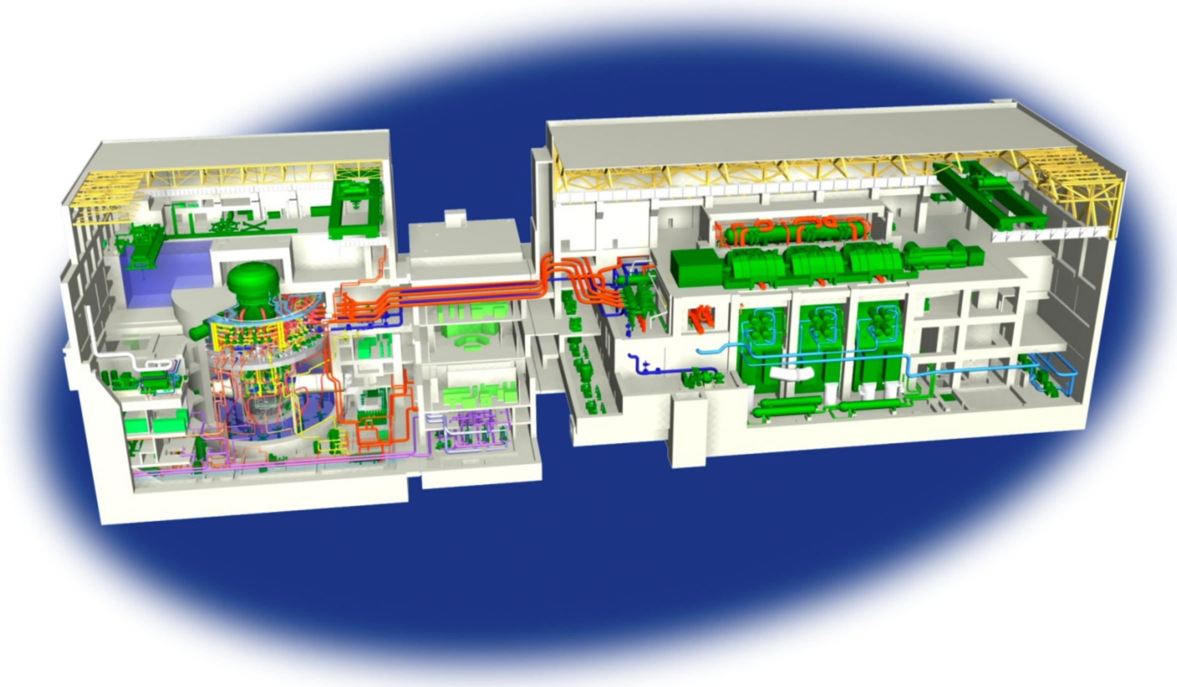
Nuclear Innovation North America LLC

South Texas Project Units 3&4 Presentation to NRC

March 20, 2013

Spent Fuel Storage Rack



Attendees

Scott Head	NINA
Steve Thomas	NINA
Dick Bense	NINA
Kenji Arai	TANE
James Fisicaro	TANE
P. Stefan Anton	HOLTEC
Indresh Rampall	HOLTEC
Charles Bullard II	HOLTEC
Danielle Castley	HOLTEC
Evrim Kalfazade	HOLTEC
Richard Springman	HOLTEC
Robert Quinn	Westinghouse

Agenda

- Introductions - All
- Opening Comments
- HOLTEC Experience Overview and Rack Design and Analysis
- Project Schedule
- Summary

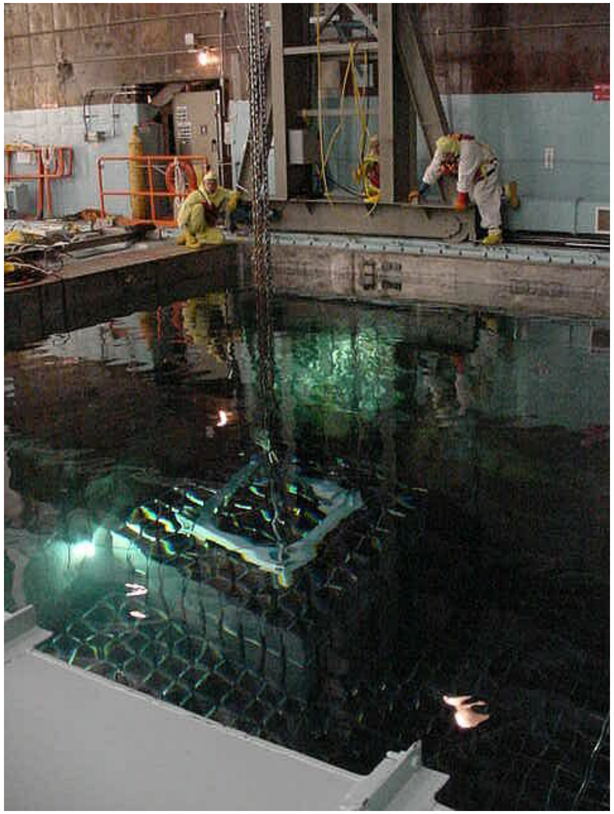
Holtec Presentation Overview

- Holtec Experience Overview
- Holtec's ABWR Rack Design
- ABWR Rack Safety Evaluations
  - Structural Evaluations
  - Criticality Evaluations

Holtec Wet Storage Racks

Holtec's Wet Storage Rack Experience

- Turnkey design, manufacturing, and installation of high density spent fuel racks
- 1987 - Awarded First Rack Project.
- Holtec has maintained 95% wet storage market share in USA for past fifteen (15) years
- Supplied over 170,000 storage locations for over 100 units on four continents (nearly ¼ of all operating units)
- Recently Completed Rack Projects:
  - Entergy's Palisades (PWR, NRC Approval 2013)
  - US AP1000 Design Certification (PWR, NRC Approval 2012)
  - First Energy's Beaver Valley Unit 2 (PWR, NRC Approval 2011)
  - Constellation's Nine Mile Point Units 1&2 (BWR, NRC Approval 2007)
  - Entergy's Cooper (BWR, NRC Approval 2007)
  - Exelon's Clinton (BWR, NRC Approval 2007)



Holtec Wet Storage Racks in a Spent Fuel Pool

Holtec Manufacturing Division (HMD)

- HMD was formerly UST&D, Inc. Acquired by Holtec International in January 2004
- Factory workspace is over 450,000 square feet (one of the largest in the U.S.), 400-ton overhead crane lifting capacity, over 380 employees (full time).
- HMD manufactures all of Holtec's nuclear equipment, including dry and wet storage systems and heat exchangers.
- NRC is familiar with the facility and has recently toured HMD on February 5, 2013.

Holtec racks in fabrication at HMD

U.S. Wet Storage Rack Experience

Ameren
- Callaway - PWR

American Electric Power
- D.C. Cook 1 & 2 - PWR

CENG
- Nine Mile 1 & 2 - BWR

Detroit Edison Co.
- Fermi 2 - BWR

Dominion Energy
- Kewaunee - PWR
- Millstone 1 - BWR & 3 - PWR

Duke Energy Corp.
- McGuire 3 & 4 - PWR
- Shearon Harris - PWR

Entergy
- ANO 1 & 2 - PWR
- Indian Point 2 - PWR
- J.A. FitzPatrick - BWR
- Palisades - PWR
- Pilgrim - BWR
- Vermont Yankee - BWR
- Waterford 3 - PWR

Exelon
- Braidwood 1 & 2 - PWR
- Byron 1 & 2 - PWR
- Clinton - BWR
- LaSalle 1 - BWR
- Limerick 1 & 2 - BWR
- Oyster Creek - BWR
- Three Mile Island 1 - PWR
- Zion 1 & 2 - PWR

FirstEnergy
- Beaver Valley 1 & 2 - PWR
- Davis-Besse - PWR

Luminant (TXU Energy)
- Comanche Peak 1, 2, 3 & 4 - PWR

Nebraska Public Power District
- Cooper - BWR

NextEra/Florida Power & Light
- Duane Arnold - BWR
- St. Lucie 1 & 2 - PWR
- Turkey Point 3 & 4 - PWR

