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Cable Performance Challenges in Nuclear Industry

Presentation To

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Agenda

- Cable Performance Requirements
- Operating Experience
- Service Life Issues
- IEC & IEEE perspective on Qualification
- Standards & Regulatory Guides
- Research Plans

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CABLE PERFORMANCE REQUIREMENTS

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Cable Functions

- Operational Significance
  - Cause a plant trip
  - Reduce power output
- Nuclear Safety Significance
  - Mitigate the effects of an accident
  - Monitor critical parameters to ensure safety
  - Monitor the emergency core cooling
  - Monitor, gauge and prevent the potential for a containment breach and offsite release

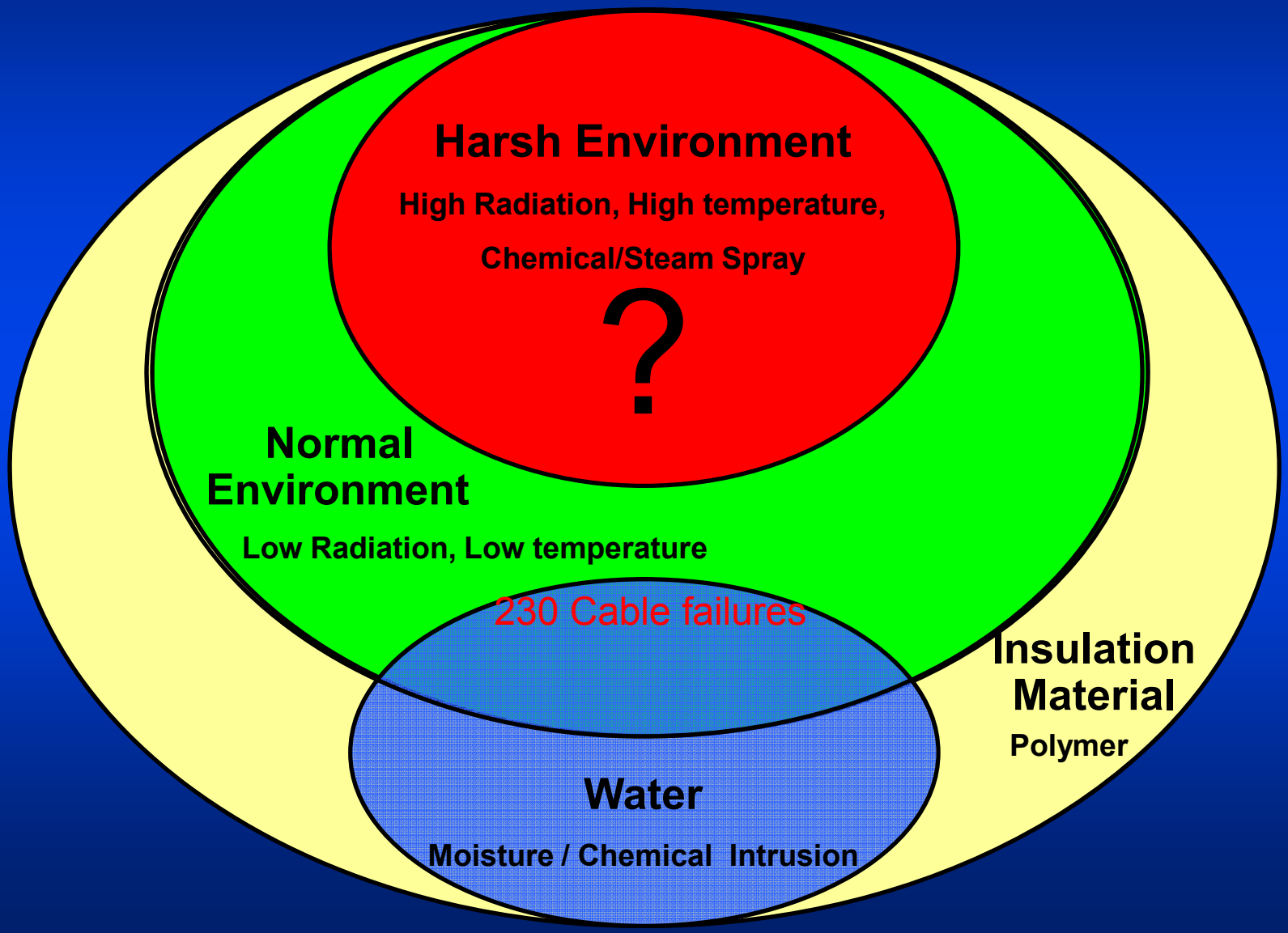
Operational Cable failures

- Operational failures are usually well addressed through cable replacements
- Normal operational environment is well understood with years of experience
- Cable chemistry has improved over the years in designing suitable cables that meet general industrial requirements in temperature, humidity, steam environment etc.,

