UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 2, 2000

MEMORANDUM TO: Susan F. Shankman, Deputy Director
Licensing and Inspection Directorate
Spent Fuel Project Office, NMSS

FROM: Chester Poslusny, Jr., Senior Project Manager
Transportation and Storage Safety
and Inspection Section
Licensing and Inspection Directorate
Spent Fuel Project Office, NMSS

SUBJECT: SUMMARY OF PUBLIC MEETING WITH THE NUCLEAR ENERGY INSTITUTE

On December 17, 1999, a workshop on spent fuel storage generic issues was conducted at the U.S. Nuclear Regulatory Commission (NRC) headquarters in Rockville, Maryland. The workshop was attended by over 70 representatives from NRC, the U.S. Department of Energy (DOE), the Nuclear Energy Institute (NEI), the Electric Power Research Institute (EPRI), utilities, cask vendors, and the public. Attachment 1 is the agenda for the meeting. Attachment 2 is a list of those who attended the meeting.

William F. Kane, Director of the Office of Nuclear Material Safety and Safeguards and Ralph Beedle, Senior Vice President of the Nuclear Energy Institute (NEI) opened the workshop and set the tone for the meeting by defining the objectives for the conduct of a generic issue panel and roundtables on high burnup and burnup credit. These objectives were 1) reaching consensus on which key generic issues need to be resolved and priorities for their resolution, 2) considering options for resolving these issues such as topical reports and lead plant submittals to NRC, and 3) establishing a realistic framework and path for issue resolution. Mr. Beedle noted that the most critical issues to the industry are 1) the need to be able to store high burnup fuel, 2) the need to streamline the certificate of compliance amendment process, and 3) the need to permit consideration of burnup credit for cask designs as outlined in Attachment 3.

Generic Issues Panel

A panel of representatives from both NRC and the industry discussed various issues and their relative priorities. Attachments 4-7 are slides presented by the industry representatives on the panel. Based on these discussions, 13 issues (Attachment 8) were identified by the industry representatives during discussions, 12 additional issues were identified by NRC as those which could be addressed through interim staff [review] guidance, and 6 items were identified by NRC as generic issues (Attachment 9). High burnup fuel, streamlining the amendment approval process, burnup credit, and standard technical specifications received the most discussion during the session. The NRC asked NEI and industry to consider all identified issues and requested that the industry identify the top 25% in priority order. NEI agreed to coordinate this ranking in the near term.

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High Burnup Roundtable

A roundtable discussion on high burnup fuel was conducted by NRC and industry representatives. An EPRI representative began the session with a discussion of the methodologies that could be pursued to obtain approval of casks for storage of fuel with burnup in excess of 45,000 MWd/MTU (Attachment 10). Consensus was reached that the number of fuel assemblies that exceed the 45,000 MWd/MTU is increasing at operating reactors and needs immediate attention for future dry cask storage needs. NEI and NRC agreed that thermal modeling and data availability issues are critical to establishing a basis for approval of new cask designs for higher burnup fuel.

Industry representatives suggested that existing data on cladding durability should be "slightly extrapolated" using engineering judgement to provide a basis for storage of fuels with higher burnups. They also noted that additional cladding data could be obtained by analyzing the fuel being shipped from the Limerick plant to GE Vallecitos. Further, it was stated that utilities need to take the initiative to obtain the necessary data to justify the storage of the quantities of high burnup fuel with support from EPRI and NEI. The NRC staff noted that cladding corrosion accelerates after fuel has reached the 45,000 MWd/MTU burnup and that even minor extrapolation of cladding characteristics would be difficult to justify and approve. The NRC's Office of Nuclear Regulatory Research (RES) noted that it has a program in place to obtain data from the GE Vallecitos analysis of the Limerick fuel but that the information would not be available until FY 2001. The NRC staff stated that it would welcome an industry topical report to address the high burnup issue and would assign priority for staff review of such a topical report.

Based on the need to address the high burnup fuel issue, NEI agreed to establish a working group with NRC and industry participation and to submit to NRC in the near term, a "white paper" to define a framework and plan for obtaining approval of the dry cask storage of fuels with burnup greater than 45,000 MWd/MTU.

Burnup Credit Roundtable

A roundtable discussion on burnup credit was conducted by about a dozen representatives of NRC and industry. Benefits from additional burnup credit would be to increase the cask storage capacity for fuel assemblies, thereby requiring fewer casks at each site, and permitting smaller storage pads. A representative of EPRI provided a discussion of the issue (Attachment 11). Industry representatives noted that Interim Staff Guidance-8, "Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks," needs to be clarified regarding what is and what is not accepted in the DOE methodology for giving burnup credit. The NRC staff stated that the interim staff guidance would be further updated using information being developed by RES. The RES staff committed in the near term to issue its report on burnup credit with recent findings and recommendations.

Industry comments included a suggestion that establishing a design basis for a hardened shell canister to serve as a secondary containment for the stored fuel could resolve the burnup credit issue. Another comment was that the dry cask storage of BWR fuel could take advantage of some burnup credit and this should be pursued. The NRC staff also identified a number of areas where industry could provide information and data to support additional burnup credit and further revisions to the interim staff guidance. These included defining burnable poison designs used in PWR fuels, providing analytical benchmark data to support calibrated estimates of fission product margin, providing histories of assembly burnup with control rods inserted for worst-case PWR plants and cycles, submitting post-irradiation assay data on assemblies with burnable poisons, and providing operating history data for maximum soluble boron concentration. NEI committed to evaluate both the RES report and NRC workshop suggestions and to continue to work with the staff on this issue.

No proprietary information was disseminated or presented at this meeting. No regulatory decisions were requested or made.

Please contact me if you wish to further discuss these issues.

Attachments:

1. Meeting Agenda
2. Attendees List
3. NEI Slides
4. Duke Power Slides
5. Holtec Slides
6. NAC Slides
7. "The Fabricator's Viewpoint"
8. Industry Issues List
9. NRC Generic Issues Panel Slides
10. EPRI High Burnup Roundtable Slides
11. EPRI Burnup Credit Roundtable Slides

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OFC:	SFPO	SFPO	SFPO	SFPO	SFPO	
NAME:	CPoslusny:dd*	VTharpe*	PEng	S. Shankman	W Hodges	
DATE:	1/13/2000	1/28 /2000	1/31/2000	1/31 /2000	2/2/2000	

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Attachment 1
Meeting Agenda

NRC/NEI JOINT WORKSHOP
SPENT FUEL CASK GENERIC ISSUES
December 17, 1999
AGENDA

9:00-9:30 a.m.	Welcome, introductions, workshop objectives,conduct and format

William Kane, Director, Office of Nuclear Material Safety and Safeguards, NRC
Ralph Beedle, Senior Vice President, NEI

930-11:45 a.m.	Generic Issues Panel Key Issues, Status, Priorities, Schedules

William Brach, Director, Spent Fuel Project Office, NMSS, NRC
Thomas Palmisano, Site Vice President, Consumers Power
David Culp, Manager Spent Fuel Management, Duke Power
Dr. Kris Singh, President, Holtec International
Edward Davis, President, CEO, NAC International
Lewis Detter, Quality Assurance Manager, Precision Components Corp.