Northeast Utilities System
- Connecticut Yankee - PWR

Omaha Public Power District
- Fort Calhoun - PWR

Pacific Gas and Electric Co.
- Diablo Canyon 1 & 2 - PWR

PPL Susquehanna LLC
- Susquehanna 1 & 2 - BWR

PSEG Nuclear
- Hope Creek - BWR
- Salem 1 & 2 - PWR

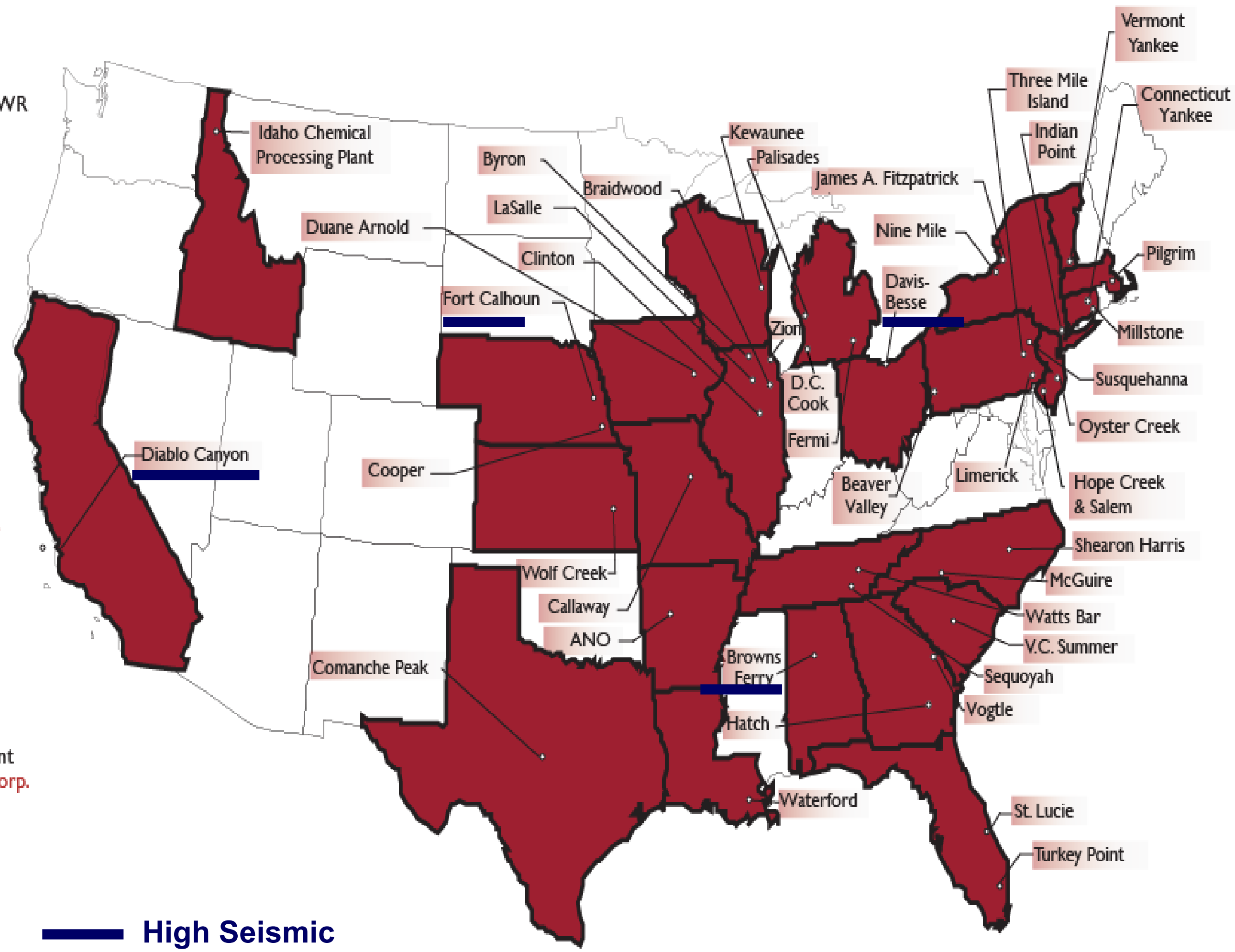
South Carolina Electric & Gas Co.
- V.C. Summer 2 & 3 - PWR

Southern Nuclear Operating Co.
- Hatch 1 & 2 - BWR
- Vogtle 1, 2, 3 & 4 - PWR

TVA Nuclear
- Browns Ferry 2 & 3 - BWR
- Sequoyah - PWR
- Watts Bar 1 - PWR

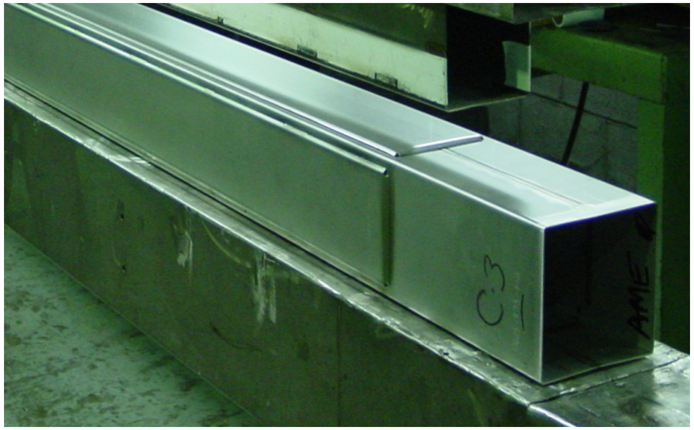
Westinghouse
- Idaho Chemical Processing Plant

Wolf Creek Nuclear Operating Corp.
- Wolf Creek - PWR

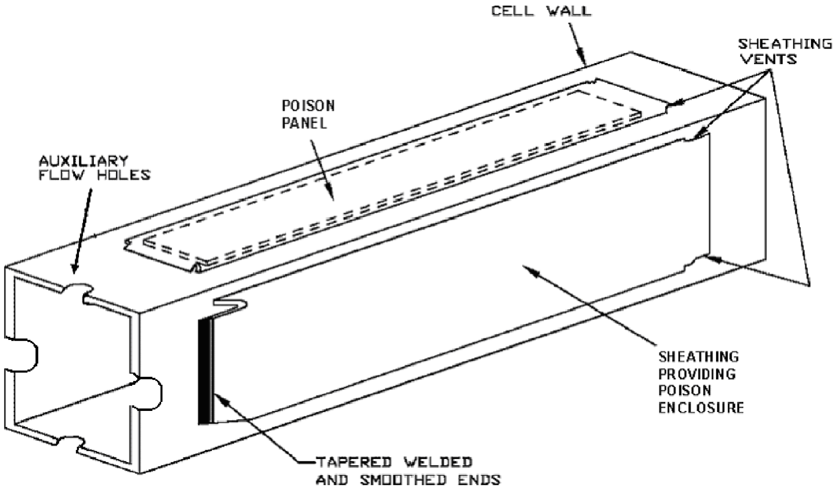


Holtec's Rack Design – "Cell Box"

- Holtec's rack designs have remained essentially unchanged since 1986.
- Basic component is the "cell box"
  - Stainless Steel Box
  - Metamic Neutron Absorbing Poison secured by stainless sheathing
  - All welds are stainless-to-stainless
- Cell box dimensions and construction are standardized as much as possible.
  - PWR/BWR Designs
  - Accommodation of various fuel sizes
  - Small changes as needed for site-specific designs



Holtec Rack Cell Box Fabricated at HMD



Holtec Rack Cell Box

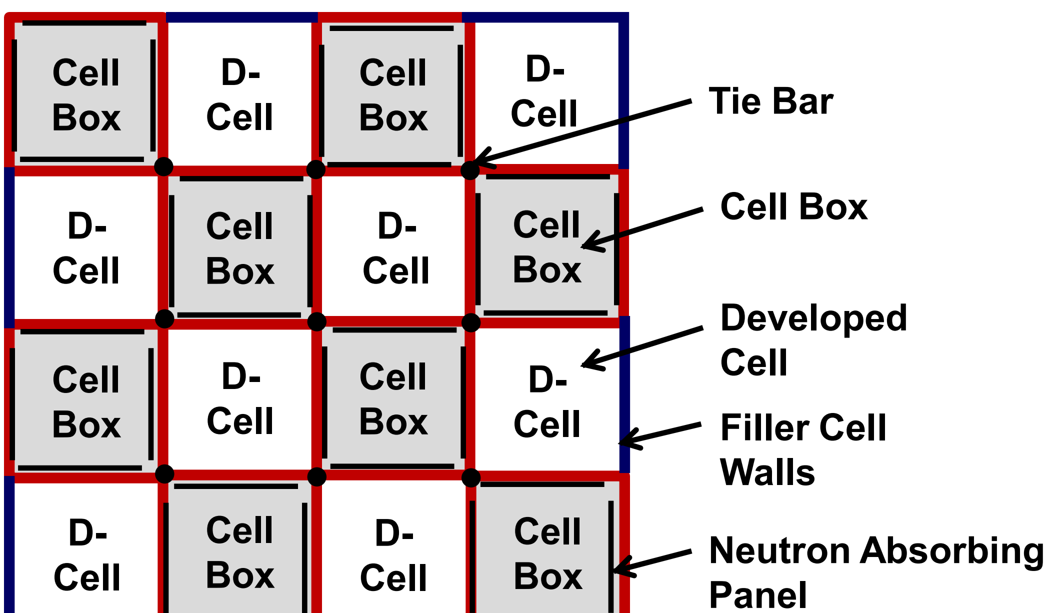
METAMIC™ (Neutron Absorber)

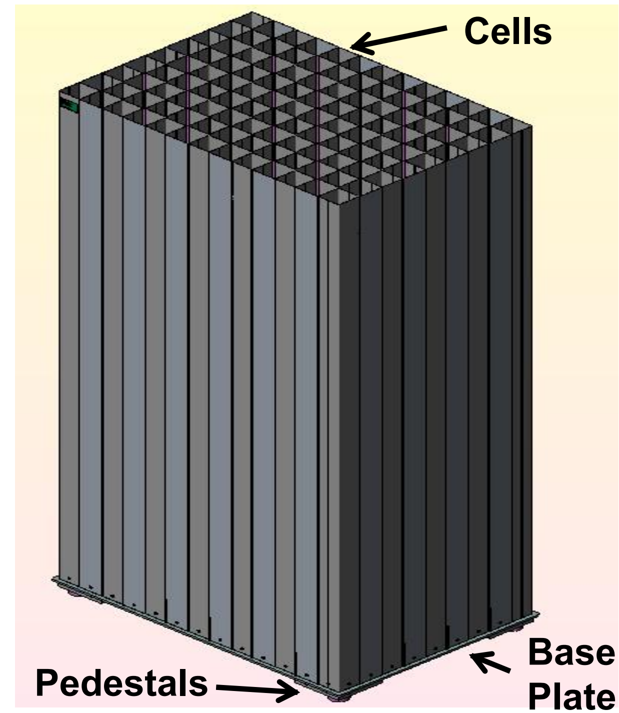
- METAMIC™ is a metal matrix composite with a mixture of Aluminum and Boron Carbide.
- Fabricated using powder metallurgy technology from nuclear grade boron carbide (ASTM C750 Type 1) and high-purity aluminum-6061 alloy powder.
- Extremely homogeneous distribution of boron carbide particulate can be obtained in the composite microstructure
- Benefits
  - Homogeneous: very uniform, lot-to-lot/piece-to-piece
  - High boron carbide volume loading
  - Fully dense which prevents moisture infiltration
  - Does not swell in any spent fuel storage environment
  - Stable under high neutron and gamma fluences
  - Homogenous small particulate boron carbide particle size exhibits no neutron streaming
  - Excellent stability in all chemical and thermal environments
- Use of Metamic by Holtec International has been approved for both wet storage (USNRC Docket 50-313) and dry storage (USNRC Docket 72-1014).
- Recent Wet Storage Applications
  - Westinghouse AP1000 Racks
  - Clinton Nuclear Plant Racks
  - Palisades Nuclear Plant Racks