Potential Cable Failures in Harsh Environment

- Harsh Environment
  - Any environment that undergoes significant changes as a the result of a design basis accident (LB-LOCA,MSLB etc.,)
- Most safety significant cables are in standby mode during normal operation
- **Limited operating experience in the performance of cables in accident environment**

Factors for Acceleration of Cable Failures



Safety Related Cable Failure

- Random failure or single failure can generally be managed with the redundancy and diversity in design (generally two train systems)
- Common-causes (Radiation, temperature, humidity) that exceed demonstrated limits in cable performance could increase core damage probability

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Operating Experience

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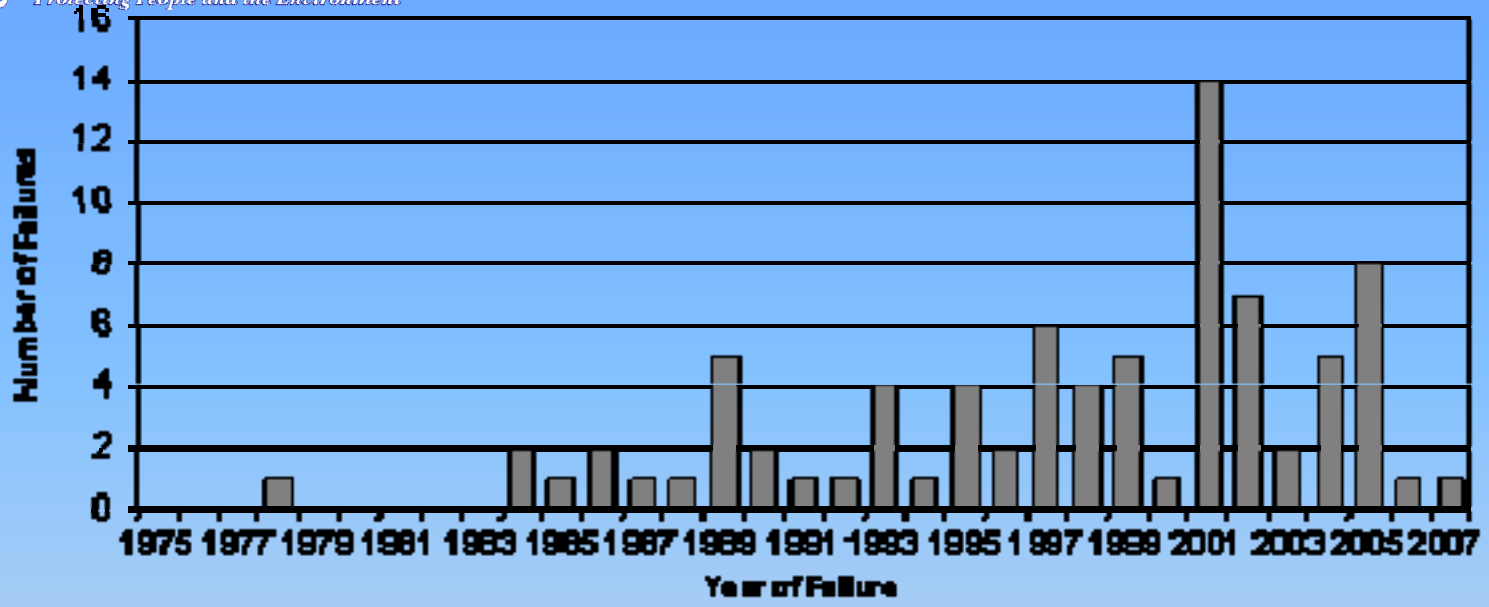
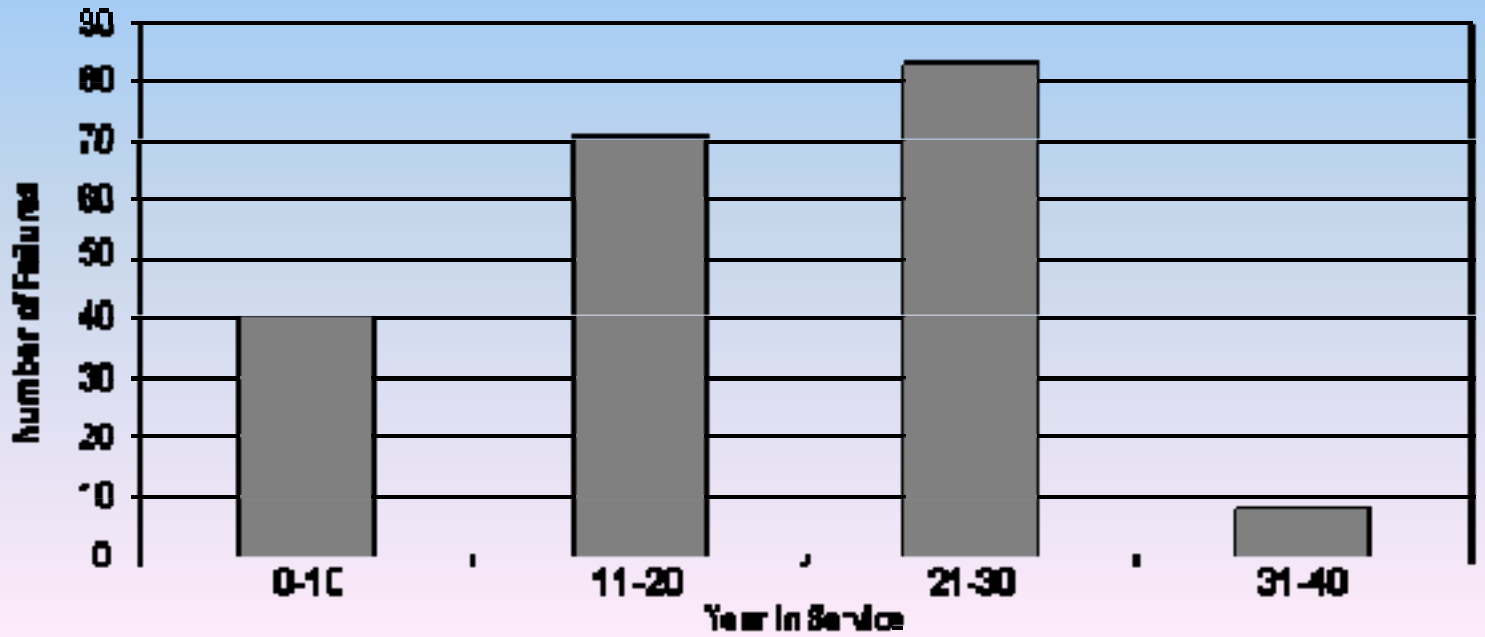
US Data