11:45-12:00 noon	Summary Discussion (Kane/Beedle)
12:00-1:00 p.m.	Lunch
1:00-2:30 p.m	Roundtable on High Burnup (NRC,utilities, vendors, NEI, and EPRI) ISG-11 overview Acceptance criteria and criticality and retrievability concerns Limiting drying temperatures Achieving a protocol, integrated approach-burnup credit and convective heat removal methods Wrap up-NRC/industry initiatives and schedules
2:30-2:45 p.m.	Break
2:45-4:00 p.m.	Roundtable on Burnup Credit (NRC, utilities, vendors, NEI, and EPRI) ISG- 8 overview Benefits for cask design/usage Criticality margins for cask design Code use validation/benchmarking data End effects Burnable poisons Wrap up-NRC/industry initiatives and schedules
4:00-4:15 p.m.	Workshop summary and closing

Attachment 2
Attendance List

NRC/NEI MEETING
WORKSHOP ON SPENT FUEL STORAGE GENERIC ISSUES
DECEMBER 17, 1999

Name	Organization	Phone Number
Chet Poslusny	NRC/NMSS/SFPO	301-415-1341
Carl Withee	NRC/NMSS/SFPO	301-415-8534
Kim Gruss	NRC/NMSS/SFPO	301-415-8586
Don Carlson	NRC/NMSS/SFPO	301-415-8502
Chris Brown	NRC/NMSS/SFPO	301-415-1988
Darren Piccirillo	NRC/NMSS/SFPO	301-415-3130
Rob Lewis	NRC/NMSS/SFPO	301-415-8527
Marissa Bailey	NRC/NMSS/SFPO	301-415-8531
Patricia Eng	NRC/NMSS/SFPO	301-415-8577
M. Wayne Hodges	NRC/NMSS/SFPO	301-415-2398
Susan Shankman	NRC/NMSS/SFPO	301-415-2287
E. William Brach	NRC/NMSS/SFPO	301-415-8500
Tony Attard	NRC/NRR	301-415-2876
Ernie Rossi	NRC/OCFO	301-415-7499
Vanice A. Perin	NRC/RES	301-415-8143
Meraj Rahimi	NRC/DWM	301-415-6616
Farouk Eltawila	NRC/RES	301-415-5741
Pat Castleman	NRC/OCM	301-415-8420
Alan Nelson	NEI	202-739-8110
Ralph Beedle	NEI	202-739-8088
Lynnette Hendricks	NEI	202-739-8109
John Kessler	EPRI	650-855-2069
Jodi Furk	Entergy	225-336-6139
Paul McNeman	Entergy	225-381-4648
Chris Walker	Entergy	501-858-4311
Darrell Williams	Entergy	501-858-4668

NRC/NEI MEETING
WORKSHOP ON SPENT FUEL STORAGE GENERIC ISSUES
DECEMBER 17, 1999

Greg Broadbent	Entergy	601-437-6224
Lewis Detter	PCC	717-848-1126
Emil Zernick	Consumers Energy	616-764-2917
Phil Flenner	Consumers Energy	616-764-2544
Adam Levin	ComEd	630-663-7406
Cecil Parks	ORNL	423-574-5280
Tom Palmisano	Consumers Energy	616-764-2296
Dave Larkin	Energy Northwest	509-377-4201
Gary Walden	Duke Energy	704-382-6778
Dave Culp	Duke Power	704-382-8833
Dave Batalo	Virginia Power	804-273-2246
Michael Mason	Transnuclear	914-347-2346
Ed Davis	NAC	770-447-1144
Jack Boshoven	TNW	510-744-6018
James Hopf	BFS	831-430-5211
Matt Eyre	PECO Nuclear	610-640-6829
John Duffy	Ranor	978-874-0591
Dave Jones	Duke Energy	404-382-4080
Bill Lee	NAC	770-447-1144
Altheia Wyche	SERCH Licensing/Bechtel	301-417-4458
Dave Waters	Consumers-Big Rock	231-547-8316
Richard Chang	Southern California Edison	949-368-8105
Albert Machiels	EPRI	650-855-2054
Glenn Adams	WEPCO	414-221-4691
Christian Blessing	Holtec	856-797-0900
E. R. (Bob) Gilbert	PNNL	509-372-4091
C. E. Beyer	PNNL	509-372-4605

NRC/NEI MEETING

WORKSHOP ON SPENT FUEL STORAGE GENERIC ISSUES

DECEMBER 17, 1999

Eileen Supco	ERI	202-785-8833
Dale Lancaster	TRW	814-231-5223
Max DeLong	PFS/NSP	612-330-5850
William Lake	DOE	202-586-2840
Ed Assan	ARZ	703-631-7401
Paul Plante	Maine Yankee	207-882-5806
Tara Neider	TN	914-347-2345
Alan Hanson	TN	914-347-2345
S. E. Turner	Holtec Int'l	727-787-4625
C. R. MacDonald	PELP	410-257-6389
Archer Haskins	AA Haskins Assoc.	804-384-0113
David Rivard	Maine Yankee	207-882-5722
Joe Sapyia	Framatome Technologies	804-832-2806
Tim Smith	GSI	703-716-4846
M. Callahan	GSI	301-526-7606
William Alberque	Numark Associates	202-466-2700
Jenny Weil	McGraw Hill	202-383-2161