Holtec's Rack Design – BWR Rack Module

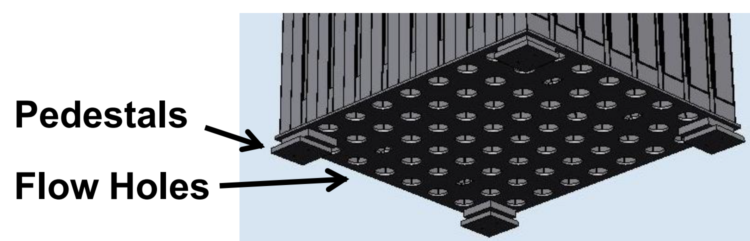
- BWR rack modules are constructed by assembling the individual cell boxes onto the baseplate.
- Welded tie bars are used to secure cell boxes in checker board configuration.
  - "Cell box" cells
  - "Developed" cells (D-Cells in figure below)
  - One neutron absorbing panel between assemblies

BWR Rack Construction





Holtec BWR Rack Storage Module



Rack Module Baseplate

Approach for US-ABWR Rack Designs

- Utilize same methodologies and computer codes as on prior applications reviewed by the US NRC, e.g. AP-1000 (2012), Nine Mile Point (2007), Clinton (2007)
- Utilize same basic rack design as on all prior US applications reviewed by the US NRC
- Optimize the rack modules for ABWR pool layout and high seismic activity at pool-floor level (per COLA Chapters already reviewed)
  - Relatively large rack modules – better stability
  - Use of large spacing between racks and walls – minimize impacts
  - Use of thick base plate – to support impact loads
  - Use of thick cell wall – for fuel drop event and impact loads

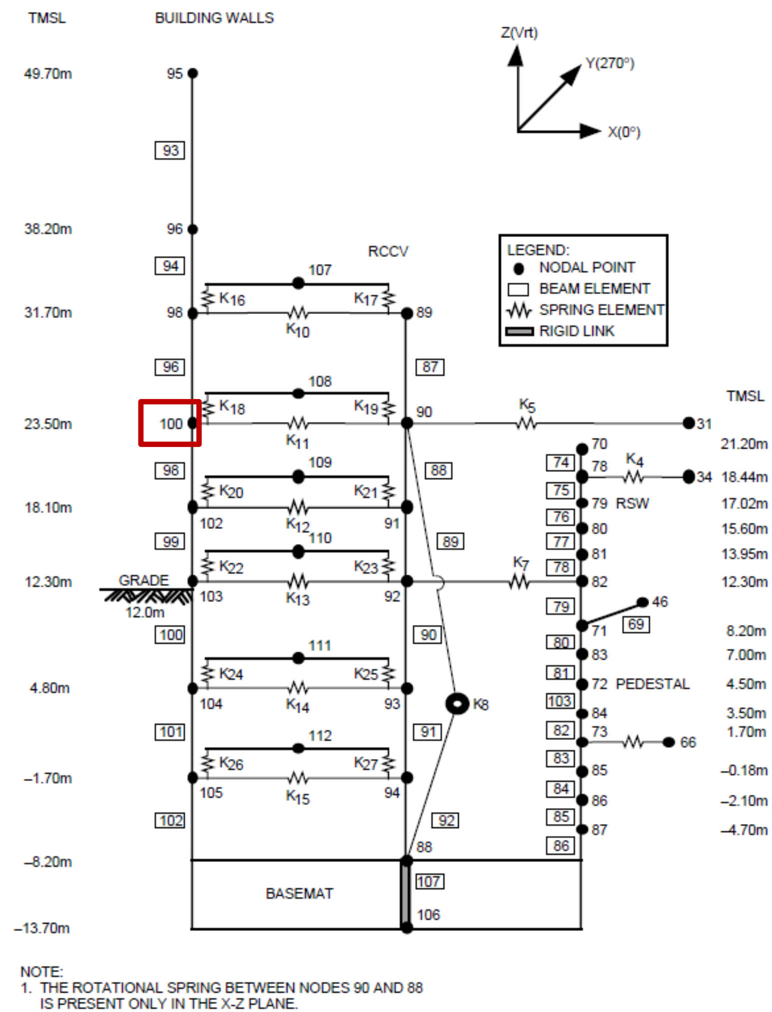


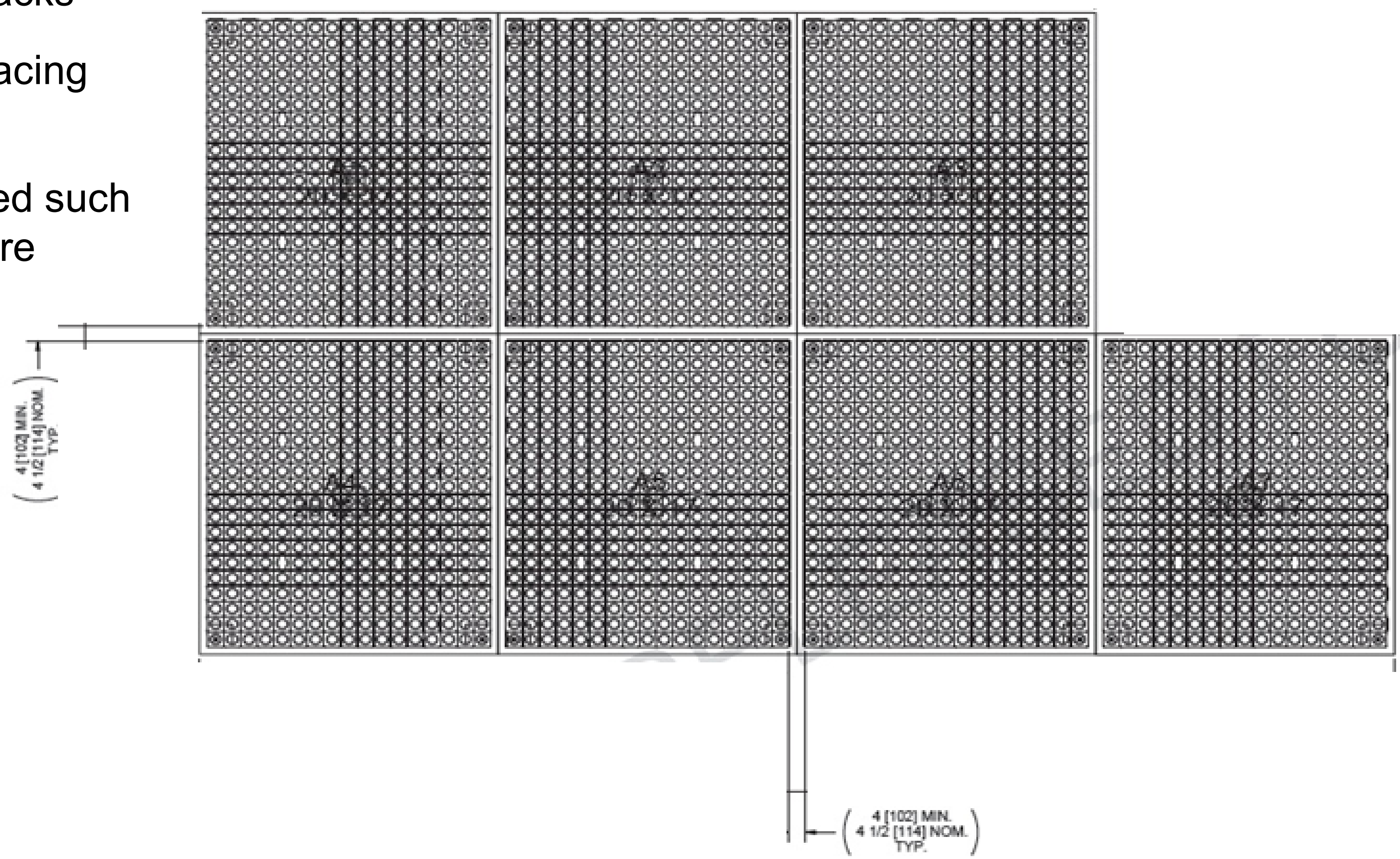
Figure 3A-8 Reactor Building Stick Model (Design Control Document)

Comparison of Rack Design Parameters – ABWR vs. BWR-6

Parameter (Nominal Value)	STP 3 & 4	Clinton
Cell Center-to-Center Spacing (in)	6.253″	6.243″
Storage Cell Inner Dimension (in)	6.00″	6.05″
Storage Cell Length (in)	171″	168″
Storage Cell Wall Thickness (in)	0.094″	0.075″
Base Plate Thickness (in)	1″	0.75″
Neutron Absorber Material	Metamic™	Metamic™
Neutron Absorber Length (in)	156″	152″
Neutron Absorber Width (in)	4.8125″	4.75″
Neutron Absorber Thickness (in)	0.106″	0.075″

