains trapped inside the ceramic fuel pellets inside the fuel rods. The portion of the fission gas that escapes the fuel pellets is termed the 'fission gas release fraction,' and contributes to the overall pressure inside the rod. Rod internal pressures, in combination with local cladding temperatures, provide the driving force for microstructural changes in the cladding.

Rod segmentation after puncture tests will be carried out for subsequent destructive testing. The following tests at the national laboratories should be performed after segmentation with the fuel pellets still inside the rod segments:

- *Hydride content and orientation.* Hydrides contribute to cladding embrittlement. During reactor operation, a fraction of the hydrogen generated by the zirconium-water reaction is picked up by the cladding and diffuses into the cladding. Typically, most hydrides are oriented circumferentially, as shown in Figure 3-9. Under higher cladding tensile stresses and temperatures, which may occur during the cask-drying operation, some of the hydrides may reorient into a radial direction, as shown in Figure 3-10. Hydrides in the radial direction may substantially reduce cladding ductility. Hydride concentration and orientation data taken from rods that have experienced typical drying and long-term storage conditions will provide valuable additional information on the behavior of high burnup SNF during storage and subsequent transportation under normal and hypothetical accident conditions.

  Similar testing on rods extracted at the end of the prolonged HDRP period will provide information on the degree of hydride reorientation into the radial direction that actually occurs during normal cask-drying and storage conditions. This is because the primary conditions of interest for hydride reorientation are the initial rod internal gas pressure

and the true temperature distribution throughout the cask during the drying and long-term storage period. At present, bounding assumptions are usually made, such as assuming 100 percent of the rods have internal gas pressures at the upper end of the known rod gas pressure distribution, and 100 percent of the length of every rod in every assembly increases in temperature to the 400°C temperature limit. Best estimate thermal models show rod temperatures are less than 400°C. Hence, it is anticipated that less hydride reorientation will occur—in the Research Project Cask and all other casks/canisters in current use—than is usually assumed.

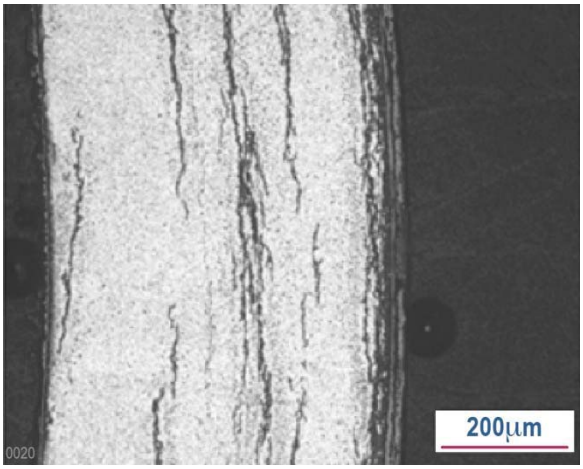


Figure 3-9: Cross-section of a Fuel Rod (Zirconium hydrides in this rod are primarily in the circumferential direction).

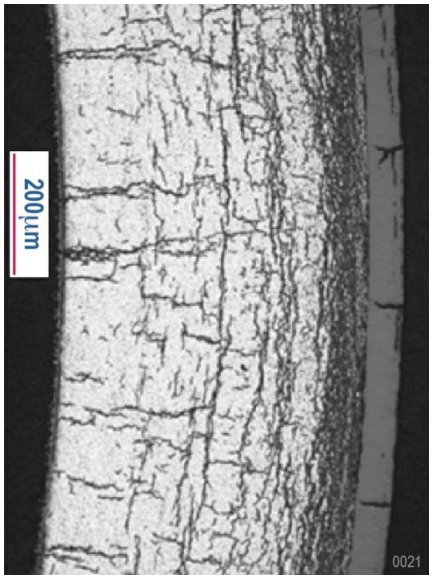


Figure 3-10: Cross-section of a Fuel Rod with Significant Radial Hydride Orientation.

- *Cladding mechanical testing.* After the above testing is completed, the cladding mechanical properties will be examined via ductility testing. Specific ductility tests will include ring compression and tensile testing with and without fuel inside the cladding segments. These ductility tests can be correlated to the hydride concentration and

orientation data to provide an evaluation of fuel behavior under dynamic mechanical conditions. Ductility testing will be performed at various temperatures to determine DBTT ranges. Along with cladding temperature measurements and models, the DBTT data can be used to evaluate when the cladding in storage enters the DBTT region.

The number of tests that should be conducted will be a function of the following issues:

- Number of rods that can be shipped in a single transportation cask. This will provide approximately two dozen rods sampled from all three high burnup fuel types and a range of burnups above 45 GWD/MTU.
- The variability of properties and cladding types of interest previously described. For example, hydride concentration and orientation is expected to vary as a function of fuel design, burnup, and axial and circumferential position.
- Laboratory capabilities. This also includes the capacity to store rods in the hot cell(s).

It is anticipated that all rods received will have the NDE performed, such as profilometry to determine the OD of the rods. Even if some of the rods will be stored for later possible examination, it is important to measure their as-received cladding diameter to ensure accurate initial diameter information for comparison to post-storage profilometry data. While it is unlikely that storage of initially untested rods in a hot cell will affect the rod diameter, performing profilometry examinations at the time of receipt will eliminate this potential variable.

Rod puncture tests will be performed for all rods that will be subsequently sectioned for additional testing.[31] This would provide up to approximately two dozen data points. It would be preferable to have such tests performed on two or more rods with the same properties (e.g., fuel type, burnup, reactor operating history) to capture the variability in the properties.

Oxide thickness, hydride concentration and orientation, and ductility measurements should be conducted at several axial and circumferential positions for all rods for which puncture testing was performed. Of particular interest will be the length of the fuel rods that would experience the highest temperatures during drying and storage. Hence, two or more axial locations within the center two meters of the rods should be selected for examination.

Cladding mechanical property testing should include replicates for combinations of fuel characteristics (e.g., fuel type, burnup, reactor operating history, axial location). Many existing tests have been conducted at more extreme conditions, using higher cladding temperatures and/or tensile stresses, than would be expected under actual operating conditions. Therefore, it is important that the mechanical property testing be performed under conditions characteristic of dry storage, which include, for example, the effect of pellet-cladding bonding and the mechanical load the fuel pellets can absorb so as to limit the amount of strain on the cladding.

[31] Some rods shipped to the national laboratory(ies) may be set aside for future testing.

3.7 Applicable Codes, Standards, and Procedures

The Research Project Cask was fabricated using an approved 10 CFR 72 Quality Assurance Program to be used with NRC CoC 1021. The codes and standards used for fabrication are identified in the TN-32 FSAR [Transnuclear 2012]. A Transnuclear CoC was issued for the Research Project Cask certifying that it was fabricated to the design requirements and specifications as required by NRC CoC 1021. The cask has been maintained in the custody of a facility with a 10 CFR 72 Quality Assurance Program. Since it has been in clean storage for several years, the Quality Assurance and fabrication documentation will be re-verified. While the cask to be used for the project has been fabricated and certified under CoC 1021, some modifications (e.g., lid penetrations for instrumentation) will still need to be performed.

Ownership of the cask will be transferred to Dominion from Transnuclear in accordance with the Quality Assurance requirements normally invoked by Dominion for SNF storage cask procurement. Transnuclear will be required to submit a CoC (a separate certificate from the CoC identified above) establishing that the cask meets Dominion's requirements. This certificate is reviewed as part of the receipt inspection of the cask. The cask will be delivered, inspected, loaded, emplaced at the ISFSI, and maintained in accordance with approved site procedures. Program testing will be performed in accordance with approved site procedures using Quality Assurance requirements typical for the types of tests performed.

As mentioned above, the TN-32 cask is currently licensed for dry storage under 10 CFR 72 (CoC 1021) for PWR fuel irradiated to a maximum assembly average burnup of 45 GWD/MTU and a maximum initial enrichment of 4.05 weight percent U-235. There is also a requirement that maximum decay heat for an assembly is 1.02 kW, and for a loaded cask 32.7 kW. In order to utilize the TN-32 cask for the HDRP at North Anna, several of these parameters will need to be modified. The maximum initial enrichment and assembly average burnup will need to be increased. Additionally, the maximum assembly decay heat will be increased; however, the currently licensed maximum cask decay heat load should be sufficient for the HDRP. The containment and shielding analyses will be revised based on the high burnup fuel sources. The structural analyses for the test lid will need to be performed again; otherwise the licensing basis for the cask will be the same as that represented in the TN-32 FSAR [Transnuclear 2012].