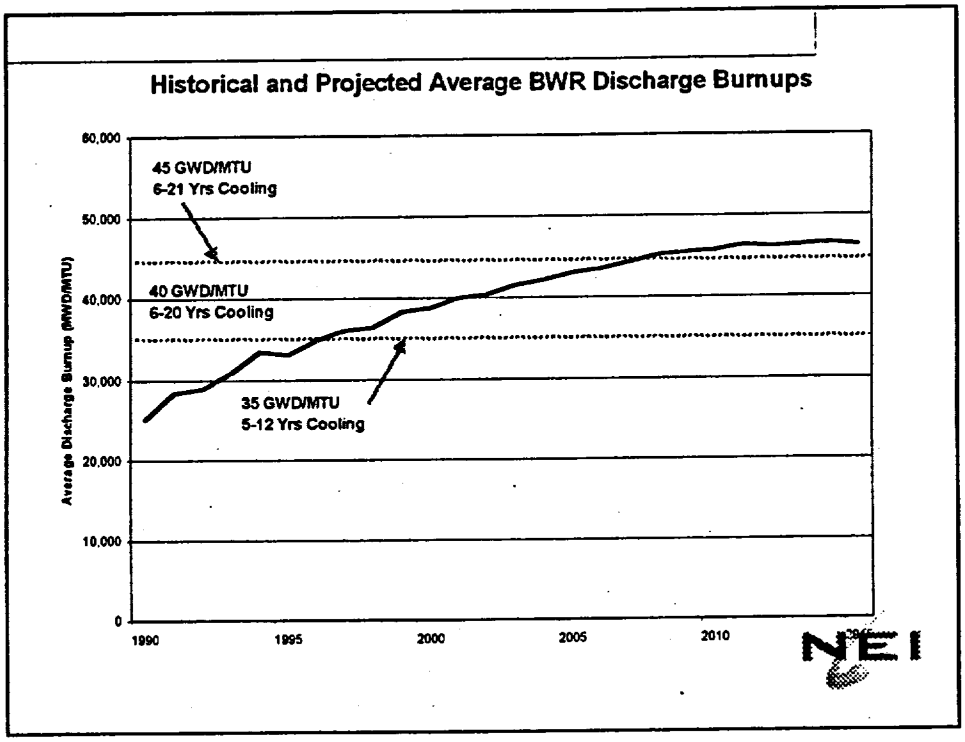
Attachment 3
NEI Slides

Industry Spent Fuel Management

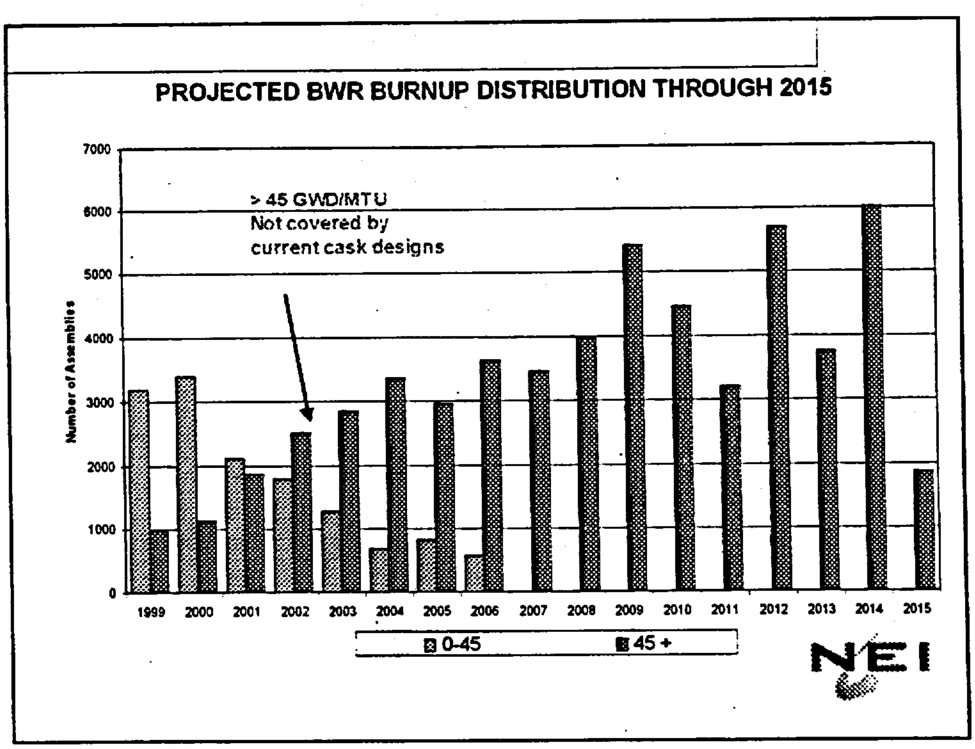
Ralph Beedle
NEI Chief Nuclear Officer
December 17, 1999

Dry Casks Essential for the Future

- Supports Safe Operations
- Supports Plant Competitiveness



Historical and Projected Average BWR Discharge Burnups
Average Discharge Burnup (MWD/MTU)
45 GWD/MTU
6-21 Yrs Cooling
40 GWD/MTU
6-20 Yrs Cooling
35 GWD/MTU
5-12 Yrs Cooling
60,000
50,000
40,000
30,000
20,000
10,000
0
1990
1995
2000
2005
2010
2015
NEI



PROJECTED BWR BURNUP DISTRIBUTION THROUGH 2015
Number of Assemblies
> 45 GWD/MTU
Not covered by
current cask designs
7000
6000
5000
4000
3000
2000
1000
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
0-45
45 +
NEI

Integrated Solution Needed for Full Capacity Casks

- Criticality through approval of burnup credit
- Shielding, including preferential loading
- Heat removal, including more realistic heat transfer and preferential loading

NEI

Integrated High Burnup Solution Will Save $4 Billion

- 10,500 casks needed without integrated solution
- Avoidance of 30% capacity loss for 50% of casks = 1730 casks
- $2M per cask times 1730 casks = $4Billion

NEI

Attachment 4
Duke Power Slides

Duke Power
A Duke Energy Company

Spent Fuel Storage Generic Issue Resolution Priorities --Duke Energy Perspective--

NRC Meeting

December 17, 1999

Duke Power
A Duke Energy Company

Oconee Spent Fuel Discharge Overview

- 3 unit PWR station
- 18 month cycles
- Current batch average burnup approximately 43,000 MWD/MTU
  - 83 % of assemblies above 40K
  - 35 % of assemblies above 45K
  - 11 % of assemblies above 50K

Duke Power. A Duke Energy Company

Oconee Spent Fuel Pool Status

- Current spent fuel pools status:
  - 46 % of assemblies > 40,000 MWD/MTU
    - 1st discharge 1989
  - 17 % of assemblies > 45,000 MWD/MTU
    - 1st discharge 1992
  - 1 % of assemblies > 50,000 MWD/MTU
    - 1st discharge 1997

Duke Power. A Duke Energy Company

Oconee Dry Storage Overview

- Initial ISFSI loading in 1990 utilizing Site-specific NUHOMS
- Completed transition to General License NUHOMS in 1999
- Current ISFSI status:
  - 46 canisters loaded (40 Site-specific, 6 General License)
  - 1,104 assemblies
- NUHOMS CofC limits burnup to 40,000 MWD/MTU
  - *Pending* Rev. 2: Increases burnup to 45K ("proposed CofC" - 4/29/99)
  - *Pending* Rev. 3: Addition of BPRAs (under NRC review)
  - *Future* Rev. "4": To remove minimum B.U. curve (target submittal: 2000)
  - *Future* Rev. "5": To increase burnup to 55K (target submittal: 2001)

Duke Power. A Duke Energy Company

Key NRC Milestones to Support Oconee Dry Storage

- Rev. 2 of NUHOMS CofC (burnups to 45K)
  - Need approval by 6/01
- Rev. 3 of NUHOMS CofC (BPRAs)
  - Need exemption by 1/24/00
- Rev. "4" of NUHOMS CofC (min. B.U. eliminated)
  - Need approval shortly after Rev. "3" (review schedule to be determined with vendor/NRC staff)
- Rev. "5" of NUHOMS CofC (burnups to 55K)
  - Need approval by 6/07
  - Aligns dry storage with ONS reactor discharges

Duke Power. A Duke Energy Company

Spent Fuel--Generic Issues Top Priorities

- Storage of high burnup fuel in dry storage
  - Resolve cladding integrity concerns
  - Increased thermal loads for dry storage systems
- Modify NRC approval process to allow amendments without rulemaking
  - Similar to Part 71 CofC amendments
- Dry storage license renewal
  - ONS Site-specific license expires 2010

Attachment 5
Holtec Slides

Dry Storage Issues & Answers:
A System Designer's Perspective

By
Dr. K.P. Singh
President & CEO
Holtec International

Presentation to NRC NEI Joint
Spent Fuel Cask Workshop
December 17, 1999

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Issues of Urgent Importance

I Storage of High Burnup Fuel (45 to 65 GWD/MTU)

II High Capacity PWR Basket (over 30 locations per MPC)

III Shorter Post Core Decay Time (PCDT) for transfer to Dry Storage (<5 yrs)

IV High Seismic Regions (ZPA>.5gs)

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I Storage of High Burnup Fuel

Facts

- To stay alive, nuclear plants will continue to move towards higher initial enrichments and longer operating cycles
- High burnup fuel (45 to 65 GWD/MTU) will be discharged in abundance in the coming years

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3

I Storage of High Burnup Fuel

Facts (Continued)

- High burnup means
  - lower allowable fuel cladding temperature
  - much greater neutron fluence
  - Higher heat generation rate
- Existing transport overpacks will be unable to meet Part 71 shielding requirements
- Required PCDTs will be too long for storage at an ISFSI