NINA STP 3&4 Spent Fuel Rack Layout

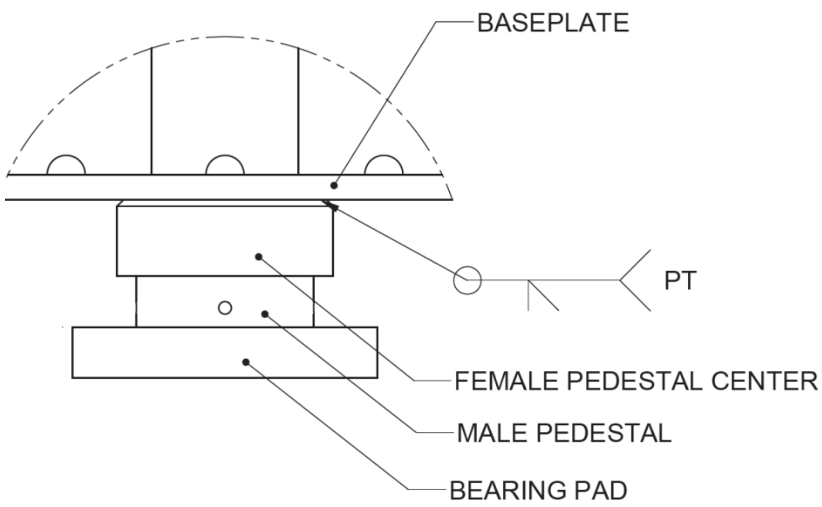
- Seven 20 x 17 Racks
- Rack-to-Rack spacing of 4” minimum.
- Racks are installed such that baseplates are initially in contact

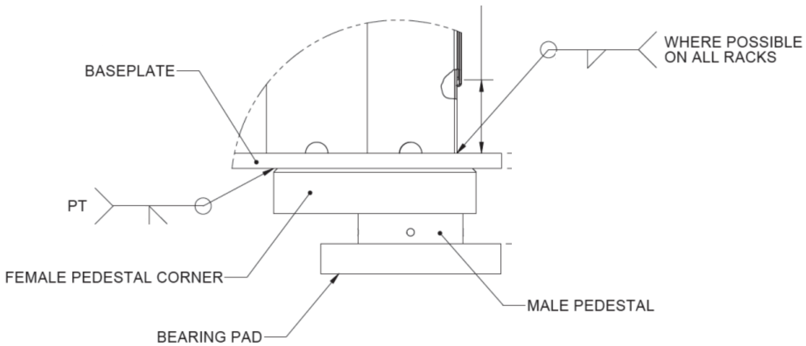


SPENT FUEL POOL RACK LAYOUT

Rack Pedestals

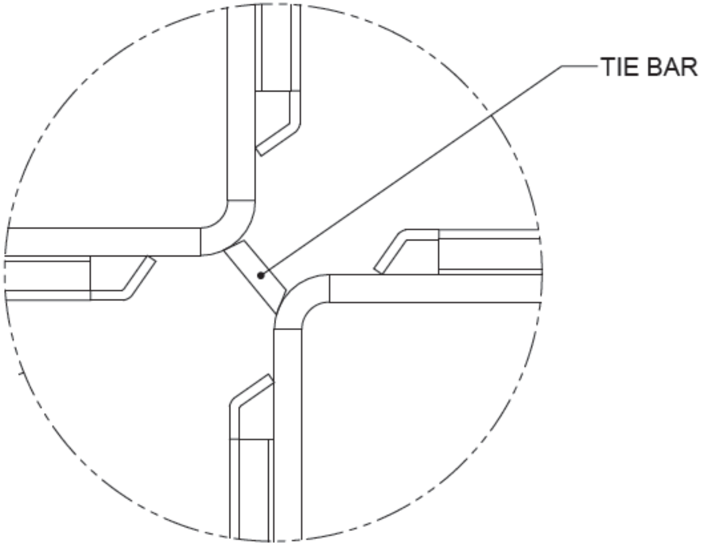
- Five (5) pedestals are utilized to support each of the seven 20 x 17 racks





Tie Bars

- Tie bar connection detail



Structural Safety Evaluations for ABWR Spent Fuel Racks in South Texas Project Unit 3 and 4 Pools

- Objective
  - Provide an overview of the safety analysis approach and methodology
- Areas covered in the presentation
  - Holtec experience
  - Design Criteria
  - Methodology
  - Computer codes
  - Summary

Structural Design Criteria

- The following codes and standards govern the structural design of the STP 3 & 4 spent fuel racks:
  - ABWR Design Control Document, GE Nuclear Energy, Rev. 4, March 1997.
  - NUREG-0800 Standard Review Plan, Section 3.7.1 (Seismic Design Parameters), Rev. 2, August 1989.
  - NUREG-0800 Standard Review Plan, Section 3.8.4 (Other Seismic Category I Structures), Rev. 2, March 2007.
  - ASME Boiler & Pressure Vessel Code, Section III, Subsection NF and Appendices, 1989 Edition.
- General approach to seismic/structural analysis of STP 3 &4 spent fuel racks will be the same as that used for Westinghouse AP1000 spent fuel racks
  - Utilize same computer codes (except for GENEQ which will be replaced by EZ-FRISK)
  - Perform same set of seismic simulations (i.e., multiple COF, full & partially loaded fuel racks, rack-to-rack gap tolerance study, spring rate sensitivity)

Applicable Load Combinations

The following loads and load combinations are taken from NUREG-0800 SRP, Section 3.8.4.

Load Combination	Acceptance Limit
$D + L$ $D + L + T_o$	Level A service limits
$D + L + T_a$ $D + L + T_o + P_f$	Level B service limits
$D + L + T_a + E'$	Level D service limits
$D + L + F_d$	The functional capability of the racks should be demonstrated

D = Dead Weight, L = Live Load, T_o = Normal Operating Thermal Load,
T_a = Abnormal Thermal Load, E' = Safe Shutdown Earthquake,
P_f = Stuck Fuel Assembly Load, F_d = Accidental Drop of Fuel Assembly

Analysis Methodology

- Seismic load combination (D + L + E’) is analyzed by performing non-linear time history analysis of the entire spent fuel rack array using Holtec proprietary code DYNARACK.
  - All racks in SFP are included in DYNARACK model
  - Analytical model includes buoyancy and fluid coupling effects
  - Seismic accelerations applied simultaneously in 3 orthogonal directions
  - DYNARACK has been used by Holtec on more than 50 spent fuel rack projects (including Westinghouse AP1000, Beaver Valley, Palisades, Nine Mile, and Clinton)

- Solution provides maximum rack displacements, maximum forces on support pedestals, maximum fuel-to-cell impact loads, rack-to-rack and rack-to-wall impact loads (if they occur).

Structural Computer Codes

- The following computer codes are used to perform the seismic/structural analyses for the STP 3 & 4 spent fuel racks:
  - **EZ-FRISK (Commercial)**: Used to develop modified real recorded acceleration time histories from design basis floor response spectra to be used in non-linear time history analysis
  - **DYNARACK (Proprietary)**: Used to perform 3-D non-linear time history analysis of freestanding spent fuel racks under earthquake loading
  - **LS-DYNA (Commercial)**: Used to perform damage assessment of spent fuel racks due to impact loads associated with fuel assembly handling accidents
  - **ANSYS (Commercial):** Limited use in rack structural and bearing pad evaluations

Seismic Time History Generation (EZ-FRISK)

- Design floor spectra are obtained from ABWR DCD for Reactor Building Node 100 (4% damping)
- Five (5) sets of acceleration time histories will be developed based on design floor spectra following the guidance from SRP 3.7.1 Rev. 2
  - Modified real recorded time histories (as opposed to synthetic time histories) will be used since spent fuel rack analysis is non-linear
- Time histories generation will be performed using the commercially available computer program EZ-FRISK, which utilizes Norm Abrahamson's time-dependent spectral matching method (RSPMATCH)
  - In past applications, Holtec has used the computer code GENEQ to develop synthetic time histories
  - EZ-FRISK is a newer technology which has the advantage of producing modified real recorded time histories

Seismic Time History Generation (EZ-FRISK)

- Seed time histories are obtained from Pacific Earthquake Engineering Research (PEER) database
- Re-generated response spectrum output from EZ-FRISK will be verified by comparing them with the computed response spectra obtained using an independent program (SHAKE2000)

Node 100 Response Spectrum (Horizontal)