Licensing of high burnup fuel for storage will be guided by established procedures in accordance with NRC Interim Staff Guidance-11 (ISG-11) Revision 3. Transnuclear has successfully licensed several storage systems for high burnup fuel and has other high burnup applications currently under review. The TN-40H high burnup cask has received a site-specific license for use at Prairie Island and Transnuclear will soon submit an application for a 10 CFR 71 transport license. The TN-40H high burnup cask has a different basket design than the TN-40 cask previously used at Prairie Island. The TN-32 is a similar design (although a newer generation) to the TN-40 cask. Although the TN-32 and TN-40 casks were licensed for a maximum fuel average burnup of 45 GWD/MTU, using the fuel payload planned for the Research Project Cask

will allow for a cask-specific analysis to be performed that meets current regulatory criteria. This type of analysis will allow the evaluation to address placement of specific fuel assemblies whose thermal and radiological parameters are well established (with appropriate contingencies in the event substitutions are required). This type of analysis could not reasonably be performed in a generic fashion to support general license use. This is the significant advantage that an ISFSI with a site-specific license has (such as at North Anna) over a facility with a general license. A one-of-a-kind cask, such as the Research Project Cask, can be amended to the site ISFSI license with its own distinct and separate analyses and its own Technical Specifications. Therefore, the preferred licensing path is to prepare an amendment to the North Anna site-specific license for storage of high burnup fuel in the TN-32 Research Project Cask.

The license amendment process for storage at North Anna's ISFSI is well defined and will be governed by Dominion's procedures for seeking license amendments. The TN-32 Safety Analysis Report (SAR), which has been reviewed and approved by the NRC, will be the primary reference for the design and analyses for the Research Project Cask. The design and performance features of the Research Project Cask that will be modified to accommodate high burnup fuel, a modified lid, instrumentation, and operation will be contained in the Research Project Cask DLBD.

The DLBD (and TN-32 SAR, by reference) will form the basis for the North Anna LAR. The LAR will provide a summary description of the changes to North Anna's site-specific ISFSI license. Together the LAR and the DLBD form a complete description of the analyses and tests required to store the Research Project Cask at the North Anna ISFSI.

The DLBD will include the TN-32 SAR by reference, but will address and modify sections of the SAR that are affected by storing high burnup fuel. All sections of the existing SAR will be evaluated for any changes. Some anticipated changes to be included in the DLBD (but not limited to) are:

- Modification of the General Description to address cask characteristics, general performance as the Research Project Cask, and proposed Research Project Cask contents
- Modifications to the Principal Design Criteria
- Modifications to the Structural Evaluation (particularly related to the modified lid or thermal related changes structural changes in the basket)
- Modifications to the Thermal Evaluation; this section may include specific locations of designated fuel assemblies and their projected respective heat loads
- Modifications to the Shielding Evaluation; this will need to change based on the analyzed cask loading plan with a modified neutron and gamma spectrum. The neutron source activity for high burnup fuel will be greater than previously analyzed in the original SAR.

- Modifications to the Criticality Evaluation; this section will address expected initial enrichment of U-235 for the proposed fuel; may also include a summary of reactivity hold-down needed for transportation. If poison rodlets are needed for hold-down, they will be described here since they will need to be inserted prior to storage. If burnup credit could provide sufficient hold-down for transportation, there may not need to be any detailed discussion regarding additional hold-down for storage. The reactivity effects of the instrumentation thermocouple lances and the funnel guide design will need to be addressed in this section.
- Modifications to the Confinement Analysis section to address the changes in the lid penetrations
- Modifications to the Operating Procedures to address any modifications to vacuum drying, leak detection, etc.
- Modifications to Acceptance Criteria and Maintenance to address any changes to inspections or leak tests
- Any necessary modifications to Radiation Protection will be addressed including any cumulative dose impact associated with a single high burnup cask on the pad
- Impacts to any of the analyzed Accident Analyses will be addressed in Section 11
- Sections 12, 13, and 14 will be used to address any changes to Operating Controls and Limits, Quality Assurance, and Decommissioning, respectively. It is not anticipated that any significant changes to these sections will occur as a result of loading the Research Project Cask, with the exception of changes to the Technical Specifications. Changes to the Technical Specifications will be addressed specifically in the LAR.

The LAR will primarily be a narrative description of the proposed changes to the North Anna license using the DLBD as the basis document. Some changes the LAR would address that may not be specifically included in the DLBD would be:

- The method for cask monitoring during the thermal soak period
- Cavity gas testing during the thermal soak period
- Cavity gas testing while in storage (if qualified and if not addressed in the DLBD)
    - This may also address relief needed for leak-rate testing if an O-ring is removed in the process of cavity gas testing
- Changes to the Technical Specifications, with potentially a new set of Technical Specifications specifically for the Research Project Cask

Transnuclear will develop a DLBD that details the design of the cask and lid as well as the design analyses that demonstrate that regulatory requirements are met by the design and anticipated fuel payload. The DLBD will be transferred to Dominion, and Dominion will adapt the DLBD into a LAR to add the Research Project Cask to the approved casks allowed for storage at North Anna's ISFSI. Since the Research Project Cask will be different than the other TN-32 casks on the pad at North Anna, the LAR will include a new set of Technical

Specifications to govern the operation and any required safety significant surveillances for the Research Project Cask. It is not anticipated that any of the Technical Specification related surveillances will affect or pertain to the data obtained to support the HDRP. Once the LAR is drafted, reviewed, and approved by Dominion, it will be submitted to the NRC for review and approval. The NRC staff will issue questions to Dominion to resolve technical concerns they (NRC staff) may have regarding the analyses and conclusion. This is called the request for additional information (RAI) process. Dominion is required to respond to the RAIs within the established time frame to maintain the review schedule. Once all issues are resolved regarding the license amendment, the NRC will begin to prepare their safety evaluation (SE) used to issue the approved license. The approved Technical Specifications will accompany the SE once finalized.

After the SE is issued to Dominion, they will review it to determine the appropriate means to implement the Technical Specifications into North Anna's system for controlling licensed processes. Also, procedures will need to be developed and reviewed to ensure they are compliant with the Technical Specifications.

After receiving a license for storage for the Research Project Cask at North Anna, technical data to support a future application for a 10 CFR 71 transport license will be provided. Based on experience with licensing the TN-40 for transport, licensing the Research Project Cask for transport should be straightforward. The main technical issues are expected to be criticality control (burnup credit/poison rod inserts) due to the higher initial enrichment of the fuel, and possible additional testing and/or analyses that may be needed to meet shipping requirements. However, applying for a transport license specifically for a one time shipment of this TN-32 cask could expedite the NRC licensing process. While obtaining a transport license for the Research Project Cask is not in the scope of the Test Plan, all bounding calculations and a sufficient number of detailed calculations for transportation will be performed to provide a reasonable expectation that the Research Project Cask design will be able to obtain a transportation license under 10 CFR 71 at some point in the future.

3.8 Unplanned Cask Opening

An unplanned cask opening is very unlikely. As part of an SNF storage program, the NRC requires the licensee to have procedures and equipment in place to open a loaded cask. The cask proposed for use in this project is a TN-32, bolted metal cask. Two metallic O-ring seals assure confinement. To verify confinement is maintained, the space between these seals is kept at a higher pressure than the cask cavity such that if the inner seal were to fail, the pressure between the seals (also referred to as the inter-seal pressure) would decrease. Likewise if the outer seal were to fail, the inter-seal pressure would decrease. The inter-seal pressure is monitored, and if the monitored set point limit is reached, an alarm is indicated at the ISFSI alarm station, which is checked at least daily. The initial action would be to inspect for cause of the alarm and to re-establish inter-seal pressure to the Technical Specification limits. It may be necessary to increase

the frequency of the inter-seal pressure checks to determine if a decreasing trend in pressure exists. Possible corrective actions could include re-torqueing of the lid bolts with increased pressure surveillance to determine if the decreasing pressure trend continues. If the inter-seal pressure cannot be stabilized at the ISFSI pad, then the cask will be returned to the station's cask preparation area for additional inspection and leak-detection surveillance. An outcome of that inspection may indicate that the cask needs to be returned to the spent fuel pool to permit replacement of the lid seals. The instrumentation planned for the Research Project Cask would have similar double metallic seals and would be monitored for leakage. It is not anticipated that these additional penetrations would result in a seal failure requiring the cask to be opened. However, if the pressure monitoring system were to indicate a problem, Dominion has experience reopening loaded TN-32 casks.

The normal process for reopening a cask if necessary is to first return the cask to the cask preparation area, remove the protective weather cover and OP tank, remove the vent and drain port covers, take a gas sample from the cask cavity to ensure no unusual radiological concerns, depressurize the cask, connect a water line to the drain port and a vent line to the vent port, and slowly add water while monitoring the pressure. When the cask is full of water, the lid bolts are de-torqued, and the cask is placed in the cask pit in the spent fuel pool to remove the lid. This process may be altered to minimize the thermal transient and the effect on the high burnup fuel to preserve as much data on the fuel as practical.

Although unlikely, should conditions indicate the need to reopen the cask, the process would be performed in a controlled manner and in compliance with the license, Technical Specifications, and site procedures. Should the cask need to be reopened, NRC and DOE would be informed; however timing of actions would be driven by compliance with the license and Technical Specifications, and may not allow additional time for desired investigations or alternative actions.

3.9 Fuel Examination Facility

As mentioned previously, the Test Plan described in this document discusses essential activities that go beyond the first five years, and/or will be executed by others. This section discusses a Fuel Examination Facility that would be needed at the end of the long-term storage period. Following the storage period, the Research Project Cask will be shipped from North Anna to a Fuel Examination Facility and opened for examination. The fuel assemblies will be removed and visually inspected. Individual fuel rods will be removed from the high burnup assemblies and have the post-characterization, non-destructive, and destructive examinations performed at the national laboratory.