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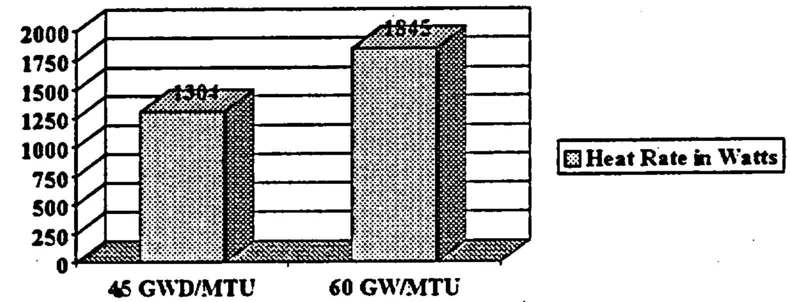
I Storage of High Burnup Fuel

Facts (Continued)

Comparision of Heat Rates for B&W 15 x 15 SNF at Different Burnups



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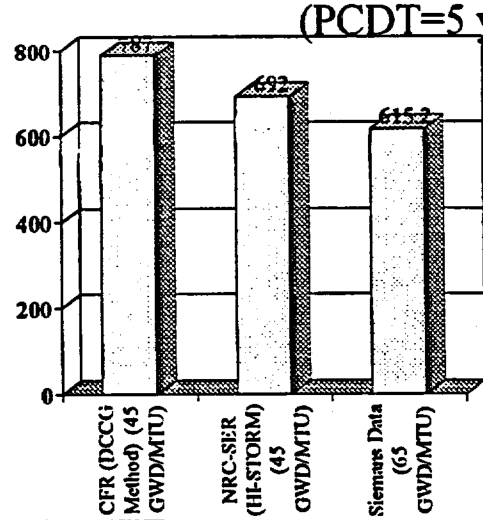
Comparison of Allowable PWR Fuel Cladding Temp. at Medium and High Burnup (PCDT=5 years)



There is a penalty of 76.8°F in the allowable cladding temp. when the burnup increases from 45 to 65 GWD/MTU

☐ Allowable Fuel Cladding Temp.

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I Storage of High Burnup Fuel

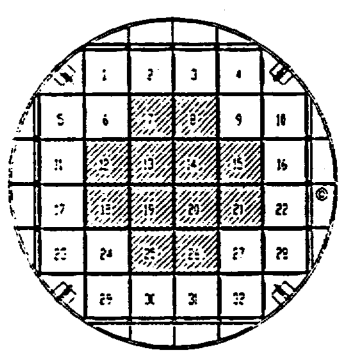
Consequences of Facts

- MPC baskets must use regionalized storage:
  - store cold and old fuel on the periphery (Region 2)
  - store high burnup and low PCDT SNF in the interior (Region 1)

I Storage of High Burnup Fuel

Regionalized Storage (RS)

Facts



Regionalized Storage in an MPC-32

- RS will reduce dose emitted by the storage cask & transfer cask
- RS is essential to storing and transporting SNF

I Storage of High Burnup Fuel
Regionalized Storage
Facts (Continued)

- RS needed in storage because high burnup SNF has lower permissible cladding temp.
- RS needed in transport to meet 10CFR Part 71 dose limits

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I Storage of High Burnup Fuel
Regionalized Storage
Consequences

- Total heat duty of the MPC will be reduced!
- The maximum permissible heat generation rate of the Region 1 SNF will increase; Region 2 SNF heat generation rate will decrease

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I Storage of High Burnup Fuel

Obstacles to Success

- Maximum permissible cladding temp. vs. PCDT relationship not yet defined by the NRC
- No regulatory guidance on regionalized storage

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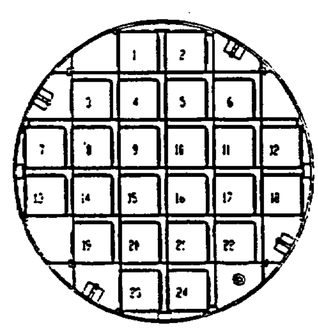
11

II High Capacity Fuel Basket

Facts

- State-of-the-art low capacity PWR fuel baskets are wasteful of money and indifferent to ALARA



Low Capacity Fuel Basket

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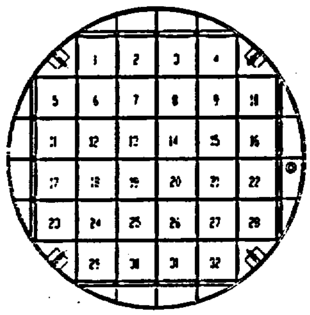
II High Capacity Fuel Basket

Facts (Continued)



High Capacity Fuel Basket

- ISG-8 in its present form will not permit real progress in this field

II High Capacity Fuel Basket

Low Capacity Basket is Wasteful & ALARA Indifferent

Let us consider a typical well run PWR: TVA's Sequoyah, a dual unit W in commercial operation since 1980 (Unit 1) & 1982 (Unit 2)

Sequoyah's End-of-Life Dry Storage Needs (6300 fuel Assemblies)		
	MPC-24	MPC-32
No. of MPCs	263	197

Over 41% of the SNF inventory at Sequoyah will be at burnup > 45 GWD/MTU

II High Capacity Fuel Basket

(Continued)

Cost Item	Using MPC-24 (in Ca. 2000 dollars)	Using MPC-32 (in Ca. 2000 dollars)
Casks & Ancilliaries	$269.6M	$220.7M
ISFSI Design & Construction	$19.5M	$13.9M
Fuel Loading & ISFSI Impl.	$157.8M	$118.2M
Decommissioning	$57.8M	$46.9M
Total	$505.0M	$399.7M

Projected Savings Using MPC-32: $105.3M

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II High Capacity Fuel Basket

Analogy with Wet Storage Experience

Sequoyah's Pool

Storage Area: 181000 in^2

Storage Capacity: 2091 assemblies

Density of Storage: 86.6 in^2/SNF

Comparison of Storage Density for Sequoyah	
Storage Mode	Density (in^2 of storage space required by each SNF)
Wet Storage	86.6
MPC-24	153
MPC-32	115

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II High Capacity Fuel Basket

Conclusion

- Storage of SNF in dry mode is clearly "more criticality proof than wet storage"
- Dry storage lags wet storage by over 75% in terms of storage efficiency in the low capacity MPC configuration

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III Reduced Post Core Decay Time (PCDT)

Need

To permit non-operating reactors to decommission on a more reasonable schedule.

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III Reduced Post Core Decay Time

Fact

The technology to reject heat at a greatly increased rate is available and proven.

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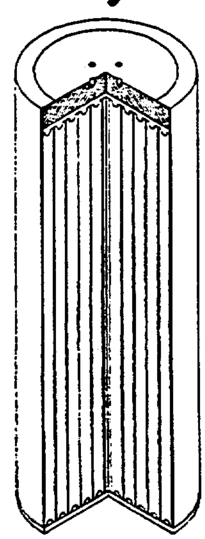
III Reduced Post Core Decay Time

Fact

Aided by the thermosiphon action, this basket rejects heat at greater than 200% of the rate of prior technologies while using all stainless internals.