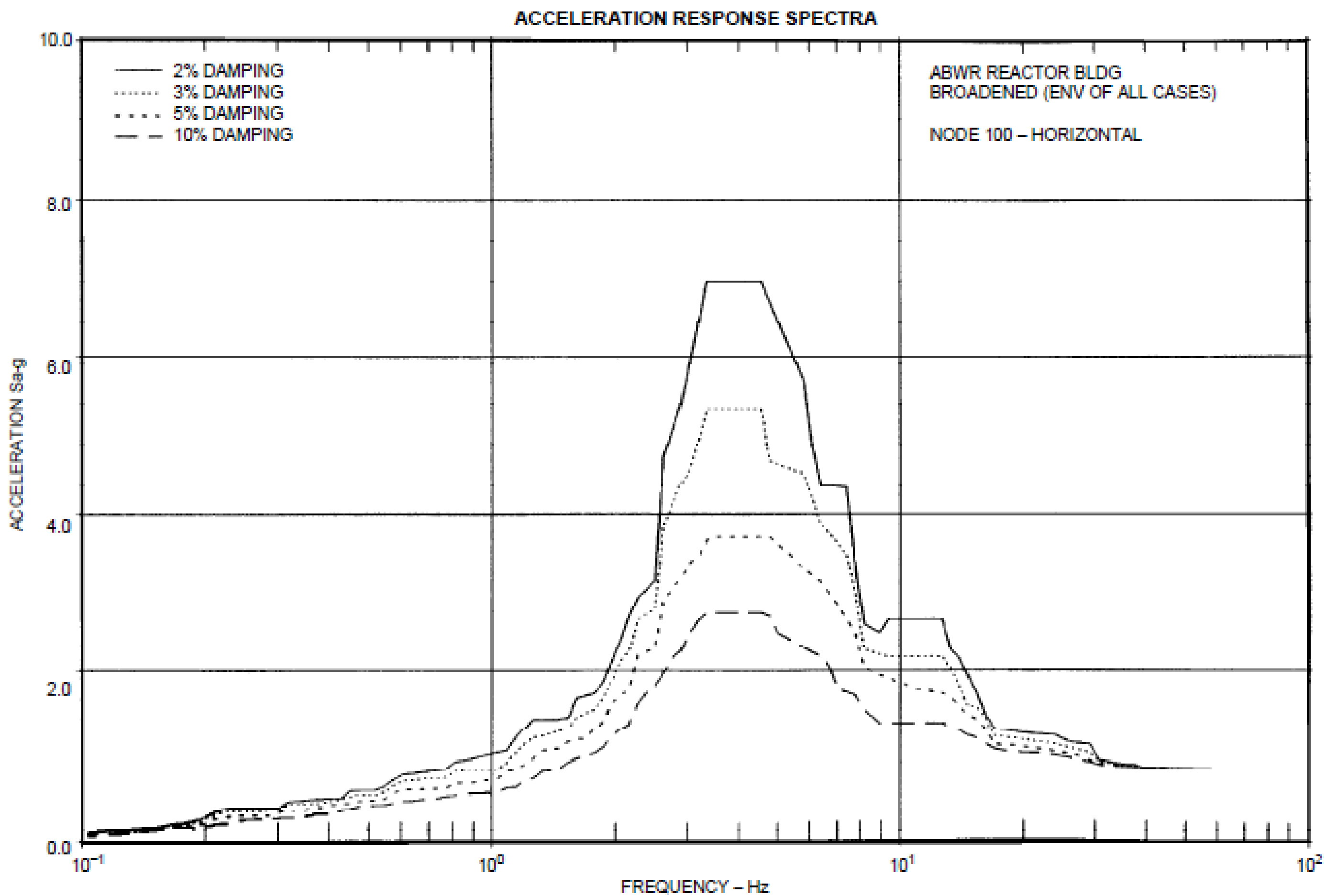


Figure 3A-161 ABWR Reactor Bldg. Broadened (Env of all Cases) Node 100–Horizontal

Node 100 Response Spectrum (Vertical)

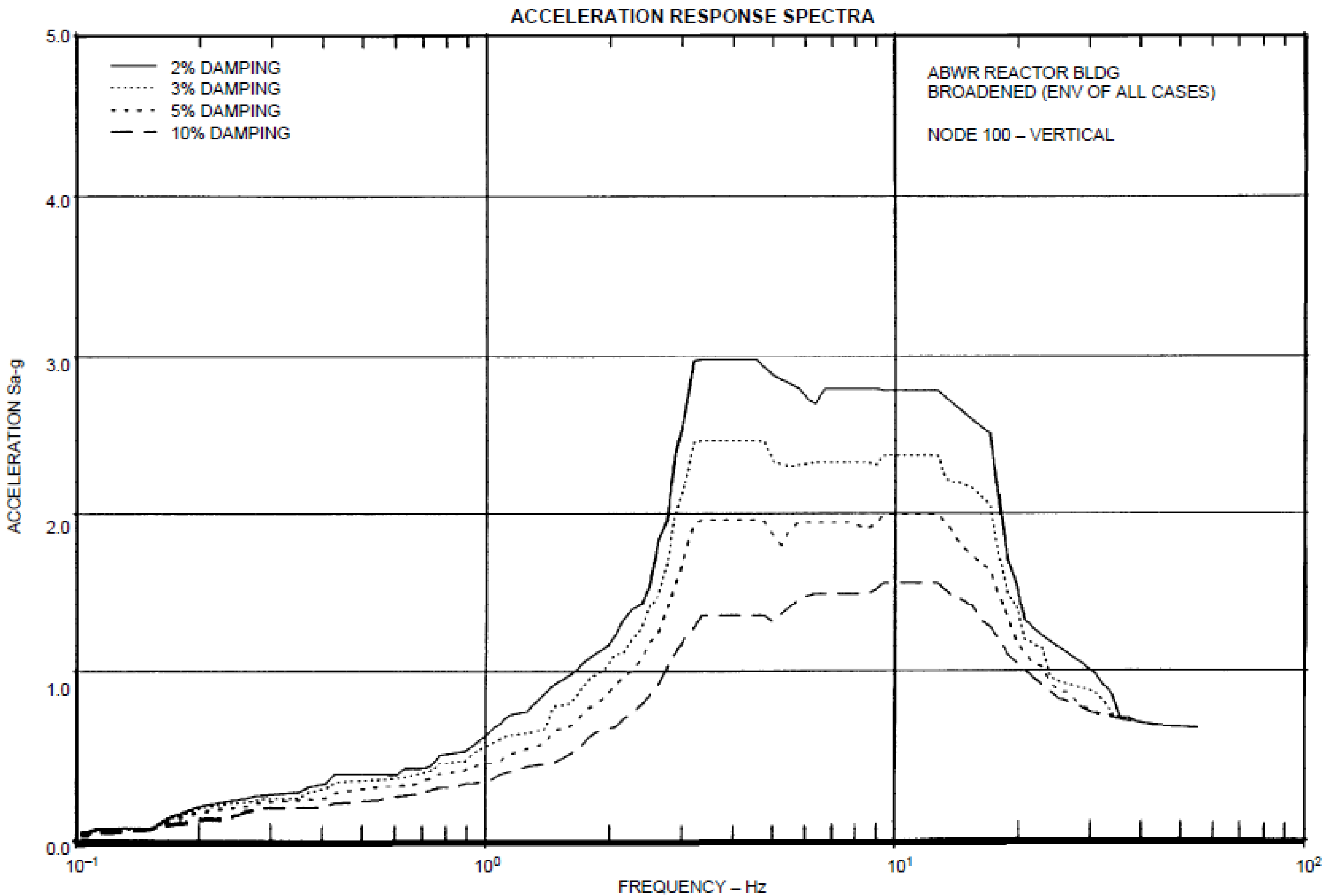


Figure 3A-199 ABWR Reactor Bldg. Broadened (Env of all Cases) Node 100–Vertical

3-D Whole Pool Multi-Rack Analysis (DYNARACK)

- Proprietary code developed by Holtec to analyze underwater fuel racks under seismic excitations.
- Whole Pool Multi Rack (WPMR) software can model all racks in a pool in one comprehensive model.
- Incorporates local and far field Fluid Coupling Effect of water between racks and racks and pool walls which results in rack displacements and forces
- Solves 3-dimensional earthquake time histories using classical Newton’s equation of motion
- Predicts rocking, tipping and sliding behavior of all racks in the pool simultaneously
- Tracks the movement of fuel assemblies inside the rack storage cells and the movement of racks simultaneously for the entire duration of the earthquake
- Has been benchmarked using experimental data
- Has been audited by the USNRC and has been used in numerous licensing applications for over twenty years

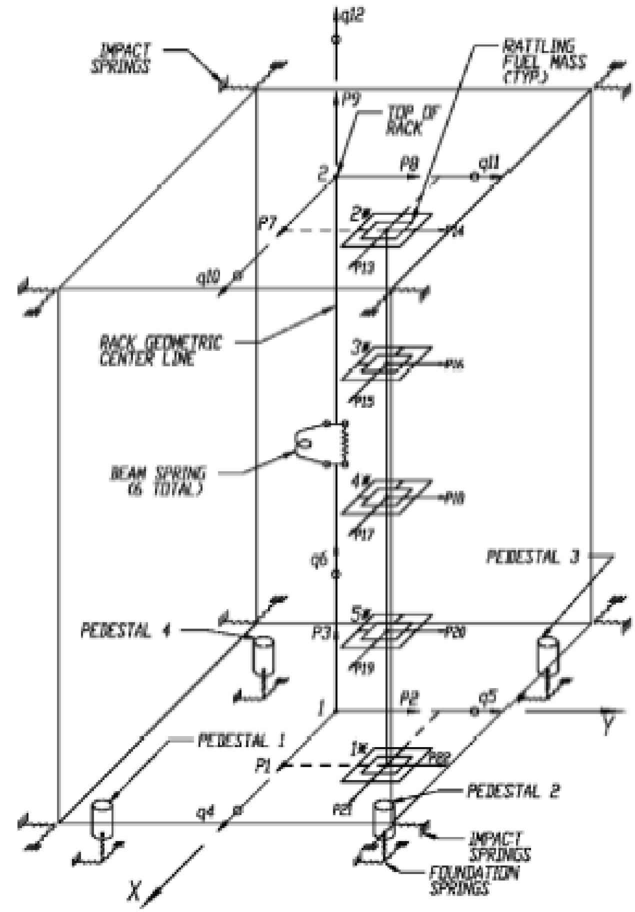


Figure 5.1: Single Rack Dynamic Model

Key Features of DYNARACK

- 3-D Non-Linear Time History Analysis
- Single and Multi-Rack Analysis Capability
- Frictional Interface at SFP Floor (fixed value or randomly generated)
- Rack Support Pedestals May Slide or Lift-off
  (no initial assumptions on behavior; depends only on seismic input)
- Fluid Coupling (Water in Pool, Water in Cells) Based on Classical Theory and Validated By Experiments
- Ability to Model Different Fuel Loading Scenarios (full, half loaded, empty)
- Rack-to-Wall, Rack-to-Floor, Rack-to-Rack, Fuel-to-Rack Contact