The Fuel Examination Facility would need to have either a hot cell or pool large enough to accept the TN-32. The facility would need a 125-ton crane capable of handling the TN-32 cask, operational room to remove the lid, a ventilation system capable of handling radioactive effluent,

structural capacity to support the cask, equipment for handling the fuel assemblies and individual rods, and equipment for extracting rods from assemblies (if necessary).

The primary difference between the use of a hot cell (dry transfer and inspection of the assemblies) and a pool (wet inspection and transfer) as it affects the subsequent fuel cladding properties is the rate of cooling that will occur when the Research Project Cask is reopened. Use of a pool will likely cause a more rapid descent of the fuel cladding temperatures from the time immediately before the Research Project Cask is reopened down to the pool water temperature.

In either the event of an unplanned cask reopening using the North Anna pool or the use of a pool at the future Fuel Examination Facility, it is necessary to conduct R&D to explore the effect of cooling rate on the resultant mechanical properties of the cladding. The potential effect due to cooling rate is related to the process by which the zirconium hydrides slowly precipitate out of the metal as temperatures descend during normal, long-term storage. At higher temperatures, such that perhaps a large proportion of the zirconium hydrides are still in solution in the metal, there is experimental evidence, as well as modeling, that suggest rapid cooling causes the zirconium hydrides that were in solution to precipitate into a separate phase with different morphologies[32] than those that precipitated via slow cooling.[33] Separate Effects Testing and modeling activities should be conducted to be able to determine if the more rapid cool-down caused by reopening the Research Project Cask in a pool would significantly alter cladding mechanical properties compared to the very slow cooling that occurs under typical, long-term storage conditions. The effects of multiple rewetting/redrying cycles should also be examined to support the potential for unplanned Research Project Cask opening (Section 3.8) or continuation of the HDRP beyond the first, long-term storage period.[34]

The process for opening the cask dry at the Fuel Examination Facility would follow roughly the same procedure as was used in the original low burnup SNF cask reopening program at INL as described in [EPRI 2002].

A dry Fuel Examination Facility (i.e., without the use of a pool) requires a hot cell large enough to accommodate the TN-32 cask with sufficient head room to extract the fuel assemblies and remove individual fuel rods for post-storage testing. A dry Fuel Examination Facility that includes a hot cell of sufficient size is not immediately available in the U.S. DOE has evaluated

[32]The zirconium hydride morphology information of relevance is: the length of individual zirconium hydride crystals, the spatial distribution of the crystals, and their orientation (circumferential versus radial). These characteristics – along with hydrogen concentration levels, irradiation damage, and test temperature – govern the overall ductility of the cladding.

[33]However, if rapid cooling occurs from lower cladding temperatures – perhaps on the order of 250°C to 300°C – most of the zirconium hydrides will have already precipitated such that rapid cooling starting from cladding temperatures at or below this temperature range will likely change the properties of the cladding very little when compared to cladding properties of fuel in actual storage conditions.

[34]There is no technical reason that would limit the use of the Research Project Cask for additional, long-term storage periods.

facilities needed for spent fuel storage research considering existing, modified, or new facilities with almost all of the requirements listed previously [DOE 2011]. The purpose of the facility will be to, among other functions, receive bolted metal casks containing both high and low burnup SNF and transfer the fuel into a different cask or canister. For the purpose of accomplishing the needs of this HDRP, additional functions for such a facility would include the ability to extract individual rods from the high burnup assemblies in the Research Project Cask and transfer those rods to a certified high burnup rod transportation cask for shipment to national laboratories that already exist to conduct the NDE and destructive examinations described in Section 3.6. If DOE desires to include additional hot cells at this same facility, then some—perhaps all—of the examinations could be conducted at the facility. This would then avoid the need to ship the extracted rods to the national laboratory.

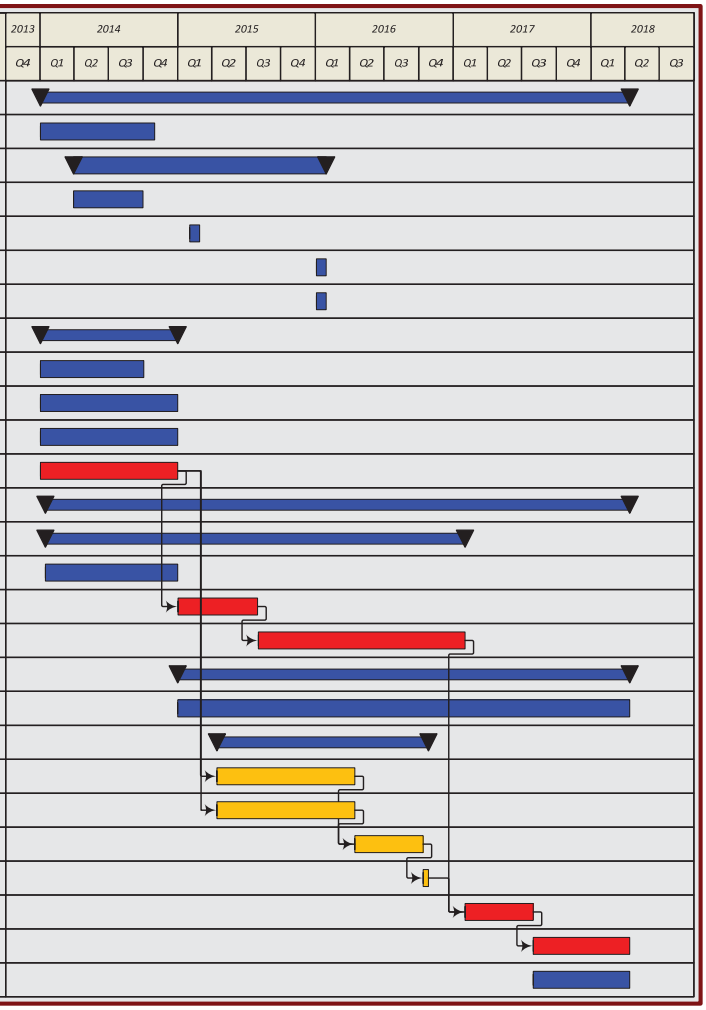
A Fuel Examination Facility using a pool would need the same capabilities as the dry facility with the addition of having a pool large enough to submerge the cask for sufficient shielding provided by the water; sufficient head room for the crane, cask, lift yoke, and extension; and capability for handling the cask and fuel under water. The process for opening the cask at the wet Fuel Examination Facility would be as follows. First receive the shipping cask in the receiving bay, remove the impact limiters and personnel barrier, and move the cask to the work area. Remove any other lid or cover to gain access to the primary lid. Remove the vent and drain port covers, take a gas sample from the cask cavity to ensure no unusual radiological concerns, depressurize the cask, connect a water line to the drain port and a vent line to the vent port, and slowly add water while monitoring the pressure. When the cask is full of water, the lid bolts are de-torqued, the cask is placed in the deep end of the pool, and the lid is removed. The fuel assemblies and rods are then accessible for movement to the examination area.

3.10 Schedule for the Plan Implementation

As part of the Test Plan, a schedule estimate to implement that portion of the Test Plan that is the responsibility of the EPRI team was developed. The schedule, with the critical path identified, is displayed in Table 3-2.

Table 3-2: Schedule

ID	Task Name	Start	Finish
1	**1.0 – High Burnup Dry Storage Research Project -Implementation Phase**	**1/2/2014**	**4/13/2018**
2	1.1 – Fuel Selection	1/2/2014	10/31/2014
3	**1.2 - Sister Pin/ Rod Removal**	**3/31/2014**	**1/29/2016**
4	Obtain Sister Rod Shipping Basket	3/31/2014	9/30/2014
5	Vendor A Pull and Place Rods in Shipping Basket	2/2/2015	2/27/2015
6	Vendor B Pull and Place Rods in Shipping Basket	1/4/2016	1/29/2016
7	Ship Rods To National Lab	1/4/2016	1/29/2016
8	**1.3 - Design**	**1/2/2014**	**12/31/2014**
9	Cask Design Review	1/2/2014	10/2/2014
10	Modified Lid Design	1/2/2014	12/31/2014
11	Instrumentation Design	1/2/2014	12/31/2014
12	Prepare Design and License Basis Document (DLDB)	1/2/2014	12/31/2014
13	**1.4 - Licensing**	**1/15/2014**	**4/13/2018**
14	**1.4.1 - Storage Licensing**	**1/15/2014**	**1/31/2017**
15	Pre -Application Meetings with NRC	1/15/2014	12/31/2014
16	Prepare License Amendment Request (LAR)	1/2/2015	7/31/2015
17	NRC Review and Grant Part 72 LAR	8/3/2015	1/31/2017
18	**1.4.2 - Transportation Licensing**	**1/1/2015**	**4/13/2018**
19	Prepare Calculations for Future Transportation License	1/1/2015	4/13/2018
20	**1.5 – Modification, Fabrication, Fit-up Testing**	**4/15/2015**	**10/26/2016**
21	Modify Cask Lid	4/15/2015	4/14/2016
22	Instrumentation Fabrication	4/15/2015	4/14/2016
23	Fit-up Test of Research Project Cask	4/15/2016	10/12/2016
24	Ship Research Project Cask to North Anna	10/13/2016	10/26/2016
25	1.6 - Cask Loading and Preparations	2/1/2017	7/31/2017
26	1.7 - Cask Data and Monitoring	8/1/2017	4/13/2018
27	1.8 - Semi Annual Reports	8/1/2017	4/13/2018



Key Milestones

There are several milestones identified in the schedule that reflect key dates for completion of activities. The milestones are presented in Table 3-3.