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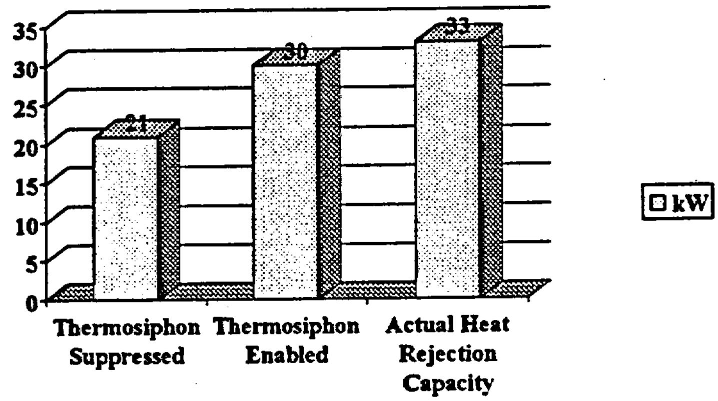
III Reduced Post Core Decay Time

Fact



HI-STORM 100 MPC-24 Heat Rejection Rate at NRC Mandated Permissible Cladding Temp.

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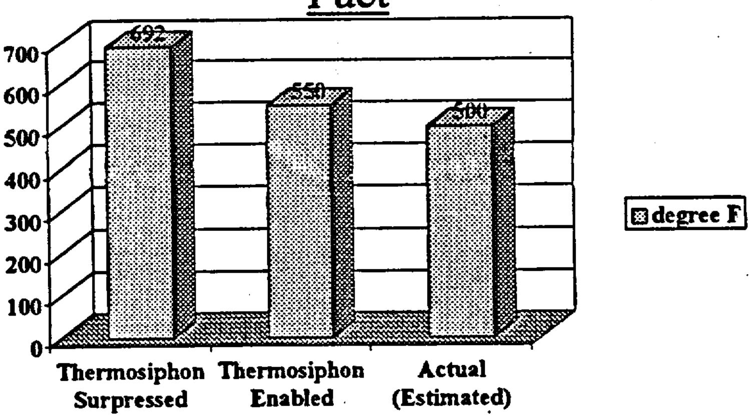
December 17, 1999

III Reduced Post Core Decay Time

Fact



Peak Cladding Temp. (°F) at Currently Licensed Heat Loads (HI-STORM 100 with MPC-24)

HOLTEC INTERNATIONAL

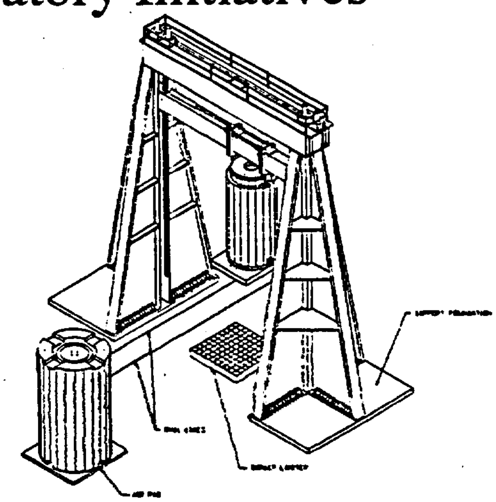
December 17, 1999

IV ISFSIs in High Seismic Regions

- Holtec's Topical Report "HI-STAR 100 and HI-STORM 100 Deployment at High ZPA Sites" provides <u>three</u> independent checks of structural integrity
- Topical Report has undergone Round One RAI
- Holtec's ongoing interactive effort with the NRC on this issue is certain to yield a permanent solution for the industry

Recent Regulatory Initiatives

- Successful recent regulatory initiatives provide an excellent template for future solutions:
  - Cask Transfer Facility for MPC transfer out-side the Part 50 containment structure



Recent Regulatory Initiatives
(Continued)

- Damaged Fuel Canister Design Criteria & ISG-1
- MPC as secondary containment for storing failed SNF
- Recognition of convective heat transfer in certain basket design configurations

In all cases, new criteria were developed and adopted through vigorous interaction between the cask designer and the NRC

Closing Remarks

- Fuel vendors jealously guard their data
- High quality experimental data is hard to come by and takes years to acquire
- NRC is reluctant to make small extrapolations from experimental data

Closing Remarks
(Continued)

- The technical issues underlying high burnup are quite complex; require a vigorous interactive effort with cask designers
- Certification of high capacity baskets will save considerable amount of money, reduce personnel exposure and reduce permanent repository capacity needs
- Regionalized storage to reduce PCDT is central to minimizing dose and reducing delays in decommissioning of shutdown reactors

Attachment 6
NAC Slides

NAC INTERNATIONAL

Spent Fuel Management Technology Licensing Trends and Issues

"Closing the Gap"

Edward M. Davis
President & CEO
NAC International

Presentation to NRC/NEI Joint Spent Fuel Technology Workshop
December 17, 1999

Atlanta Corporate Headquarters 655 Engineering Drive Norcross GA 30092 770-447-1144 Fax 770-447-1797 www nacintl com P-99097

Key Points

- SFPO and industry have worked hard to make MPC technologies available to utilities
  - Improvements instituted to "jump start" licensing and certification
- Utility needs are driving new issues
  - Need to "close the gap" between fuel inventories and licensed technologies
- Process reforms are as important and urgent as technical issues resolution

SFPO Improvements

- More focused and timely licensing reviews without compromising public health and safety
- Established constructive rules of engagement
  - Certify what is certifiable - license what is licensable
  - Committed to meeting schedules
- Issuance of standard review plans
- Issuance of interim staff guidance

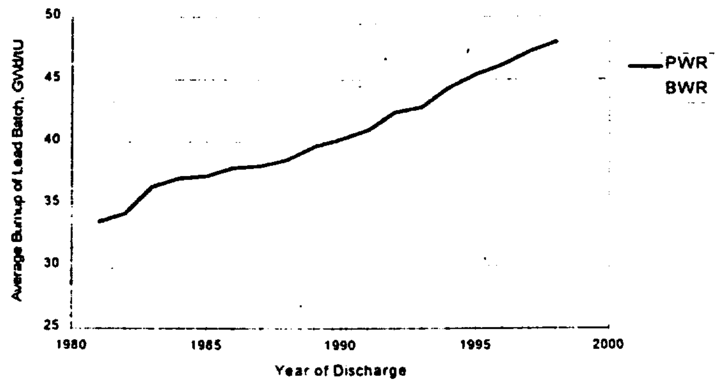
NAC INTERNATIONAL 2

Competition Driving Needs

- Operating plant needs for storage space are changing
  - Fuel characteristics are dynamic
  - Existing technologies not licensed for growing proportion of fuel
- Decommissioning plant needs are accelerating
  - Full pool solution
  - All the same issues as operating plants
  - In addition to fuel content, need to address damaged fuel, control rods, burnable poison rods, GTCC waste and other fuels

NAC INTERNATIONAL 3

Trend in Lead Batch Discharge Burnup (Typical)

