



## Overview of Degraded Containment Research at Sandia National Laboratories

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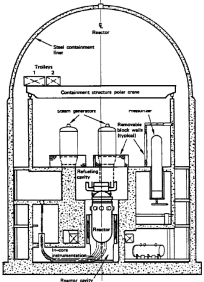

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## Degradation Containment Research Motivation

- The primary purposes of the containment system are:
  - to contain any radioactive material that may be released from the primary system in case of an accident
  - to protect the nuclear system (in some cases) from weather and other external threats such as missiles produced by earthquakes, tornadoes, wind, etc
  - to act as a supporting structure for operational equipment such as cranes
- Designed to withstand high pressures (10-60 psig) and temperatures (>300 F)


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## Degraded Containment Research Background

- Containment degradation has been discovered at a number of NPPs
- Degradation includes: liner corrosion, liner buckling exposed rebar, concrete voids, degraded liner coatings, loss of prestressing, etc
- Research on degraded containments can help demonstrate the potential effects of degradation on performance and can be used in consequence and risk assessments
- The research can also be used to support regulatory action for the existing fleet of NPP's as well as future plants
  - Maintenance/Inspection/License Extension




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### Degraded Containment Research at Sandia

- Sandia has worked with the USNRC in studying containment integrity and containment degradation research since the 1980s
- Integrity Experiments (scaled steel and concrete containments)
- Degradation Experiments
  - Bellows
  - Corrosion Effects on Strain-to-Failure
- Integrity of Degraded Containments
  - Capacity of Degraded Containments
  - Risk-Informed Degraded Containment Assessment
  - Degradation Effects on Consequences
- Liner Corrosion Causes
  - Expert Panel Workshop on Outer Diameter Corrosion
- Ongoing Research




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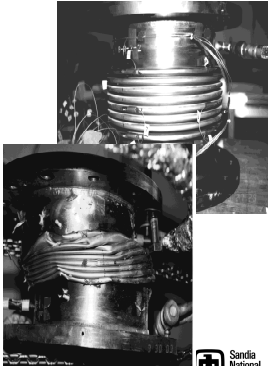

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### Degraded Containment Research Bellows Testing

- Bellows are used at piping penetrations to allow relative movement between the piping and the containment wall
- Experimental study examined the performance of bellows under hypothetical severe accident conditions
- Tests examined variations to internal pressure, temperature, axial deformation, lateral deformation, and corrosion
- Corrosion was showed to have a significant effect on the performance of the bellows


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### Degraded Containment Research Corroded Steel Coupon Tests

- NUREG/CR-6706 included a series of strain-to-failure tests on liner steels conducted to assess the effect of pitting and corrosion
- Goal was to determine the reduction in the strain to failure for use in computation models
- Due to the stress concentrations created by the corroded/pitted surfaces, the strain to failure was reduced by approximately 50%




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### Degraded Containment Research Containment Pressure Capacity

- NUREG/CR-6706 also includes computational analyses of 4 typical containments under original and hypothetical degraded conditions
  - PWR Ice Condenser (Free standing steel shell)
  - BWR Mark I (Steel shell drywell and wetwell)
  - PWR Reinforced Concrete with Steel Liner
  - PWR Prestressed Concrete with Steel Liner
- Liner/shell corrosion were the primary cases examined
- Analyses showed decreases in leak pressure when corrosion was assumed to occur in regions of high strain
- Additional work in SAND2001-1762 showed that the hoop tendon degradation was most likely to cause decreases in the leak pressure




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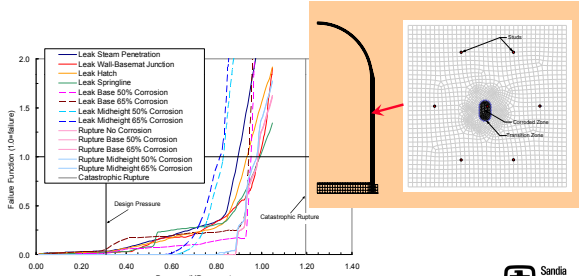

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### Degraded Containment Research Risk Informed

- NUREG/CR-6920 examined the same 4 typical containments to develop a methodology to couple integrity analyses with probabilistic risk analyses
- Used strain based failure criterion with and without various cases of hypothetical degradation (typically liner/shell corrosion)


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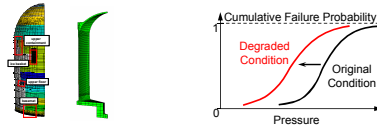
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### Degraded Containment Research Risk Informed

- Developed fragility curves (probability of leak vs. pressure) for each containment with and without various cases of hypothetical degradation



- Computed changes in the Large Early Release Frequency (LERF) from degradation using NUREG-1150 PRA models
- Attempted to assess changes in LERF using Regulatory Guide 1.174 to assess acceptability
- Local liner corrosion in concrete containments affects the probability of developing a leak with little effect on the global rupture pressure
- Determined that LERF may not be the appropriate metric for assessing containment degradation




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### Degraded Containment Research Consequence Analyses

- A recent study coupled structural analyses of a PWR plant with a reinforced concrete containment to deterministic severe accident simulations with MELCOR and MACCS
- MELCOR code developed for the USNRC to evaluate source terms for hypothetical severe accidents at nuclear power plants based on specified initiating events (e.g., station blackout – loss of offsite power)
- MACCS code developed for the USNRC to evaluate offsite consequence of hypothetical severe accidents at nuclear power plants based on calculated or assumed fission product releases
- The structural analyses performed under the previous risk study were used to develop input for MELCOR for various degradation scenarios
- Goal was to assess changes/sensitivities in consequences the various degradation scenarios




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### Degraded Containment Research Consequence Conclusions

- Small areas of local degradation may cause earlier leaks and affect consequences
- Typically, more corrosion area or deeper initial corrosion depth lead to higher consequences, but not always, as shown
  - Heavy corrosion that leads to larger crack areas at lower pressures earlier in the accident may increase consequences
  - In some cases, the earlier release of material partially depressurizes the containment prior to the accident generating the most consequence significant material
  - When the consequence significant material is then generated, the pressure is lower within the containment and the material is not pushed out to the environment as quickly
- Containment degradation should be examined on a case-by-case basis and is dependent on the timing of the accident




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### Degraded Containment Research Liner Corrosion Workshop

- Multiple cases of through wall corrosion have occurred over the past 15 years
- In September 2010, an expert panel workshop was assembled to explore the issues contributing to these events
- Panel members were gathered from national labs, academia, and industry
- The panel members specifically discussed five areas:
  - Corrosion mechanisms that initiate at the steel containment liner/concrete interface
  - Containment structure design, construction, and operation
  - Concrete aging and degradation
  - Concrete/steel NDE
  - Concrete repair and corrosion mitigation
- Summary report recently provided to the USNRC




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### Degraded Containment Research Ongoing Research

- Continue to develop methods and explore metrics for examining containment degradation effects
- Goal is to provide the USNRC with information to help assess the condition of containments when degradation is found
- Areas that may be explored include through-wall liner holes, tendon degradation, and torus corrosion



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