Table 3-3: Key Milestones

Activity	Due Date
Begin Implementation Phase of the Test Plan	02-Feb-14
Confirm Fuel Selection	31-Mar-14
Sister Rod Shipping Basket Receipt	30-Sep-14
Complete Title and Liability Transfer Agreements between Dominion and DOE	30-Sep-14
Finish DLBD	31-Dec-14
Vendor A – Pull Rods and Place into Shipping Basket Complete	27-Feb-15
Start Lid Modification and Instrumentation Fabrication	15-Apr-15
Submit North Anna Storage LAR (Part 72) to NRC	31-Jul-15
Vendor B – Pull Rods and Place into Shipping Basket Complete	29-Jan-16
Move Shipping Basket to the Transportation Overpack and Ship to National Lab	29-Jan-16
Start Fit-up Testing	15Apr-16
Finish Lid Modification and Instrumentation Fabrication	12-Oct-16
Ship Cask/Lid/Instrumentation to North Anna	26-Oct-16
Grant Storage License – NRC	31-Jan-17
Load Cask	31-Jul-17
Start Monitoring	31-Jul-17
Submit Progress Report	31-Jan-18
DOE-EPRI Contract Ends	15-Apr-18

A separate schedule for completion of the characterization of the sister rods shipped to the national laboratory is in the process of being developed by DOE. The timing of the fuel rod examinations has no impact on the schedule for initiating the HDRP as described in Tables 3-2 and 3-3.

2018 to the end of the storage period:[35]

- Continue taking periodic temperature measurements
- Prepare progress reports semi-annually

End of the storage period:

- Return the Research Project Cask from the ISFSI pad to the cask preparation area at North Anna
- Prepare the cask for transport to an off-site Fuel Examination Facility

[35]The DOE-EPRI contract includes execution of the test plan during the first five years, i.e., up to mid April 2018. Beyond that time responsibilities will need to be determined.

- Ship the cask to the Fuel Examination Facility
- Open the cask and visually examine the fuel
- Extract high burnup rods for subsequent examination
- Conduct non-destructive and destructive examinations of the rods at the national laboratory

4.0 VALUE OF THE HIGH BURNUP DRY STORAGE RESEARCH PROJECT

This High Burnup Dry Storage Research Project (HDRP) will provide important, *confirmatory* data to be used in conjunction with the modeling and experimental data that currently exist, along with additional modeling, separate effects testing, and small-scale testing that DOE has planned for the near future. With confirmatory data from the HDRP, the relevance of the present and future models and tests can be assessed. Assuming the validity of the relevant models, SETs, and SSTs are confirmed by the HDRP, then a higher degree of confidence in these models and tests can be obtained. Lower cost models, and accelerated SETs and SSTs can explore a wider range of conditions that may occur for the range of fuel types and storage conditions currently in storage and planned for future storage followed by transportation. Hence, the HDRP in this Test Plan will provide the platform for these models and tests to supply a large amount of data relevant to the assessment of the safety of long-term storage followed by transportation.

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International Dose Effect Alliance – November 2016 Workshop Proceedings

Primary Audience: Radiation protection research program managers

Secondary Audience: Radiation protection managers and communications consultants

Key Research Question

The International Dose Effect Alliance (IDEA) is a new EPRI initiative with a vision to provide an international platform for information exchange, discussion, cooperation, and collaboration in low dose ionizing radiation research. The initiative was created because there has been no established international platform to bring together the national and regional programs in Europe, Asia, and North America.

Research Overview

The EPRI Radiation Safety Program hosted a first-of-a-kind workshop initiating IDEA to provide a mechanism for organizations around the world to discuss low dose radiation research programs, priorities, and approaches. The workshop was held in EPRI's offices in Charlotte, North Carolina, on November 9–10, 2016. More than 30 attendees from Japan, Canada, France, and the United States participated in the workshop discussions, including a total of 20 presentations. The workshop was designed to facilitate information exchange and collaboration on low dose radiation research programs; identify issues, areas of synergy, and opportunities for additional research; foster integrated, outcome-oriented approaches to resolving low dose risk; develop connections between programs conducting low dose radiation research; and facilitate discussions across countries and regions.

Key Findings

- The research data seem to show both beneficial and detrimental effects of low dose radiation exposure in certain cells and tissues (Sections 6, 16, 19, and 21).
- The competing responses within the cell, tissue, organ, and organism form a complex pattern that has not, to date, allowed for an accurate quantitative assessment of risks at low doses or dose rates of ionizing radiation (Section 14).
- There is a need to move to a multidisciplinary approach to bring all of the information together, including contributions from outside the normal radiation research community, such as medical research and chemical toxicity research (Section 8).
- The research tends to be organized around particular topics rather than the possible steps in identifying the progression to harm for an individual. A new way of organizing research-along the lines of a qualitative adverse outcome pathway —could allow for the identification of gaps and consideration of a holistic view to answer the question of effects at low dose and dose rate (Section 12).

Why This Matters

The research on the health effects of low dose ionizing radiation takes many forms and covers a spectrum of topics. Although various regional platforms exist, a platform for discussion and collaboration at an international level will facilitate cooperation in research areas, establish agreement as to what research objectives will inform important regulatory outcomes, and leverage work across organizations. Recommendations, regulations, and

communications that are informed by up-to-date scientific information will protect health and safety while minimizing unnecessary burden and contribute to public awareness and communication that recognizes radiation risk in the appropriate context.

How to Apply Results

This report contains the materials from the presentations made during the workshop; provides insights on current activities in low dose research programs in Asia, Europe, and the Americas; and identifies areas of cooperation and possible collaboration. Specific results presented are useful in understanding the complexity of the response to ionizing radiation as well as the different points of view in communications about radiation risk.

Learning and Engagement Opportunities

- EPRI's work in low-dose radiation effects includes the following:
  - Program on Technology Innovation: Evaluation of Updated Research on the Health Effects and Risks Associated with Low-Dose Ionizing Radiation (1019227)
  - Epidemiology and Mechanistic Effects of Radiation on the Lens of the Eye: Review and Scientific Appraisal of the Literature (3002003162)
  - Radiation Induced Cataracts: Science, Policy, and Impacts to Radiation Protection - June 2016 Workshop Proceedings (3002009113)
- National and international organizations interested in this report include those engaged in low dose radiation research, policy formulation, and development of regulations and guidance.
- Radiation protection managers and communication professionals will be interested in the current findings on contributors to radiation risk.

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Implementation Category: Strategic Long-Term

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A PRUDENT VIEW OF EARTHQUAKE RISKS, NUCLEAR PLANTS AND NUCLEAR WASTE ALONG THE CALIFORNIA COAST

by Ray Lutz, Citizens Oversight Projects
raylutz@citizensoversight.org
Rev 5; March 1, 2017

Introduction

The San Onofre Nuclear Generation Station (SONGS) has been shut down since Jan 31, 2012, but still has some 3.6 million pounds of high-level nuclear waste to deal with. At the February 16, 2017 San Onofre Community Engagement Panel (CEP) conducted by Southern California Edison (SCE), a presentation was given by Neal Driscoll of the Scripps Institution of Oceanography regarding a study of seismic risks at the San Onofre plant.[1] This study was originally prompted by AB 1632 in 2010. As a result, the California Energy Commission directed SCE to evaluate seismic risk at the then-operating SONGS. This paper provides an alternative view of this subject.

Seismic Risk

One of the most substantial risks regarding nuclear power plants and the storage of nuclear waste is earthquakes and their associated repercussions such as tsunamis. These are substantial but perhaps not even the most important at a nuclear plant in this location. Terrorist activity or military action, human error, and equipment failure, including corrosion, are on the list and may exceed the near-term risks due to earthquake threats. With all that said, this paper will focus on seismic risks since that was the topic of the recent CEP meeting.

Seismic science has made great strides, most particularly in the past 50 years or so since the theory of Plate Tectonics became the operating framework behind observations of current and future earthquakes.

We must also recognize the following:

1. Seismology is a very new science. Although it deals with time scales on the order of hundreds to millions of years, events may be only seconds or minutes in duration. Careful observations of

1 Presentation slides: https://www.songscommunity.com/docs/021617_CharacterizingtheSeismicSettingOffshoreSouthernCalifornia.pdf

the movement of the tectonic plates have only been within the last 50 to 100 years. The theory of Plate Tectonics really got its start after the 9.2 magnitude Alaska earthquake in 1964.[2]

2. Although a great deal can be discerned about the large-scale events in terms of the movement of the tectonic plates throughout the larger spans of time, it is much more difficult to know how disruptive a specific event might be, and it is very difficult to clearly test most theories as you have to successfully predict at least the magnitude of a future earthquake. Seismic scientists agree they cannot accurately predict earthquakes at this juncture although they can make approximate predictions.