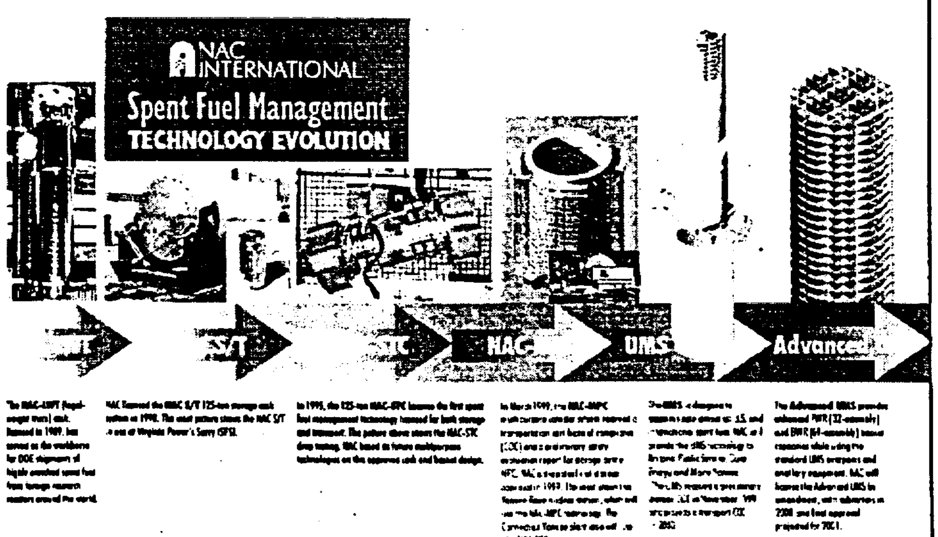


Urgent Resolution of Generic Technical Issues Is Critical

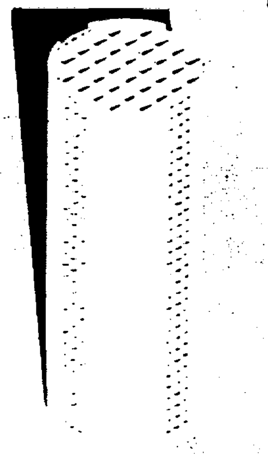
- Burnup credit
- High burnup fuel
- Standardized technical specifications
- Other - e.g., cask tipover, high seismic, convective heat transfer

Next Generation Solutions Are At Hand

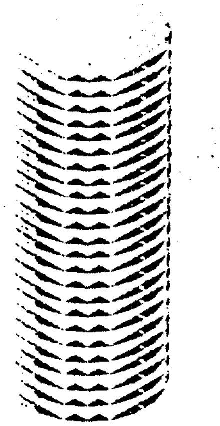
- Advanced designs are ready for NRC review
- Full potential of advanced designs will fail to be realized absent resolution of generic issues



UMS-32 and UMS-69 Fuel Baskets



32-Assembly PWR Fuel Basket



69-Assembly BWR Fuel Basket

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Process Refinements Needed

- Generic issue resolution program needs to be established
  - Prioritization and alignment with utility needs
  - Schedule certainty
  - Dedicated resources

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Process Refinements Needed
(continued)

- Design change approval process needs overhaul
  - Amendment process needs to be rethought
  - Implement direct to final approval process
  - Implement revised 72.48 process
  - Realign Part 72 with Part 71 approval process
- COC rulemaking process needs to be expedited

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Summary

- Efforts to date have broken logjam and have led to licensing of initial MPC spent fuel management technologies
- NRC SFPO mission and program should be dynamic in order to meet changing industry needs
- Programs and resources to address both technical and process issues are necessary to "close the gap" between emerging needs and currently licensed MPC technologies

NAC INTERNATIONAL 11

Attachment 7
"The Fabricator's Viewpoint"

THE FABRICATOR'S VIEWPOINT

Foremost Priority of a Fabricator –

Insure manufacturing is completed in accordance with Contract Requirements.

Tools needed to accomplish the above -

1) Clear Understanding of the requirements
2) System to incorporate those requirements
3) Educated workforce to complete the instructions correctly
4) Method to evaluate the effectiveness of the organization

Clear Understanding of the Contractual Requirements -

Fabricators want to supply what the ultimate customer desires –

To do so, the Designer, the Utility, and the Fabricator must all interpret the requirements to mean the same thing.

Effective tool is an up-front meeting after order award to review the areas that may be subject to misinterpretation at a later date.

System to incorporate those requirements -

A Fabricator's System or Program must insure the customer requirements are incorporated into the manufacturing cycle.

Typical program would include the following:

1) Procurement Document Control – Vendor Base and Vendor Control

2) Software Control

3) Identification and control of items- throughout all phases of manufacturing

4) Detailed process planning and control of that processing

5) Inspections and tests

6) Record Generation – Data Book Preparation

Educated workforce to complete the instructions correctly -

The typical fabricator needs to have employees that are not only technically competent, but proficient in the paperwork systems as well.

1) Qualifications maintained

2) Regularly scheduled Training sessions to review system changes

3) Knowledge of customer requirements

Method to Evaluate the effectiveness of the Organization -

An organization must be evaluated on its performance to established programs

1) Audits-Internal (All elements are evaluated yearly)
   Customer and Utilities (Conducted every three years)
   NRC (Usually an inspection for each product line)

2) Tracking and trending of Non-Conformances

3) Corrective Action Program

Interface of Designers, Utilities, and Fabricators

Most fabricator shops have full time resident inspectors from not only the utilities, but the Designers as well.

Requires continual coordination and co-operation from all parties to ensure all desired inspection points are fulfilled with the least impact to schedule.

A common understanding of the requirements of these hold and witness points is also needed to avoid misunderstandings on the shop floor.

Communication can not be over- emphasized.

Documentation Requirements

Very large portion of the typical fabricator's time is spent in completing and compiling the needed records that eventually go into the data book.

All customers have data book requirements that are just slightly different.

A very important meeting for any contract is a designer, utility, and fabricator understanding of how data books will be constructed(formatted), reviewed, and the exact contents of these books.

Attachment 8
Industry Issues List

ISSUES LIST

- High Burnup
- Burn up Credit
- Procedure Streamlining
- Maximum Cladding Temperature
- Shipping Storage Only Casks
- Standard Technical Specifications
- Renewal
- Minimum Burnup in Certificate of Compliance
- Pool Contentsw Storage Issues
- High Seismic
- Preferrential Loading
- High Capacity Fuel Basket
- Communication Lead Times

Attachment 9
NRC Generic Issues Panel Slides

SPENT FUEL PROJECT OFFICE

UNITED STATES NUCLEAR REGULATORY COMMISSION

DECEMBER 17, 1999

INTERIM STAFF GUIDANCES

IN DRAFT:

- COATINGS
- DEFINITION OF REAL INDIVIDUAL UNDER 10 CFR 71.104
- COVERAGE OF THE ACTIVE FUEL REGIONS BY NEUTRON POISONS
- APPROVAL OF NEUTRON ABSORBER MATERIALS FOR SPENT FUEL STORAGE AND TRANSPORT
- SUPPLEMENTAL SHIELDING (BERMS)

INTERIM STAFF GUIDANCES

UNDER DEVELOPMENT:

- UPDATE OF ISG-8: BURNUP CREDIT
- CLADDING TEMPERATURE LIMITS
- EQUIVALENT - STATIC EVALUATION OF CASK STABILITY DURING A DESIGN BASIS EARTHQUAKE
- HEAVY LOADS

GENERIC ISSUES

- LICENSE RENEWAL
- BURNUP CREDIT
- HIGH BURNUP FUEL
- THERMAL MODELING
- PRA's FOR STORAGE AND TRANSPORTATION
- SEISMIC

Attachment 10
EPRI High Burnup Roundtable Slides

Storage of High Burnup Spent Fuel

NRC-NEI Workshop
December 17, 1999

Albert Machiels
EPRI

Outline

- Topics Relevant to High Burnup Spent Fuel
- Methodology for Allowable Peak Cladding Temperatures
  - DCCG
  - CSFM
  - German-Approach-Based Methodology (Creep-Limited Methodology)