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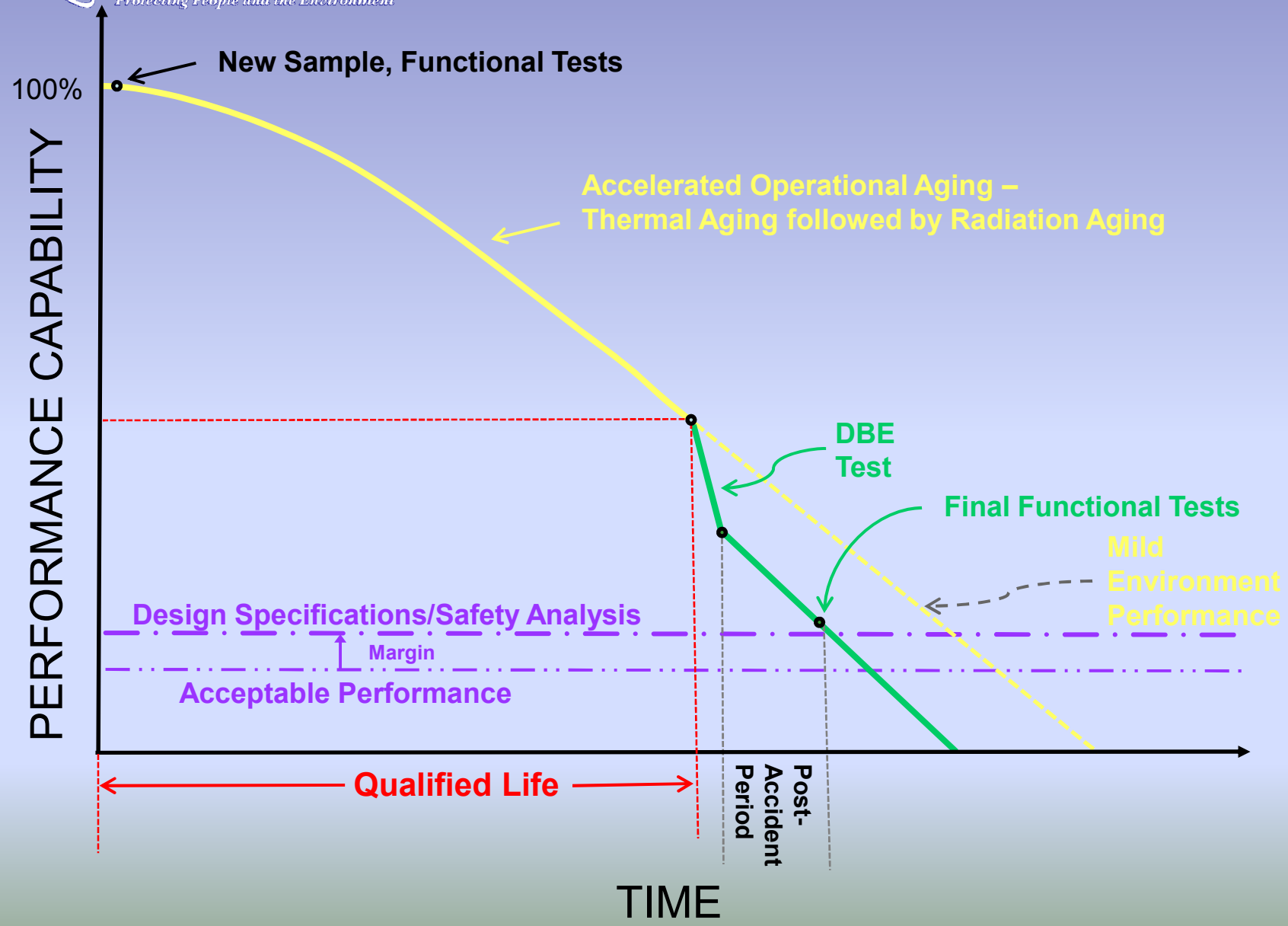
Service Life issues

Qualification Procedure

- Visual inspection
- Measurement of initial functional properties
- Simulation of normal operational ageing
- Simulation of accident, post-accident period and functional verification
- Final properties measurement
- Final visual inspection

Existing Qualification Method



Historic Perspective

- Qualification testing involved sequential testing for radiation and thermal aging
- The operating environment in temperature and radiation was calculated with recommended margin from IEEE 323-74
- The goal was to qualify components for 40 years
  - In certain cases replacement or refurbishment was needed

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Life Extension

- The licensees examined the margins in qualification assumptions and found that there was temperature and radiation margin
- The available margin was used for extending life of the cables and other EQ components
- 10 CFR 54 provisions were used for demonstrating qualification for the renewed period

Margins in IEEE 323-1974

- The margins were intended for the following because a single successful sample test was considered adequate for qualification:
  - “Variations in commercial production”
  - “Reasonable errors in defining satisfactory performance”

Margins in IEEE 323-1974

- Margins
  - Peak temperature: + 8 °C
  - Peak pressure: + 10 % of gauge
  - Radiation: +10 % accident dose
  - Power supply voltage: + 10 % but not exceeding cable design limits
  - Operating Time: +10% min. 1 hr
  - Vibrations requirements: +10% added to the acceleration
  - Frequency: + 5% of rated value