3. What happened over thousands or millions of years is indeed interesting. But our concern is in the next 100 years or so, approximately one 40,000,000th of Earth history. No matter how good the science might be, accurately predicting anything in such a narrow window is next to impossible. Any predictions or risk calculations should make this clear. With this in mind, it is probably prudent not to make any predictions. Considering the time frame, it would be reckless indeed to make decisions based on seismic models or probability risk assessments.

4. Seismology is largely an observational science. It is not generally possible to conduct the gold-standard of scientific experimentation -- the double-blind study. Instead, we are left with peer-review, which can provide a false sense of security. Essentially, just because a bunch of people think something is written well, and all agree, does not mean it must therefore be true. The reality, unfortunately, is that the vast majority of peer-reviewed science, even in experimental fields, is false or unreliable.[3]

> "[A] research finding is less likely to be true when the studies conducted in a field are smaller; when effect sizes are smaller; when there is a greater number and lesser preselection of tested relationships; where there is greater flexibility in designs, definitions, outcomes, and analytical modes; when there is greater financial and other interest and prejudice; and when more teams are involved in a scientific field in chase of statistical significance."[4]

2 http://www.aeic.alaska.edu/quakes/Alaska_1964_earthquake.html

3 Ioannidis JPA (2005) Why Most Published Research Findings Are False. PLoS Med 2(8): e124. doi:10.1371/journal.pmed.0020124 -- http://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.0020124

4 *ibid.* Underlining added.

We must note that in the field of seismology, testing is very limited, and in the case of evaluating the risks of nuclear plants, there is significant financial interest in the result. Thus these studies are subject to the risk that their results may be false or misleading.

5. Any estimate of earthquake risk in a specific area only provides the floor of the risk level, that earthquakes of a certain magnitude or greater can be expected at a specific location based on recent movements. There is no way to prove that a really big earthquake won't happen somewhere.

6. The implications of failure at a nuclear plant or nuclear waste storage site can be devastating, potentially resulting in uncontrolled and uncontained nuclear reactions, such as the triple melt-down in Fukushima which is still absolutely out of control and an on-going disaster.

   The consequences of a low probability event at a nuclear power plant can be widespread catastrophe, loss of life, and permanent contamination of large areas of land. There is very little relevant comparison with other areas of scientific prediction or risk assessment. It is therefore not prudent to judge any possibility as “unlikely” or “low risk,” especially when there are so many unknowns and confounding factors. Traditional inferential statistics may be the norm for much of science, but they should not be applied in this situation. This is far different from estimating the outcome of a research experiment or even predicting an ordinary earthquake.

7. The standard system engineering risk assessment process is shown in Figure 1. It involves assessing the risk and the consequences of any failures. Storing nuclear waste at San Onofre includes very high risk, and remains dangerous for 2,500 centuries. The consequence of a failure and contamination of the surrounding area would cause serious damage and threaten the health of over 1 million people (approximately 8.4 million people live within the 50-mile zone.) Therefore any failure is unacceptable because the risk impact is too high.

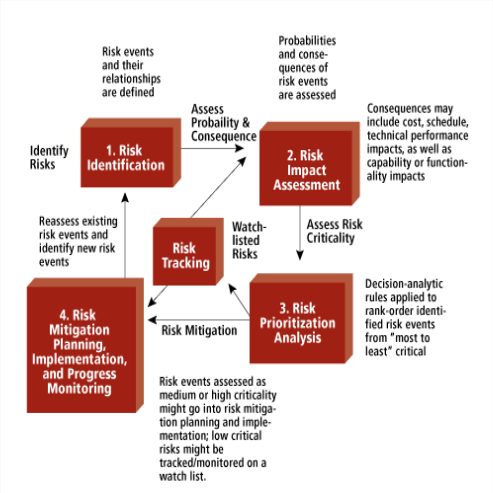


Figure 1. Risk Management: Fundamental Steps

8. On-site nuclear waste storage in an "ISFSI" (independent spent fuel storage installation) has been *generically* approved by the NRC using a "generic environmental impact statement" which allows these installations to remain for an indefinite period of time, certainly decades and perhaps centuries. This long time scale means we must also be concerned with relatively rare events. The Generic EIS should be challenged for applicability in this seismically active region, and indeed, no ISFSI's should probably be allowed as a result. The NRC has a problem in that they have already approved these based on immature seismology and any new analysis has a bias to support earlier positions rather than to undermine or reverse them, as they should.

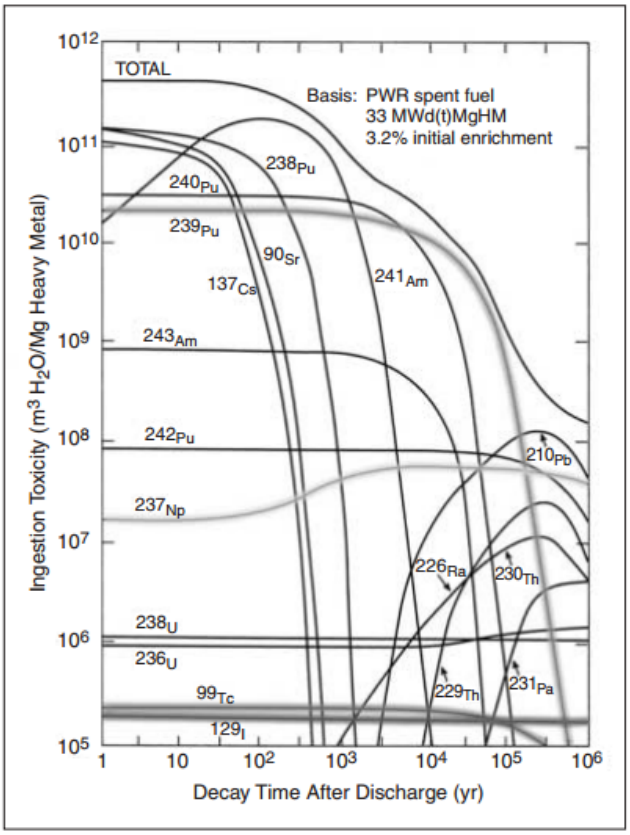


FIGURE 2 Toxicity from ingestion as a function of decay time for a number of nuclides in spent fuel from light-water reactors. Source: NRC, 1996.

9. Seismic risk assessment likes to use acceleration at the plant rather than the Richter scale. Peak Ground Acceleration (PGA) or Design Basis Earthquake Ground Motion (DBGM) is measured in Galileo units – Gal (cm/s^2) or **g** – the force (acceleration) of gravity, one **g** being 980 Gal. PGA has long been considered an unsatisfactory indicator of damage to structures, and some seismologists are proposing to replace it with Cumulative Average Velocity (CAV) as a more useful measure since it brings in displacement and duration.[5] On this basis alone, we should be very suspect of any claim that a system can withstand an earthquake of a given magnitude.

10. In addition, these simple numerical values do not include damage to structures and systems that can result from resonant magnification of ground movement vibrations.[6] Extensive damage can result if the system under consideration has components which have resonant frequencies which match spectrum components of the earthquake vibration. Thus, using peak acceleration in

5 http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/nuclear-power-plants-and-earthquakes.aspx

6 https://www.iris.edu/hq/inclass/animation/building_resonance_the_resonant_frequency_of_different_seismic_waves

design basis analysis simply shows that system components can withstand that acceleration; it is hardly a robust analysis methodology which would also include resonant vibrations in the analysis.

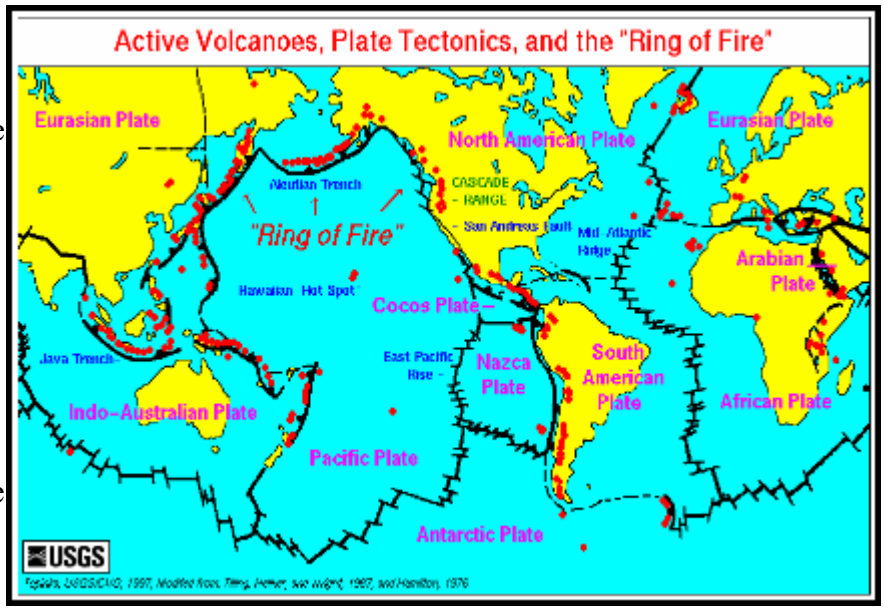
Boundaries of the problem

Essentially when discussing earthquake risks, we are speaking about the vibrations imparted to a system of interest by an earthquake or the forces and effects of being flooded by a tsunami. Certainly, there is no absolute upper bound because a release of magma could occur at any spot on earth and destroy any material known to man. But putting that extreme case aside, there IS an upper limit of the amount of shaking the earth can impart if it does not result in a release of magma at the location of interest.