Outline (cont.'d)

- Creep-Limited Methodology
  - Type of Cladding
  - End-of-Life Condition
  - Calculation of Hoop Stress
  - Calculation of Temperature
  - Limiting Value of Creep Strain
- Potential Topics for Future Discussions or Interactions

Topics Relevant to High Burnup Spent Fuel

- Fuel Cladding Degradation Mechanisms Under Storage Conditions
- Thermal Evaluation
  - Setting Peak Cladding Temperature
  - Heat Dissipation Modeling
- Confinement Evaluation
- Shielding Evaluation
- Criticality Evaluation

Methodology for Allowable Peak Cladding Temperature

- Diffusion-Controlled Cavity Growth
  - DCCG model was developed by LLNL in 1987 [UCID-21181, September 1987]
  - Updated DCCG Model [UCRL-ID-134217, April 1999]
    - Complete updating of the thermal-physical properties of Zircaloy
    - When applied to Zircaloy, the results indicate that Zircaloy is not susceptible to DCCG at any reasonable dry storage temperature

Methodology for Allowable Peak Cladding Temperature (cont.'d)

- The Commercial Spent Fuel Management (CSFM) model
  - Originally developed by PNL in the early- to mid-1980's
  - The CSFM model relies on the development of deformation maps similar to maps used to predict such behavior for 316 stainless steel, but applied to Zircaloys
  - Several generalized categories of mechanisms for deformation and for predicting time-to-failure were identified

Methodology for Allowable Peak Cladding Temperature (cont.'d)

- The Commercial Spent Fuel Management (CSFM) model (cont.'d)
  - The resulting sets of equations require a total of 36 fixed parameters that need to be based on Zircaloy properties
  - In the domain of parameters expected to be applicable to dry storage conditions, the "Cavitation-diffusional growth" equation dominates the resulting CSFM calculation; DCCG was eventually used for benchmarking; this equation effectively represents a variation of the LLNL DCCG model
  - The approach remains acceptable to NRC per ISG-11

Methodology for Allowable Peak Cladding Temperature (cont.'d)

- German-Approach-Based Methodology [Spilker et al., JNM 250 (1997) 63-74]
  - The limiting defect mechanism for spent fuel rods in dry storage is hoop strain
  - Degradation can therefore be prevented by <u>limiting creep</u>
  - Post-irradiation creep of fuel rod cladding can be described conservatively by the creep of <u>un</u>irradiated cladding
  - Allowable uniform strain in its typical post-irradiation condition preventing tertiary creep is >1-2%

Methodology for Allowable Peak Cladding Temperature (cont.'d)

- German-Approach-Based Methodology (cont.'d)
  - The German approach has been backed by an experimental program
    - Creep strain as a function of (type of cladding, temperature, hoop stress, time up to 10,000+ hr)
    - Creep rates and rupture strains for irradiated Zircaloy-4
  - This methodology is licensed in Germany for dry storage of spent fuel with batch-average burnup up to 55,000 MWd/MTU, and peak rod burnup up to 65,000 MWd/MTU
  - ISG-11 appears to invite applicants to use this type of approach

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Creep-Limited Methodology

- Technical consensus is that leading failure mechanism in dry inert storage is excessive fuel rod hoop strain caused by creep
  - May not lead to failures leading to gross degradation ...
- Other mechanisms [Fracture Mechanics, Delayed Hydrogen Cracking (DHC), Stress Corrosion Cracking, etc.] have been considered, but are generally evaluated as being less limiting under the stress and temperature conditions existing during dry storage

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Creep-Limited Methodology (cont.'d)

- Creep rate is a function of:
  - Type of Zircaloy alloy cladding
    - Alloy composition and thermo-mechanical treatment
  - End-of-Life Condition
    - Both radiation damage and compositional changes (hydrogen pickup) leads to higher cladding strength and lower cladding ductility
    - Effects due to radiation damage tend to saturate after a couple of in-reactor cycles
    - Waterside corrosion reaction produces hydrogen

$$Zr + 2H_2O \longrightarrow ZrO_2 + 2H_2$$

[Note: Waterside corrosion is the limiting in-reactor fuel performance concern for PWRs]

Creep-Limited Methodology (cont.'d)

- Creep rate is a function of:
  - Hoop stress (σ)
    - Exponential dependence [$\propto \exp(An\sigma/E)$], or power law dependence [$\propto \sigma^n$], or combination [$\propto (\sinh(B\sigma/E))^n$]
    - Evaluation of Hoop Stress

$$\sigma = d\,\Delta p/t$$

    - d = mid-wall diameter
    - $\Delta p = p_{rod} - p_{He}$, i.e., difference between rod internal pressure and cask/canister helium fill pressure, with
    - t = cladding thickness

Creep-Limited Methodology (cont.'d)

- Creep rate is a function of:
  - Temperature (T)
    - Exponential dependence [$\propto \exp(-Q_{act}/RT)$]
    - Heat transport modeling is critical
      - Creep deformation is a thermally-activated process under dry storage conditions
        - Cask/canister design (helium pressure; free convection flow path)
        - Choice of heat transfer correlation (Wooton-Epstein; Manteufel & Todreas; DOE M&O and LLNL's effective thermal conductivity approach; detailed 3-D modeling; etc.)
        - Temperature also directly influences the driving force (hoop stress)

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Creep-Limited Methodology (cont.'d)

- Strain due to creep is a function of:
  - Time (t)
    - Creep strain is the integral over time of creep rate
- Failure due to excessive hoop strain is due to onset of plastic instabilities (typically, necking)
  - Standard creep engineering practice limits value of creep strain in order to confine creep deformation to its primary and early secondary stages

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Creep-Limited Methodology (cont.'d)

- Limiting Value of Hoop Strain
  - 1% is presently used in the German approach (Pending application for using 2%)
  - Data (burst and expanding ring tests, which use large driving forces and large strain rates, and testing using slow strain rates) obtained on irradiated claddings have been used to support these values

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Proposed Topics for Future Discussions or Interactions

- Cladding integrity under accident conditions
  - Part 72
  - Part 71
- Fuel degradation mechanism(s) and acceptance criteria
- Methodology for setting peak cladding temperatures
- Equations for calculating degradation/deformation rates

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Proposed Topics for Future Discussions or Interactions (cont.'d)

- Appropriate values of parameters
  - Fission gas release
  - Cladding wastage
  - ...
- Others (?)