Key Features of DYNARACK (continued)

- Can Be Used for Various Rack Designs
  - Make reasonable strength of materials or finite element model and define simple problems (in air environment) to establish the appropriate stiffness values for input to DYNARACK
- Used Successfully in High Seismic Applications
  - Diablo Canyon racks licensed and extensively scrutinized during Atomic Safety and Licensing Board (ASLB) hearings (1987)

Fuel-to-Rack Impacts

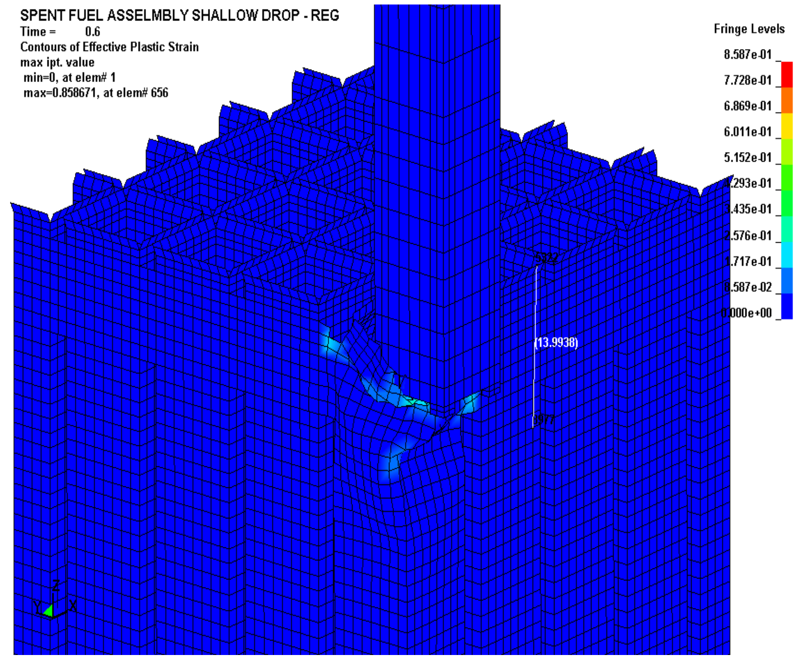
- Fuel-to-rack impacts will be computed using the same analytical method that has been used by Holtec for more than a decade.
- All stored fuel assemblies will be assumed to rattle in-phase in DYNARACK computer model, which conservatively overestimates their impact momentum.
- Total mass of stored fuel assemblies is divided among five (5) lumped masses equally spaced over the height of the spent fuel rack.
- Non-linear compression springs (gap elements) are used to track impacts between five (5) lumped fuel masses and surrounding storage cells.

List of Dynamic Simulations

Run Number	Coefficient of Friction	Loading Configuration	Seismic Input	Integration Time Step (sec)	% of Calculated Stiffness
1	0.8	Fully Loaded	SSE	1×10^{-5}	100%
2	0.5	Fully Loaded	SSE	1×10^{-5}	100%
3	0.2	Fully Loaded	SSE	1×10^{-5}	100%
4	0.8	Fully Loaded, modified gaps (max. tolerance)	SSE	1×10^{-5}	100%
5	0.8	Mixed Loading	SSE	1×10^{-5}	100%
6	0.8	Fully Loaded	SSE	1×10^{-5}	80%
7	0.8	Fully Loaded	SSE	1×10^{-5}	120%
8	0.8	Fully Loaded	SSE	2.5×10^{-6}	100%
9	0.8	Empty	SSE	1×10^{-5}	100%

Drop Accident Analyses

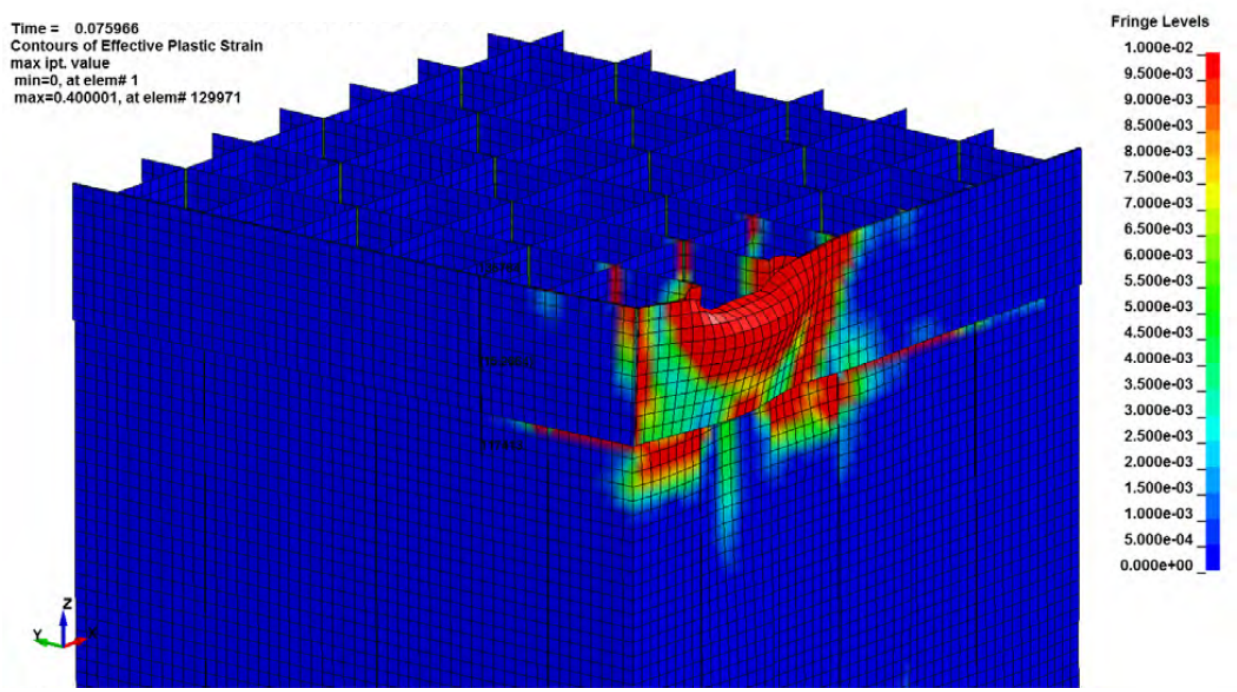
- Holtec uses LS-DYNA to simulate fuel assembly drop accident events.
  - Elasto-plastic impact and deformation analysis code widely used to simulate high energy impact phenomena
- Holtec's code has been benchmarked using drop experiments, as well as by using test data reported by others and available in the public domain.
- Holtec's LS-DYNA formulation for predicting damage to the rack structure under postulated mechanical accident events has been accepted and approved by the USNRC on numerous dockets (Clinton, AP1000, Beaver Valley).
- The model has the following essential attributes:
  - A fine finite-element grid for the impacted region (region of large deformation)
  - Use of material constitutive relationships that include strain rate effects
  - Model equipped to capture elastic/plastic buckling effects
  - Fuel assembly structural characteristics modeled with due recognition to the effect of in-core irradiation on material properties



Shallow Drop Accident Analysis

Drop Accident Analyses (continued)

- Fuel impact load (D + L + F_d) is analyzed using the LS-DYNA finite element method.



Fuel Assembly Shallow Drop

Structural Summary

- Structural/seismic analysis of STP 3 & 4 fuel racks use the same approach used to successfully license the Westinghouse AP1000 spent fuel racks.
- Only exception is the time history generation method:
  - EZ-FRISK will be used for STP 3 & 4 spent fuel racks versus GENEQ for AP1000 racks

Criticality Safety Evaluations for ABWR Spent Fuel Racks in South Texas Project Unit 3 and 4 Pools

- Objective
  - Provide an overview of the safety analysis approach and methodology
- Areas covered in the presentation
  - Holtec experience
  - Acceptance criteria and relevant documents
  - Design basis fuel assembly
  - Principal approach to show compliance with regulation
  - Aspects and phenomena considered in the analyses
  - Computer codes
  - Summary

Holtec Experience

- More than 100 criticality safety evaluations performed and approved over the last 25 years
  - PWR and BWR
  - Holtec Racks/Equipment and Third Party Racks/Equipment
  - US and International
  - New racks and re-qualification of existing racks
  - Highly complex applications (Boraflex Remedy)
- Spent Fuel Pool Criticality Safety Evaluation recently approved by NRC
  - Palisades (2013), St. Lucie 1 (2012), St. Lucie 2 (2012), Westinghouse AP1000 (2012), Beaver Valley (2011)
- Standard BWR analyses for new racks
  - Clinton (2007), Nine Mile (2007), Cooper (2007)

Holtec Experience (continued)

- Recent Areas of Interest
  - Criticality Computer Code Validation and Benchmarking
    - Holtec's criticality computer code validation and benchmarking covers over 400 critical experiments, easily separated into applicable subsets
    - All appropriate parametric trending analysis performed
    - NRC has reviewed and approved Holtec's validation and benchmarking approach on all recent applications
  - Conservative depletion calculations
    - Comprehensive approach showing how each depletion related parameter impacts reactivity in the storage rack
    - Bounding calculations are used for design basis calculations which require depletion isotopic compositions or are used for qualitative studies (i.e. determination of peak reactivity)

Acceptance Criteria and Relevant Documents

- Acceptance Criteria / Regulations
  - GDC 62: Prevention of Criticality in Fuel Storage & Handling: "Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations."
  - 10 CFR 50.68 (b) (4): The k-effective of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity must not exceed 0.95, at a 95 percent probability, 95 percent confidence level, if flooded with unborated water.
- Relevant Documents
  - Interim Staff Guidance (DSS-ISG-2010-01), and applicable referenced documents