Largest Earthquakes

The world's largest earthquake with an instrumentally documented magnitude occurred on May 22, 1960 near Valdivia, in southern Chile. It was assigned a magnitude of 9.5 by the United States Geological Survey. The United States Geological Survey reports this event as the "largest earthquake of the 20th Century." Other earthquakes in recorded history may have been larger; however, this is the largest earthquake that has occurred since accurate estimates of magnitude became possible in the early 1900s.[7]

Of course, we haven't been measuring this for very long so we really don't know what the largest earthquake might be, and some areas are riskier than others.



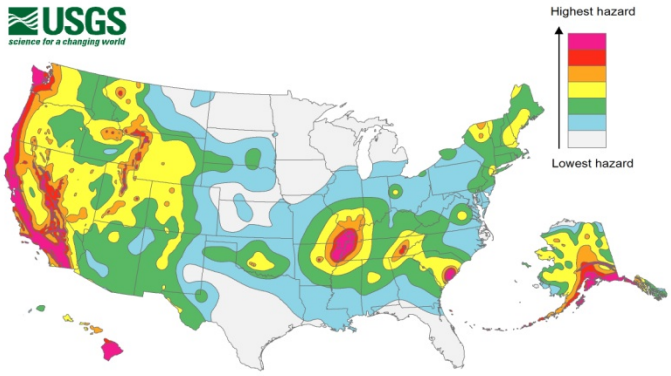
Where earthquakes occur

Earthquakes generally occur in the regions around tectonic plate boundaries, most specifically, in

7 http://geology.com/records/largest-earthquake/

the “ring of fire” around the Pacific Ocean, where about 90% of the world's earthquakes and 81% of the world's largest earthquakes occur.[8]

Anything built in the vicinity of tectonic plate boundaries may experience extremely large earthquakes.



More importantly, nuclear plants or nuclear waste along the California Coast is generally in a very vulnerable location.

The boundary between the Pacific Plate and North American Plate is along the San Andreas fault and nearby faults.

Geologic studies show that over the past 1,400 to 1,500 years large earthquakes have occurred at about 150-year intervals on the southern San Andreas fault. The last large earthquake on the southern San Andreas occurred in 1857.”[9] So we may expect movement here around 2007, meaning we are overdue for the “big one.” Since advanced scientific instruments were not in place in 1857 to measure the prior movement of the southern San Andreas, the magnitude of the upcoming earthquake is based only on informed guesses, and not hard data. In addition, we don't know how much nearby faults will also move in the “big one.”

Tsunami Risk

Tsunamis result from earthquakes or underwater rock slides. We have only limited information about the absolute maximum tsunamis. But it is actually easy to avoid tsunamis by avoiding coastal areas and building at higher elevations.

The largest tsunami ever: A tsunami with a record run-up height of 1720 feet occurred in Lituya Bay, Alaska. On the night of July 9, 1958, an earthquake along the Fairweather Fault in the Alaska Panhandle loosened about 40 million cubic yards (30.6 million cubic meters) of rock high above the northeastern shore of Lituya Bay.[10] But this is a very limited example that would not apply to the open ocean, and the actual height of the wave in this case was about 100 ft.

8 according to Wiki.
9 https://pubs.usgs.gov/gip/earthq3/when.html
10 http://geology.com/records/biggest-tsunami.shtml

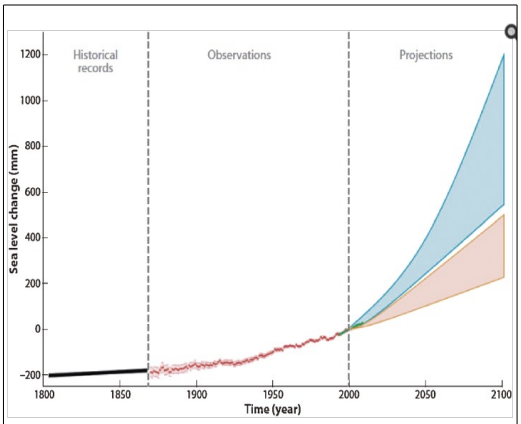
The 50 foot Indian Ocean tsunami ten years ago traveled at speeds reaching 500 miles per hour and barged up to a mile inland. It killed some 200,000 people, making it the deadliest wave known.[11]

San Onofre is in a tsunami inundation area.

Again, it would not take much to avoid this risk, simply by building farther inland and above several hundred feet. Unfortunately, nuclear plants are typically built very close to mean sea level to make it easy to pump cold ocean water into the plant for cooling. Now, Southern California Edison has proposed building an Independent Spent Fuel Storage Installation (ISFSI) within 100 feet of the sea wall and only inches above the water table. There is no functional reason why the ISFSI needs to be close to the ocean. Building in this location subjects it to tsunami and corrosion risks.

Furthermore, the tsunami wall is not maintained and is not included within the approval requirements for the ISFSI by the California Coastal Commission.[12]

Climate change scientists warn that Global Mean Sea Level (GMSL) will be rising in the future.[13] Estimates are 0.2 to 1.2 meters over the next 100 years.



Predicted Sea Level Rise

NRC scientists disagree[14] about the safety of Diablo Canyon Nuclear Power Plant, which is located about 85 feet above MSL and theoretically safe from tsunami waves up to 32 feet in height. This is better than the situation at Fukushima which was doomed after the 20 foot wave in 2011.

Unfortunately, the planned location of the new ISFSI is only inches over the ground water level.

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11 http://www.smithsonianmag.com/science-nature/biggest-waves-recorded-history-180952432/

12 See page 7 of the California Coastal Commission permit: "No new shoreline protective device(s) shall ever be constructed to protect the development approved pursuant to Coastal Development Permit #9-15-0228, including the ISFSI facility, associated ancillary structures and any future improvements, in the event that the development is threatened with damage or destruction from erosion, landslides, waves, storm conditions, flooding, sea level rise or other natural coastal hazards in the future. By acceptance of this permit, the applicant hereby waives, on behalf of itself and all successors and assigns, any rights that may exist under Public Resources Code Section 30235 to augment, enlarge and/or replace any of the existing shoreline protective devices adjoining the NIA in order to protect the development approved by this coastal development permit. -- https://documents.coastal.ca.gov/reports/2015/10/Tu14a-10-2015.pdf

13 MIMURA N. Sea-level rise caused by climate change and its implications for society. HORIKAWA K, ed. Proceedings of the Japan Academy Series B, Physical and Biological Sciences. 2013;89(7):281-301. doi:10.2183/pjab.89.281. -- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3758961/

14 http://www.copswiki.org/Common/M1472 -- Diablo and the deep blue sea: A shelved NRC tsunami study is generating new interest 11 years later

Calls for Worst-case Design

Based on the fact that earthquakes have been observed up to 9.5 magnitude and that the California coast is on the ring of fire and is in a "highest hazard area," anything designed with a potential for devastating results should they experience damage (such as a nuclear plant or nuclear waste storage facility), SHOULD be designed to survive a worst-case quake. To be "conservative" we must give ourselves a margin of error. Thus, any such facility SHOULD be built to withstand quakes up and above the largest quakes observed so far, PLUS that margin for error. Therefore, we should probably assume an earthquake of magnitude 10.0, with the epicenter of the quake nearby and with rock with maximal transfer between, and with the design basis analysis using CAV rather than PGA and resonant vibration analysis. Obviously a prudent approach given the ultimate danger of a nuclear plant or nuclear waste storage facility is to simply avoid this location altogether.

It would likely be nearly impossible and very expensive to build any large rigid structure that would withstand such vibrations. Additionally, it is very difficult to actually design structures and systems that will endure any rare event because those systems are never adequately tested. Design methodology focuses on discrete components of the overall system which meet vibration ratings. It is very difficult to know how such vibrations will affect larger and interconnected systems.

