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Challenges in the Qualification of First of a Kind Components

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Design Validation

- The validation that a safety-related component is suitable for its application is required by Criterion III of Appendix B to 10CFR Part 50
- Design Validation Involves
  - Identifying design requirements
  - Defining critical parameters that need to be controlled (and establishing acceptance criteria)
  - Verifying through a combination of analysis or testing that the above design requirements have been achieved

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Equipment Qualification

- Equipment qualification is a subset of design validation and applies to certain classes of safety-related equipment
- Equipment qualification is:
  - Generally performed to prescriptive industry standards
  - Typically a go/no go test
  - Does not directly address equipment reliability

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Problem Statement

- Many environmental qualification activities are fairly straightforward and are associated with evolutions to component designs for which the nuclear industry has a broad experience base, both in operating experience and in qualification methods
- However, on occasion, efforts are made to introduce new and innovative components into the nuclear industry
- This presents several challenges:

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Challenges

- For new plant designs, system design requirements may still be evolving
- Lack of nuclear industry standards
- Lack of experience/knowledge on acceptable testing methodologies
- Lack of applicable operating experience
- Unclear/evolving regulatory expectations
- Timing – qualification programs can take a long time

Example – AP1000 Squib Valves

- Each AP1000 Reactor contains eight large squib valves:
  - Four 14-inch Automatic Depressurization Valves
  - Two 8-inch Passive Core Cooling Injection Valves
  - Two 8-inch Passive Core Cooling Recirculation Valves

AP1000 14” Squib Valve

RCS Pressure Side *(Inlet)*

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Evolving System Design Requirements

- Submergence requirement added for recirculation valves
- Changes to accident profile made during EQ program
- Excessive vibration levels detected during pre-operational testing requiring additional qualification testing

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Lack of Industry Standards

- No comprehensive nuclear standards on how to qualify or verify/validate the design for an explosive valve
- Existing operating experience for squib valves not really applicable
  - Located outside of containment
  - One stage vs two stage
  - Different explosives
- No nuclear standards on how to demonstrate/verify assumed reliability for new component designs

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Lack of Applicable Operating Experience

- Reliability uncertainty was compounded by lack of applicable operating experience
  - Existing nuclear squib valve reliability really not applicable
  - Applicability of data from non-nuclear applications also questionable
- Reliability target of 1 in 1,500 failures on demand (for the entire system) would be difficult and extremely costly to demonstrate through repetitive testing alone

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Unclear Regulatory Expectations

- Licensing description was at a very high level
- No real regulatory buy-in on qualification plan
- Simultaneous ongoing assessments by three different regulatory bodies (US/UK/China)

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Significant Issues Identified During Qualification Program

<u>Issue</u>

- Failed submergence testing on 8” valve (self-revealing)
- Inadequate design validation/testing of initiator/initiation circuitry (NRC identified)
- Insufficient analytical basis and or testing to demonstrate the acceptability of the cartridge design with respect to the ability of the initiator to reliably ignite the cartridge under design basis conditions. (NRC identified)
- Failure of cartridge to ignite during lot acceptance testing (self revealing)
- Acceptability of firing circuit resistance path under DBA conditions (NRC identified)
- Vibration in excess of previously tested levels detected during hot functional testing (Self revealing)
- Inadequate commercial grade dedication of certain key squib valve subcomponents (NRC identified)

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Major Corrective Actions Taken

- All previously identified issues have now been resolved including:
  - Design changes to valves to address leakage issues
  - Greatly expanded qualification program to address issues associated with design margins and reliability
  - Development of new insitu testing procedure for firing circuit
  - Additional vibration testing

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Lessons To Be Learned

- Establishment of a multidisciplinary design review team with a wide range of technical experts including possibly experts from outside the nuclear industry
  - Possible upfront involvement of regulatory bodies
- Identify and clarify approach for design validation and qualification
- Establish and communicate reliability requirements consistent with probabilistic risk assessment and determine approach for ensuring requirements are met
- As practical, determine the full range of in-situ conditions and allow for margin to account for possible design changes

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Lessons To Be Learned

- Clarify approach for dedication of commercial grade components/sub-components
  - Who is responsible for design validation?
  - Clarification of design validation testing vs testing to verify critical characteristics
- Maintain awareness of how system specifications can influence component designs
  - Interface requirements
  - Margins