Uncertainties in EQ Testing

- Identified the impact of the following:
  - sequential test of radiation & thermal aging and sequence in which it was conducted
  - concurrent thermal & radiation aging
  - oxygen starved LOCA chambers
  - dose rate
  - Non-conservative /incorrect activation energy used in Arrhenius equation
  - Inverse temperature effects

Uncertainties in EQ Testing

- Non conservatism in sequential testing (thermal and radiation aging)
  - Concurrent temperature and radiation aging could result in significantly more damage to cable
- Small LOCA chambers that became oxygen starved within few hours of the test and prevented further degradation
  - Oxygen starved LOCA chambers could limit degradation to the outer surface and stop further degradation during the test

Uncertainties in EQ Testing

- Application of a integrated radiation dose at a high rate to account for operational & accident conditions resulted in limited surface damage to cables
  - Homogeneous degradation in operational aging simulation may occur only in radiation dose rates less than 100Gy/hr for most polymers
- Use of non-conservative Activation energy values
  - Choice of activation energy needs to be appropriate to the operating temperature

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Inverse Temperature Effects

- Certain cables are exhibiting degradation at lower temperatures.
- Cross-linked polyolefin (XLPO) does not follow Arrhenius methodology. Conclusions from accelerated aging needs further verification

Uncertainties in EQ Testing

- It is necessary to determine the impact of above non-conservative influences on the qualification margin for 40 years of operation and for renewed license period.

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IEC & IEEE perspectives on Qualification