Design Basis Fuel Assembly

- Design basis assembly is principally defined in the DCD
  - Standard 8x8 assembly, 62 fuel rods, 2 water rods
  - K-inf in SCCG less than or equal to 1.35
  - Principal dimensions (fuel rod diameter, active length)
  - Operating parameters (power, temperatures, void)
- Some minor parameters not specified in the DCD are taken from other public documents
- Parameters are consistent with those in the WEC analysis

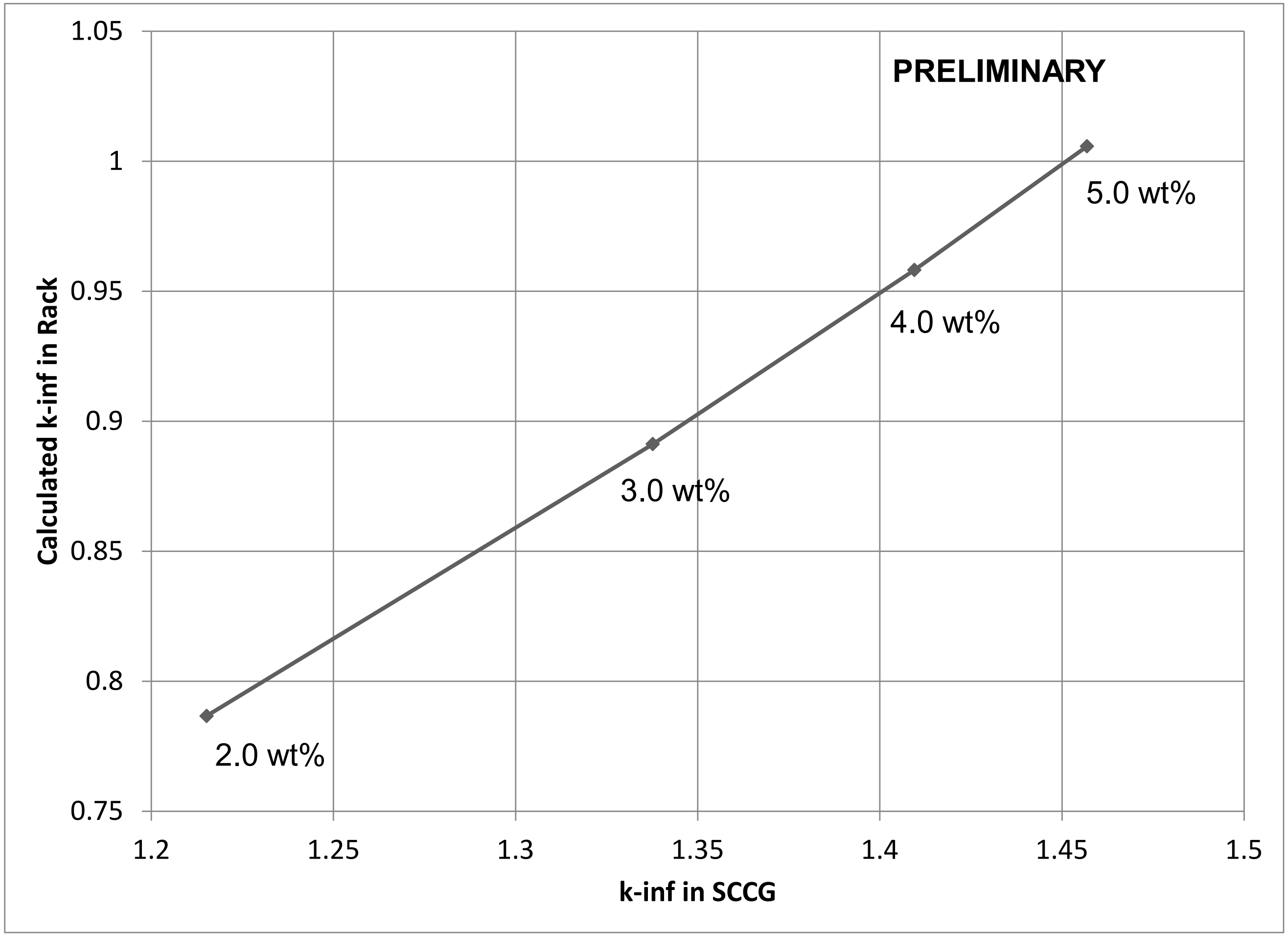
Principal Approach

- Show an assembly that meets the DCD requirement also meets the regulatory rack requirement
  - DCD: k-inf in SCCG of 1.35
  - Rack: max k-eff <= 0.95
    - The target value for the max k-eff will be less than 0.95, providing additional margin
- Axial considerations
  - BWR fuel typically have several different lattices, with different enrichments and neutron poison content, including lower enriched blankets at the ends
  - All calculations are performed for an axially infinite arrangement of the bounding (most reactive in the pool) lattice
  - This approach avoids the complex and problematic modeling of axially zoned fuel in the pool analysis
- Two independent acceptance criteria for fuel
  - Fresh fuel of varying enrichment, no integral neutron poison
    - results in a limiting enrichment for unpoisoned fuel
  - High enriched fuel with integral neutron poison
    - results in minimum poison loading for fuel exceeding enrichment for unpoisoned fuel

Fresh Fuel Approach

- Preliminary calculations were performed to determine k-inf as a function of enrichment
  - k-inf in SCCG as a function of enrichment
  - k-inf in rack as a function of enrichment
- Results and conclusions (see plot on following slide)
  - Comparison of k-inf in rack versus k-inf in SCCG
    - This gives the first and most important confirmation that the rack is capable to accommodate the design basis fuel
  - Limiting enrichment for fuel without neutron poison
    - Expected to be about 3.2 wt%

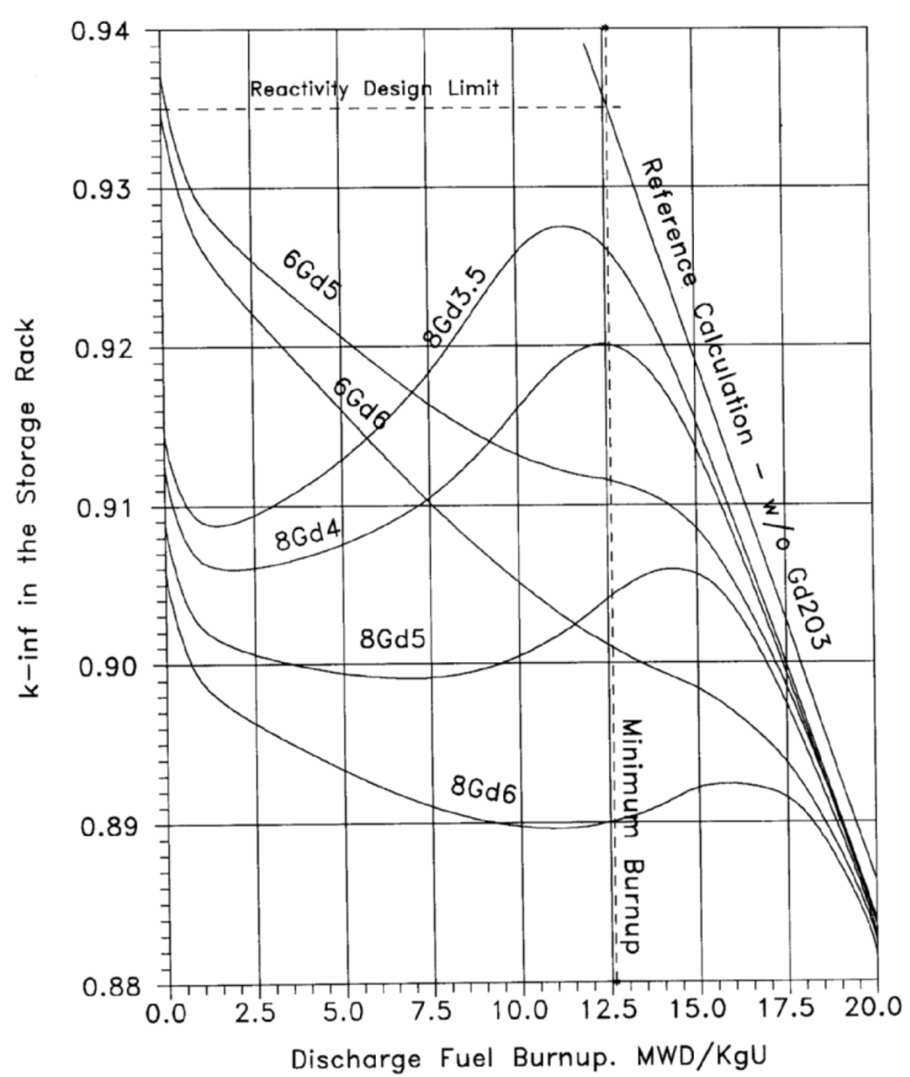
Fresh Fuel Approach (continued)



High Enriched Fuel with Neutron Poison Approach

- Bounding enrichment of 5 wt% is used for all fuel rods
  - Avoids complex considerations/arguments with respect to planar average enrichments
- Integral Poison Effect
  - Integral neutron poison reduces the reactivity of fuel at lower burnups (up to about 10 to 20 GWd/mtU)
  - For some (larger) poison amounts, the most reactive condition may no longer be 0 burnup fuel. As an example, see plot on next slide.