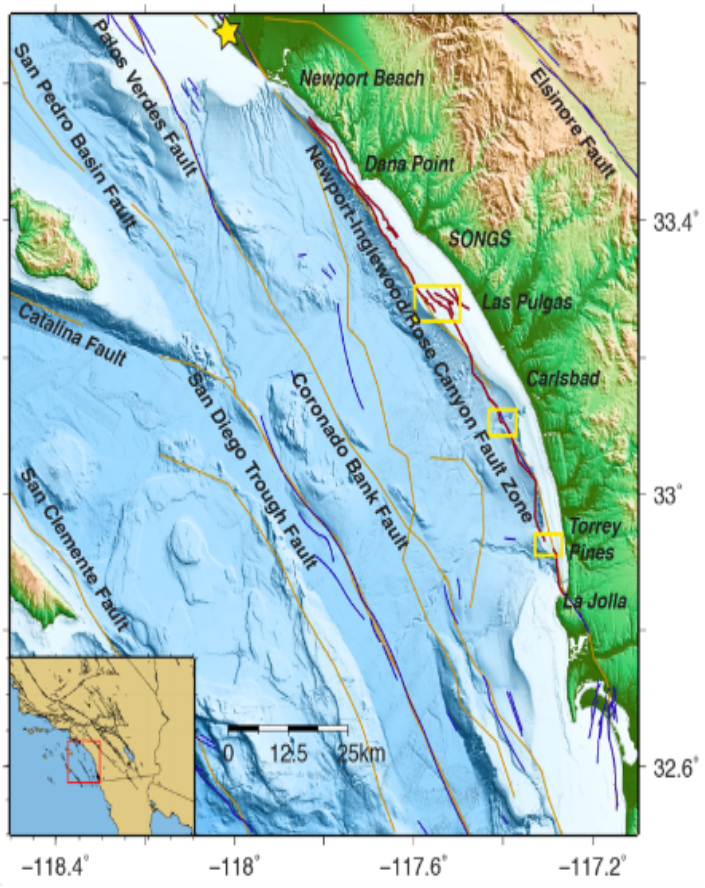
Proof to this point is clearly provided by the failure of the replacement steam generators at San Onofre which were carefully designed to withstand internal vibrations of their own during operation, but failed in record time, resulting in the demise of the San Onofre nuclear plant. Analysis of vibrations due to the expansion of boiling water into steam is VERY DIFFICULT and exceeds the computational capability of the best engineers and top super computers. Claims that a plant meet a specific "design basis" such as the Peak Ground Acceleration is convenient way to lie to ourselves, and convince us that a plant that was already built and operating can continue to do so safely. These analyses rarely challenge the design sufficiently and typically include limiting constraints, such as limiting the analysis to one failure at a time rather than multiple failures, because the problem then may grow almost without bound. They also typically assume other infrastructure (outside power, roads, access, water, etc.) is available when a huge and devastating earthquake would likely also impact if not eliminate those support systems.

Fukushima is a good example of how many issues combine to result in a catastrophe that is well beyond the capabilities of mortal man to contain.

Seismic Studies Give False Security

The nuclear plants built along the California coast, including San Onofre, Diablo Canyon, and Humbolt Bay, were designed and built just as we were starting to gain knowledge about earthquake risk. The small Humbolt Bay nuclear power plant was actively shut down in 1976 due the discovery of extreme seismic risks in that area and the resulting expense required to upgrade it.[15]

At the February 16, 2017 San Onofre Community Engagement Panel conducted by Southern California Edison, a presentation was given by Neal Driscoll of the Scripps Institution of Oceanography regarding such a study of the risks at the San Onofre plant.[16] The most significant result of the study was that the Newport-Inglewood/Rose Canyon (NI/RC) fault line immediately off the coast from San Onofre could result in a 7.4 magnitude quake. Due to the proximity to the plant, this would result in very high accelerations, dangerously close to the design limit of the plant, which is supposedly rated to magnitude 7.5.



Map of faults provided by Driscoll at the CEP meeting.

However, we also know that the plant was originally designed to withstand only a 6.0 quake, then upgraded to 7.0 and later to 7.5. The process of upgrading the ratings of the plant largely are performed by “sharpening the pencil” to provide reasons why such large quakes won't hurt anything rather than actually changing the design of the plant.

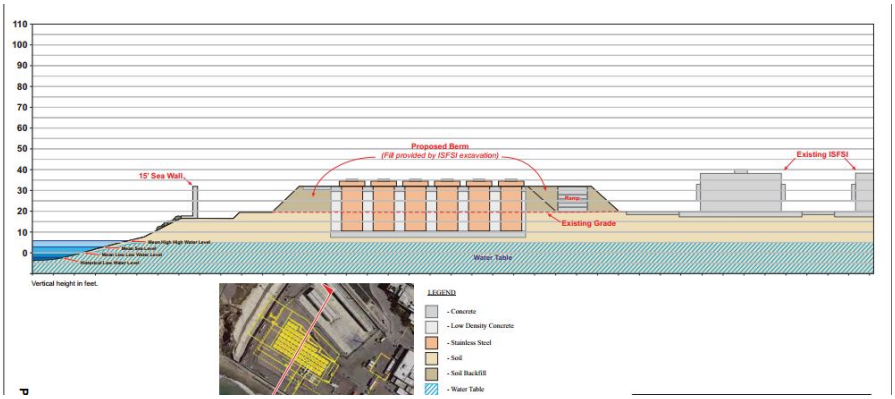
Had the plant been operating, the conclusion by Driscoll and his team should have been enough evidence that the plant should be shut down on this basis alone. Luckily, we don't have to fight that battle as the plant is no longer operating.

15 https://en.wikipedia.org/wiki/Humboldt_Bay_Nuclear_Power_Plant
16 Presentation slides: https://www.songscommunity.com/docs/021617_CharacterizingtheSeismicSettingOffshoreSouthernCalifornia.pdf

Interestingly, the study also considered an additional hidden fault line and then showed reasonable evidence that it most likely did not exist. News media covered this as “the danger is lower than we thought.” This is a very advanced form of sleight of hand to make a devastating result look better than it is. A fault which will likely result in a 7.4 magnitude quake only yards from the site should prevent the ISFSI from being built, that is if we could allow ourselves to think it through.

The result of this study was in harmony with the larger theory of plate tectonics in this area. This is a very dangerous location. But even though the study does support the notion that a 7.4 magnitude quake is certainly possible at the location, it is IMPROPER to then conclude that a 7.4 magnitude quake is the upper limit of what can occur. Actually, given the difficulty we have in studying the vast time scales of seismology of hundreds or thousands of years punctuated by rapid movements on the order of seconds or minutes, we have no idea how large the quakes at this location might be, except to say they are probably bounded at the top at perhaps magnitude 10.0 unless there was a release of magma at that exact location and the whole thing melted into a pool of lava.

Had we known more about seismology and assuming we would make rational decisions, no nuclear plants or nuclear waste storage facilities would be built along the ring of fire, such as in California. Indeed, knowing that the San Andreas fault is about to trip, the remaining operating plant, Diablo Canyon, should be shut down immediately and secured for the expected “big one” to occur at any time now.



Side cutaway view of the proposed Holtec ISFSI

Proposed ISFSI

Southern California Edison has proposed the installation of Holtec “UMAX” ISFSI on a pad near the existing reactors at San Onofre. They have gained approval of this plan by the California Coastal Commission.[17]

17 Citizens Oversight has filed a challenge to this approval in CA Superior Court. See http://www.copswiki.org/Common/NukeWasteLawsuit

The proposed system stores the canisters in a vertical orientation in an area only 100 feet from the seawall, only inches over the current mean sea level, in massive school-bus size but thin-walled, (5/8") stainless steel canisters placed in cavities in a massive block of concrete.

Corroding Nuclear Waste Canisters

Storing nuclear waste this close to the ocean, just barely over Mean Sea Level, is difficult to square with the risk factors of this area. Proximity to salty ocean air means these canisters will start to corrode once canister surface temperature drops to below 85°C. Corrosion will encourage the development of cracks. These cracks may not extend through the thickness of the wall but will weaken the canisters and may result in complete failure, most particularly when extraction is attempted. However, over time, they may extend through the 5/8" thickness of these canisters, and begin to release radioactive particles.[18]

According to CFR Part 72.122[19]:

> (i) Structures, systems, and components important to safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lightning, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform their intended design functions. The design bases for these structures, systems, and components must reflect:
>
> > (A) Appropriate consideration of the most severe of the natural phenomena reported for the site and surrounding area, with appropriate margins to take into account the limitations of the data and the period of time in which the data have accumulated, and
> >
> > (B) Appropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena.

Clearly, when corrosion is combined with severe earthquakes for the area, existing designs are not sufficient to "withstand the effects natural phenomena." We object to the notion that we should constrain our concerns only to such phenomena that have been "reported for the site" as we must also take a more prudent view of what may occur in the future, given the location on the ring of fire, the long period of time waste may be stored at the location according to the Generic Environmental Impact Statement for the ISFSI, and the relative immaturity of seismology.

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18 D.G. Enos and C.R. Bryan Sandia National Laboratories, "Understanding the Risk of Chloride Induced Stress Corrosion Cracking" -- SAND2015-4671 PE http://www.nwtrb.gov/meetings/2015/june/enos.pdf

19 https://www.nrc.gov/reading-rm/doc-collections/cfr/part072/part072-0122.html

Given the history of delays in moving waste from nuclear power plants by the Department of Energy, it seems likely that if the proposed ISFSI is installed at this location and filled with waste, it will take longer than expected to move it to any other location. Assuming there may be complications with one or more canisters such that it becomes difficult or impossible to extract them from the ISFSI without risking inducing a critical nuclear reaction, it may then be necessary to seal over the ISFSI with concrete and ENTOMB it rather than move it. Proximity to the ocean risks that radioactivity will leak into the ocean, especially during storms, tsunamis or ocean rise due to climate change. This is absolutely possible and may result in an untenable situation that was never intended.

Some risks of degradation of these canisters may be reduced by adopting either thicker canisters or using a dual-layer approach, neither of which are being considered with any seriousness.