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Attachment 11
EPRI Burnup Credit Roundtable Slides

Burnup Credit

NRC-NEI Workshop
December 17, 1999

Albert Machiels
EPRI

Outline

- Overview
- Actinide-Only Licensing History
- Comments on NRC's ISG-8, Rev.1
- Risk Informed Perspective
- Summary

Overview

- Current regulatory practices require a demonstration of subcriticality under prescribed conditions
  - Subcriticality is assured when $k_{eff} < 1$
  - Moderation by water occurs to the most reactive credible extent
  - Full reflection of the system on all sides by water occurs
  - The system is in its most reactive credible configuration consistent with the chemical and physical form of the material

Overview (cont.'d)

- The allowable k_{eff} is then reduced from 1 to account for such things as modeling and calculational biases and uncertainties
- Additionally, the allowable k_{eff} is further reduced by applying an arbitrary criticality safety margin of 5% (i.e., $\Delta k_{eff} = 0.05$)
- The fuel is assumed to be new (fresh) fuel

<u>The last item is the practice that is being modified when burnup credit is used</u>

Overview (cont.'d)

- Burnup Credit allows an increase of the number of fuel assemblies in the same size and lower cost package (PWR only)
  - DOE's Rev. 2 isotopes: U-234, U-235, U-238, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241
  - Using just actinides is generally sufficient to remove flux traps for spent fuel having reached the "target" or normal burnup

Overview (cont.'d)

- Example
  - Burnup Credit package - 32 assemblies
  - Non-Burnup Credit package - 24 assemblies
- Burnup Credit means ~30% less
  - Storage units (cost and space)
  - Shipments (cost, risk, permits)
  - Handling Operations (cost and risk)
  - Dose (ALARA)

Actinide-Only Burnup Credit Timeline

- May 95, DOE submitted Rev. 0 to the NRC
- March 96, NRC replied with RAI#1
- May 97, DOE submitted Rev. 1 to the NRC
- April 6, 1998 NRC replied with RAI#2
- October 6, 1998 DOE submitted Rev. 2 to NRC.
- May 17, 1999 NRC issued Interim Staff Guidance 8 (ISG-8)
- August 8, 1999 NRC issued ISG-8, Rev. 1

The NRC Bottom Line in ISG-8, Rev. 1

"The technical information provided in the literature and in the various TR revisions, together with the initial confirmatory analyses by the U.S. Nuclear Regulatory Commission (NRC) research program, have provided a sufficient basis for the staff to proceed with <u>acceptance of a burnup credit approach in the criticality safety analysis of PWR spent fuel casks</u>"

The Confusion

"Although insights gained from reviewing the TR (DOE's Actinide-Only Topical Report) submittals form a part of the basis for the staff's position, this interim staff guidance does not approve the TR or its supporting documentation."

Then the NRC provides two pages of Recommendations

Limits for the Licensing Basis

"This licensing-basis analysis should assume an out-of-reactor cooling time of five years and should be restricted to intact assemblies that have not used burnable absorbers."

Comments:

- Cooling time limited to 5 years?
- Exclusion of burnable poisons?
  - Significant take-away

Code Validation

- The NRC recommendations in this section seem to be consistent with DOE's Topical Report.
  - "Bias and uncertainties associated with predicting the actinide compositions should be determined from benchmarks of applicable fuel assay measurements."
  - "Bias and uncertainties associated with the calculation of k_{eff} should be derived from benchmark experiments"
  - "Nuclides used to determine the k-effective value should be limited to that established in the validation process"

Code Validation

- The NRC states:

  "Particular consideration should be given to bias uncertainties arising from the lack of critical experiments that are highly prototypical of spent fuel in a cask."

DOE handles this by fission product margin.

Comments:

Not clear if DOE's approach is acceptable to the NRC

Licensing-Basis Model Assumptions

- The NRC recommendations in this section also seem to be consistent with DOE's Topical Report.
  - "in-reactor operating parameters selected to provide conservative estimates"
  - "account for the axial and horizontal variation of the burnup"
  - "consider the more reactive actinide compositions of fuels burned with fixed absorbers"

Licensing-Basis Model Assumptions (cont.'d)

- But the NRC also states:

  "consider the more reactive actinide compositions of fuels burned with control rods fully or partly inserted"

- DOE utilized fission product margin for this

Comment:

Not clear if DOE's approach is acceptable to the NRC

Loading Curve

- The NRC States:

  "Loading curves should be established based on a 5-year cooling time and only fuel cooled at least five years should be loaded."

Comment:

Is NRC not allowing credit for Pu-241 decay (beyond 5 year) to Am-241? This is big!

Assigned Burnup Loading Value

- The NRC requires the use of burnup measurements:

  "measurement that confirms the reactor record assembly burnup"
- The NRC helps with guidance on calibration:

  "measurement technique may be calibrated to the reactor records"
- But the NRC states that both the measurement and record uncertainty be used for burnup reduction

Estimate of Additional Reactivity Margin

- The NRC states:
  - "provide design-specific analyses that estimate the additional reactivity margins available from fission product and actinide nuclides not included"
  - "margins should be verified using available experimental data (e.g., isotopic assay data) and computational benchmarks"
  - "Nuclear Energy Agency's Working Group on Burnup Credit provides a source of computational benchmarks"

Estimate of Additional Reactivity Margin (cont.'d)

- Finally the NRC states:

"estimated margins should then be assessed against estimates of:

(a) any uncertainties not directly evaluated in the modeling or validation processes for actinide-only burnup credit (e.g., k_{eff} validation uncertainties caused by a lack of critical experiment benchmarks with either actinide compositions that match those in spent fuel or material geometries that represent the most reactive ends of spent fuel in casks)

(b) any potential non-conservatisms in the models for calculating the licensing-basis actinide inventories (e.g., any outlier assemblies with higher-than-modeled reactivity caused by the use of control rod insertion during burnup)

Estimate of Additional Reactivity Margin (cont.'d)

Comment:

What is the required rigor in evaluating margins?

Can this be interpreted as acceptance of DOE's positions on use of fission product margin?

Recommendations

- DOE's Topical Report (Rev. 2)
- Need for clarification of what the NRC accepts and what the NRC does not accept
- Extend enrichment range as NRC specified
- Discussion may be needed on:
  - Cooling time
  - Consideration of burnable poisons
  - Rigor in estimating margins
  - Reactor records versus measurements

Risk Informed Perspective

- Need to be submerged in water and with cask failed to allow any criticality concern. The probability of this is estimated as 10^{-7} per year (Modal Study)
- Also need to under predict reactivity by more than 5% administrative margin plus the systematic bias due to conservative assumptions
- Total probability is about 10^{-13} to 10^{-17} per year or a negligible probability.

Risk Informed Thoughts

- Burnup Credit can reduce the number of shipments by 30%.
- This is a real risk reduction compared to an imaged reduction in risk associated with criticality

Summary

- Burnup Credit can be regarded as being ready for license applications based on DOE's Topical Report plus some additional steps specified by the NRC
- Better delineation of what is, or is not, acceptable would be most useful
- Risk-informed thinking does promote higher capacity casks through the use of burnup credit (vs. fresh fuel assumption) as a much better approach for minimizing overall risks

Industry comments included a suggestion that establishing a design basis for a hardened shell canister to serve as a secondary containment for the stored fuel could resolve the burnup credit issue. Another comment was that the dry cask storage of BWR fuel could take advantage of some burnup credit and this should be pursued. The NRC staff also identified a number of areas where industry could provide information and data to support additional burnup credit and further revisions to the interim staff guidance. These included defining burnable poison designs used in PWR fuels, providing analytical benchmark data to support calibrated estimates of fission product margin, providing histories of assembly burnup with control rods inserted for worst-case PWR plants and cycles, submitting post-irradiation assay data on assemblies with burnable poisons, and providing operating history data for maximum soluble boron concentration. NEI committed to evaluate both the RES report and NRC workshop suggestions and to continue to work with the staff on this issue.

No proprietary information was disseminated or presented at this meeting. No regulatory decisions were requested or made.

Please contact me if you wish to further discuss these issues.

Attachments:

1. Meeting Agenda
2. Attendees List
3. NEI Slides
4. Duke Power Slides
5. Holtec Slides
6. NAC Slides
7. "The Fabricator's Viewpoint"
8. Industry Issues List
9. NRC Generic Issues Panel Slides
10. EPRI High Burnup Roundtable Slides
11. EPRI Burnup Credit Roundtable Slides

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