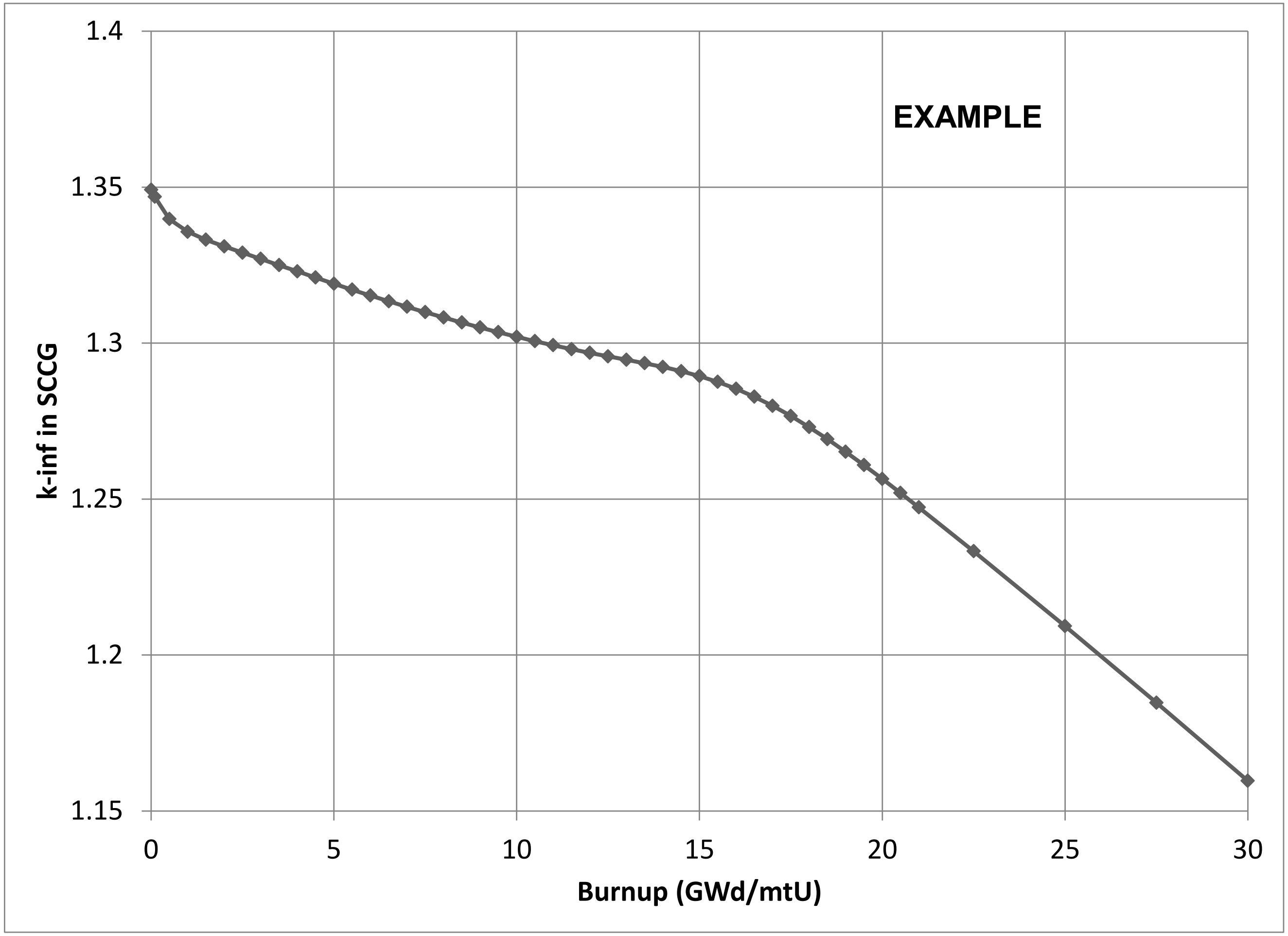
High Enriched Fuel with Neutron Poison Approach (continued)



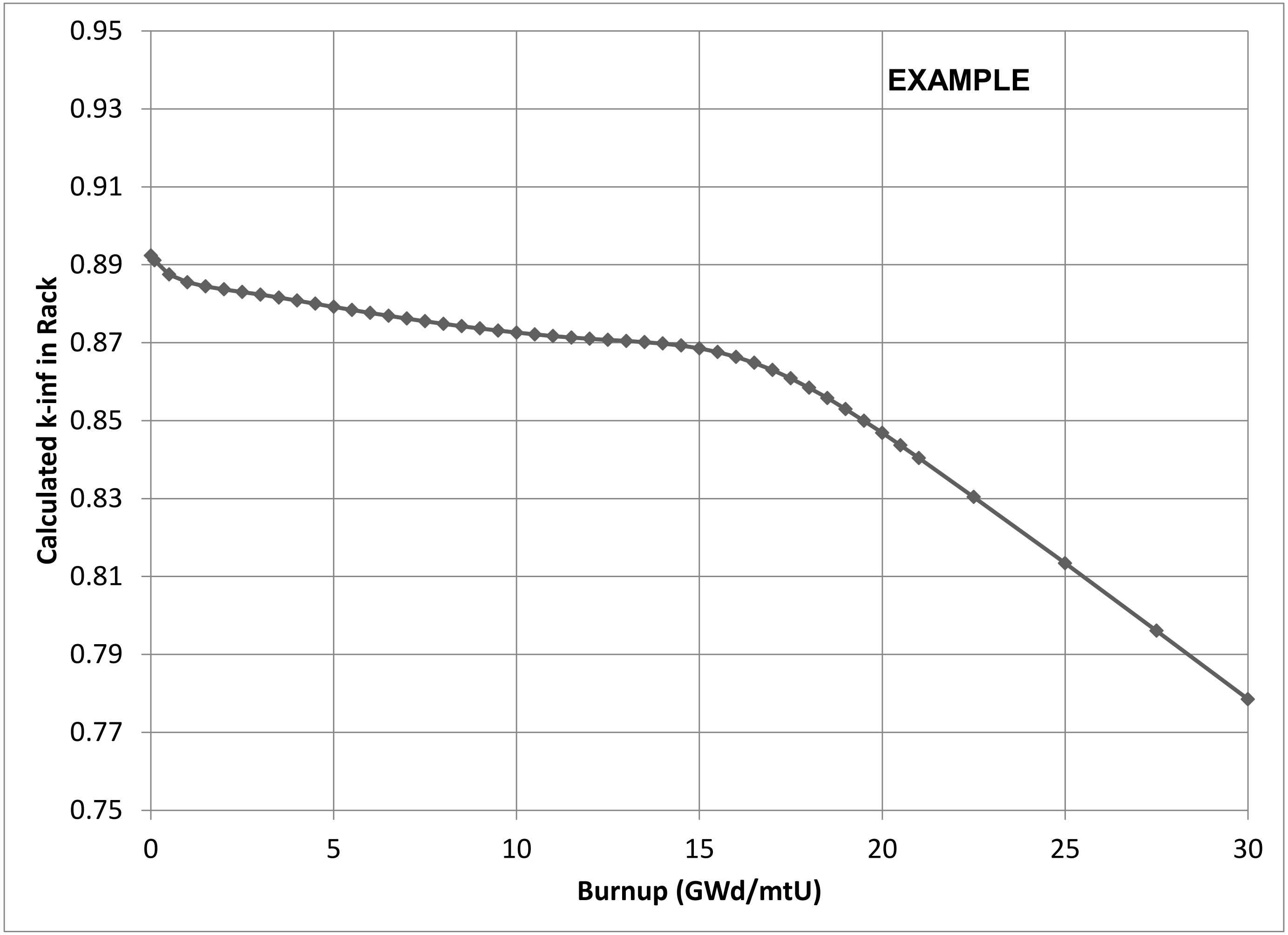
High Enriched Fuel with Neutron Poison Approach (continued)

- Neutron Poison Effect (cont.)
  - The limiting k-inf in SCCG of the design basis assembly only requires a modest neutron poison amount. For reasonable selected distributions of neutron poison rods, the maximum reactivity will occur for 0 burnup fuel
  - Acceptable lattices are restricted to maintain the zero burnup peak reactivity, therefore avoiding the possibility of future lattices having a peak at some burnup greater than zero burnup.
  - Plots of reactivity as a function of burnup are shown on the following slides
  - This simplifies the safety analysis
    - The design basis (Monte Carlo) calculations only need to consider 0 burnup fuel with neutron poison. Sufficient validation is available for those isotopes.
    - The depletion analysis only provides qualitative information

High Enriched Fuel with Neutron Poison Approach (continued)



High Enriched Fuel with Neutron Poison Approach (continued)



Aspects and Phenomena considered in the Analyses

- Aspects and Phenomena include (but are not limited to):
  - Design basis lattice(s)
  - Normal and accident conditions (including misplaced assembly and rack damage from accidents)
  - Fuel tolerances
  - Rack tolerances
  - Parametric studies for depletion parameter variations
  - Eccentric positioning
  - Model simplifications
  - Temperature effects
  - Validation and benchmarking trending analysis

Criticality Computer Codes

- Design Basis
  - MCNP5 Monte Carlo Code (LANL) – (Commercial)
    - k-inf SCCG for 0 burnup fuel
    - Max k-eff in rack for 0 burnup fuel
  - Validation
    - We have a total set of >400 critical experiments to choose from
    - Bias and bias uncertainty are calculated from the subset of experiments that are applicable to the current condition
    - Normality tests, trend analyses etc.
- Depletion Analyses
  - CASMO-4 (Commercial)
  - Used for qualitative evaluation only (reactivity reduces with burnup)

Criticality Summary

- Safety evaluations use proven methods and validated codes
- Conservative and simplifying assumptions
- Consistent with WEC calculation
- Additional margin maintained

Project Schedule

Project Schedule – Major Milestones	
Data Definition Document Completion	January 23, 2013
Rack Design Drawing Completion	March 20, 2013
Structural Analysis Completion	May 15, 2013
Criticality Analysis Completion	May 22, 2013
Safety Analysis Report Submittal	August 31, 2013

Summary