Canisters are too big to transport and store

There is a lack of integration between storage, transportation, and disposal in the nuclear waste management system. Utilities have moved to larger school-bus size canisters to optimize on their storage needs and reduce near-term costs. However, these large canisters may or may not be disposable into any future geologic repository. If large canisters are not directly disposable, the contents will need to be repackaged, with potential to increase costs, dose, and handling operations.[20] Consideration of a possible "Standardized Transportation, Aging, and Disposal (STAD) Canister Design" which would be compatible with a future geologic repository is complicated by the lack of a known geologic repository. We are continuing to use canisters that will likely be too big and too hot for a repository such as Yucca Mountain.

Conclusion

The presentation given at the recent CEP meeting on seismic concerns was covered in the media that the location is "safer than we thought." But in reality, it provided only more evidence that this location is far too dangerous for nuclear plants or a nuclear storage facility. Prudent design should required that it meets worst-case design criteria, to withstand a quake of up to magnitude 10.0 and tsunami of 100 ft, and not the hope and prayer of the sort of study provided by Driscoll. A better approach is to avoid the construction of an ISFSI in this area and store the high-level radioactive waste at a more suitable location, i.e. far from earthquake and tsunami risks.

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20 http://www.nwtrb.gov/meetings/2015/june/jarrell.pdf -- "Standardized Transportation, Aging, and Disposal (STAD) Canister Design" by Josh Jarrell, PhD.

A full review of the ISFSI at this location is obviously called for. It should include consideration of other locations far from seismic and ocean concerns, and review of the design of canisters to see if thicker or canisters with dual shells may be an effective way to reduce the risk so as to comply with worst-case design requirements.

To avoid most seismic risks, the spent fuel should be moved to a location far from the coast and preferably on the North American Plate, which is relatively stationary compared with the Pacific plate, and placed far from tsunami risks.

And this analysis does nothing to deal with perhaps the largest set of risks, that is of a terrorist attack of some sort at the site, given that it is easily accessible from the ocean and freeway.

Frankly, this is a really bad location for a nuclear plant or a nuclear waste site. We MUST reconsider our options and get serious about relocating it far from population concentrations, seismic areas, and waterways or oceans.

Nuke waste can be safely transported

Express-News Editorial Board **Updated 8:04 pm, Saturday, March 18, 2017**



IMAGE 1 OF 23

The Waste Control Specialists site near Andrews near the Texas-New Mexico border is suited for spent nuclear waste. And the casks that transport nuclear waste are virtually indestructible.

There's been no shortage of local anxiety over a proposal to transport and store high-level nuclear waste in West Texas.

Bexar County Commissioners Court unanimously voted to oppose the transport of spent nuclear fuel to Andrews County, and City Councilman **Ron Nirenberg** has said he wants the city to legally oppose Waste Control Specialists' application.

The concern is that rail transport of high-level nuclear waste from across the U.S. to Andrews

County will pass through Bexar County, putting our community at risk. But the facts don't fully support the concern.

Nuclear waste is transported safely all the time. And there needs to be a solution to either the interim or long-term storage of spent nuclear fuel at more than 62 sites across the nation. This includes 29 years of high-level waste stored at the South Texas Project.

Waste Control Specialists hopes to begin accepting high-level nuclear waste by 2021. Its application with the Nuclear Regulatory Commission has been deemed complete, but extensive review and deliberation remains.

Because the U.S. has failed for decades to develop a permanent storage site for high-level nuclear waste at Yucca Mountain in Nevada, roughly 70,000 metric tons of it is being stored at power plants across the country. This includes "stranded" fuel at shuttered plants. It's an immense public safety issue to have so much high-level waste at so many sites.

Waste Control Specialists, which receives low-level nuclear waste from hospitals and other sources, has applied to store up to 40,000 metric tons of this waste for 40 to 100 years. It would be an interim location until permanent storage sites could be developed.

One concern is transport. Two longtime and respected advocates for the environment, **Tom "Smitty" Smith**, formerly of **Public Citizen**, and wife **Karen Hadden** of the **SEED Coalition** have raised fears about a rail accident or terrorist attack in San Antonio.

But the reality is that the nuclear waste transport casks are virtually indestructible. These metal casks, often weighing about 100 tons, have remained impervious despite extreme tests. They've been smashed by trains, crashed into walls at high speeds, burned with jet fuel and dropped from the sky — and stayed intact.

In 2006, the **National Academy of Sciences** reported it "could identify no fundamental technical barriers to the safe transport of spent fuel and high-level radioactive waste in the United States."

Over the last 40 years, there have been thousands of shipments of spent nuclear fuel in the U.S.

without any radiological release or environmental harm, according to the **U.S. Nuclear Regulatory Commission**.

Back in 2012, under President **Barack Obama**, the **Blue Ribbon Commission on America**'s Nuclear Future recommended establishing interim storage sites for spent nuclear fuel. Such sites could safely store "stranded fuel" presently kept at shutdown plants. They would give the nation much-needed flexibility as other nuclear plants shut down, and, of course, the gift of time to develop permanent storage sites.

"The nation's failure to come to grips with the nuclear waste has already proved damaging and costly and it will be more damaging and more costly the longer it continues," the report warns.

If not Andrews County, then where?

Andrews County, on the Texas-New Mexico border, is sparsely populated, arid, and has few watersheds and deep groundwater. It's not a part of the country likely to be hit by natural disaster. Andrews County officials want the nuclear waste, which will bring revenue to the county and the state of Texas.

Not addressing the interim and long-term storage needs for spent nuclear fuel only provides a false sense of security. The spent fuel will keep collecting at sites across the country. The cost of storage to ratepayers and taxpayers will only increase. And the U.S. will fall behind on the global challenge of nuclear safety, security and storage.

Perhaps there is a debate to be had on building new nuclear plants, but the fact is, we have them and they have produced waste that must be stored. Let's deal with that.

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SONGS document provided by Gary Headrick

Obviously, I wish to remain anonymous. I would like to continue to work at SONGS and others that have spoken out in opposition to the chosen vendor (Holtec) in public have been ————— ——————

However, the decision to change dry cask storage designs does not seem to be advantageous and rightly raised a lot of questions with the public. I have been ————————— ——————————————————————and as I see it, there is no clear advantage (semiburied) for the Holtec design as proposed to be installed at SONGS vs the AREVA TN design and appears to have some disadvantages (nearness to water table, this design is not currently licensed for SONGS,etc).

I just think the wrong design was chosen for whatever reason (I have been told that the decision makers and their relationships with the vendors appear to have influenced the decision, ———————————— I understand there was a difference in the bid values amongst the bidders, but that AREVA resubmitted a new bid value which was not accepted. Perhaps the bid window had closed.

You can do what you wish with these two issues – the choice to change vendors and the fuel inspection results.

SONGS document provided by Gary Headrick

Issue 2

The spent nuclear fuel inspection effort underway at SONGS is being currently performed to characterize all the remaining fuel stored in the spent fuel pools (~2700 fuel assemblies) as "intact" or "failed/damaged" (i.e. each fuel pin cladding does not have any breaches in it) per NRC ISG-1 criteria. This is accomplished by visually examining each fuel assembly with underwater cameras for damage and debris along with "canned sipping" each fuel assembly by placing it in a can and drawing a vacuum on the fuel assembly. If there is a breach in the fuel pin cladding, radioactive fission product gases will escape and are counted by detectors. The fuel assembly is then classified as failed and is required to be "canned' in a damaged fuel can in the dry storage container when placed in ISFSI.

During the inspection effort, somewhere around 10 fuel assemblies out of ~2000 which had not been previously sipped were determined to be failed. The other ~ 700 fuel assemblies in the spent fuel pools were to only visually inspected as they had previously been sipped when the fuel assembly was being removed from the reactor during a refueling outage. However, at the end of the visual only effort bubbles were observed coming from a fuel assembly. This assembly was sipped and determined to be failed. A sample ~50 fuel assemblies of the ~700 to be only visually examined were sipped and ~5 of these were determined to be failed. I believe the remaining ~650 fuel assemblies will be sipped to ensure they have been characterized correctly.

Everything I have ever read in industry and government literature/regulations about storage of spent nuclear fuel in spent fuel pools and in dry cask storage does not postulate further damage to spent nuclear fuel in those environments for up to 100 years. Storage of fuel in spent fuel pools is the most benevolent environment the fuel will see during the rest of its existence. During vacuum drying of the dry storage container in preparation for dry cask storage the fuel pin cladding is stressed as the fuel pellet temperature rises significantly (to ~900 degrees) due to no cooling during vacuum drying and fuel pin internal pressures are higher. While in dry cask storage, the temperature of the fuel pellet is significantly higher than when in stored in the spent fuel pool, so internal pressures in the fuel pin are higher also. I recall there was a fuel pin failure in a dry cask container during vacuum drying at a plant in the Midwest recently. Not sure of the resolution to the failure.

Additionally, if the fuel is not considered damaged/failed, it is not placed in a damaged fuel can in the dry storage container prior to being stored in the ISFSI. The real issue is that fuel is experiencing additional damage/degradation while in spent fuel pool storage and potentially in dry cask storage. I do not believe that this has been seen previously. This is not a criticality issue during this time, but when it becomes one is during transportation of the dry storage containers to interim storage sites or ultimate burial or reprocessing. The purpose of the damaged fuel cans in the dry storage containers is to prevent the migration of fuel within the dry storage container during a transportation accident such that a criticality accident cannot occur.