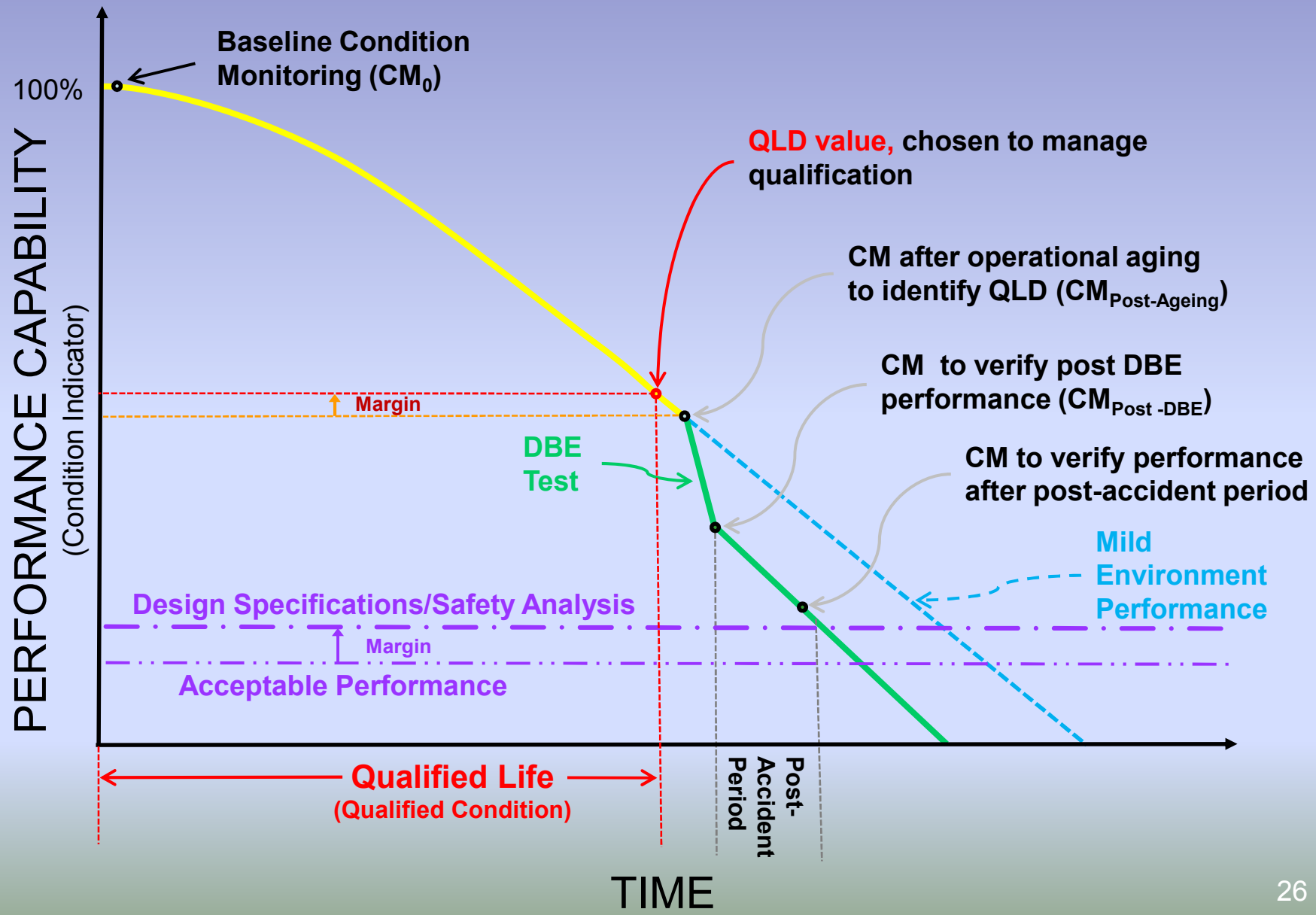
IEEE & IEC Approach to EQ

- Condition Based Qualification: IEEE 323-2003 states, "Condition monitoring may be used in place of a qualified life to determine if qualified equipment is suitable for further service. Condition monitoring for equipment qualification purposes monitors one or more condition indicators to determine whether equipment remains in a qualified condition. The trend of the condition indicator is determined during the performance of age conditioning of the test specimen during qualification testing. The condition indicator must be measurable, linked to the functional degradation of the qualified equipment, and have a consistent trend from unaged through the limit of the qualified pre-accident condition. Condition monitoring may be used with or independently from the concept of qualified life. As the qualified equipment approaches the end of its theoretical qualified life, periodic condition monitoring may be implemented to determine if actual aging is occurring at a slower rate, and if further qualified service is possible based on the condition monitoring results."

IEEE & IEC Approach to EQ

- Condition Based Qualification
  - During the qualification test, conduct condition monitoring of critical parameters before and after operational aging
  - Conduct the LOCA/accident environmental test and verify satisfactory performance again through condition monitoring
  - Identify the Qualified Level of Degradation (QLD) that the equipment can endure LOCA test
  - Manage the operational degradation to QLD with suitable condition monitoring (Regulatory Position 6, RG 1.211)

Condition-Based Qualification



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Benefits of Condition-Based Qualification

- Greater confidence in predicting cable performance
- Increased service life without any additional qualification testing if ambient conditions are less severe than design assumptions or rate of degradation is lower
- Increased savings
  - Reduced maintenance (Possibly delaying replacing equipment)
  - Reduced radiation exposure to personnel
  - Adjusted maintenance schedule based on demonstrated results

Condition-Based Qualification

- NRC currently requires qualified life for EQ components (10 CFR 50.49)
- Condition-Based Qualification can be implemented within the provisions of the existing US Regulations.

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STANDARDS & REGULATORY GUIDES

Regulatory Guide Status

- RG 1.89 (EQ)
  - To endorse IEEE 323-2003)
- DG-1240 – Condition Monitoring Program for Electric Cables Used in NPPs
  - Resolving Public Comments
  - Expected to be published in 2Q 2011
- RG 1.211 – Qualification of Safety-Related Cables and Field Splices in NPPs -Published April 2009
    - IEEE 383-2003, "IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations"

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Challenges

Research Activities

- EQ
  - The review of relevant documents to confirm that adequate margin is available for the current and renewed license periods in the qualification of electrical equipment.
  - Based on the re-examination of existing cable aging test results, recalculate the margin for equivalent aging conditions in light of the known uncertainties.
  - This project will consider the need for confirmatory testing to quantify margins to address uncertainties.

Gain Confidence in Cable Performance

- Identify an aging indicator(s) that can be tracked for the variety of polymers in cable and other EQ components
- Identify techniques that can produce repeatable results for a variety of applications in the field
- Standardize the techniques for widespread industry use to build greater confidence in predicting cable performance

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QUESTIONS?