# NEI Steam Generator Task Force

# Industry Update

September 16th, 2009

NUCLEAR ENERGY INSTITUTE

# Agenda

0830 Introductions

0835 NRC/Industry Opening Remarks

0845 NEI Steam Generator Task Force Update on Technical Issues

1500 NRC Summary Comments
Public Questions/Comments

1530 Action Item Review

1600 Adjourn

# NEI Steam Generator Task Force Update on Technical Issues

- Operating Experience
- Divider Plate Cracking Update
- Noise Monitoring
- Time Dependent Leak Rates
- Examination Technique Equivalency
- Detection of Foreign Objects
  Detection & Sizing of Foreign Object Wear
- SGMP Website Access
- TSTF-510, Rev. 0
- EPRI SGMP Guidelines Status and Revisions
- NEI 03-08 Overview
- Performance Standard for SG Tube Integrity

# Operating Experience

- Domestic
- International

# Domestic Operating Experience

- Catawba 2 Spring 2009 - ODSCC Indications
  - Model D5 SGs with A600TT tubing and 18.7 EFPY
  - Inspected all tubes with potential elevated stress with Array Probes at all hot leg support locations
  - ODSCC indications in 3 higher row tubes R24-C62 (SG B), R41-C59 and R41-C55 (SG D). Tube supports affected were 02H, 03H, 04H and 05H

# Domestic Operating Experience

- Catawba 2 ODSCC Indications
  - 7 Axial ODSCC indications detected
    - 6 Single Axial and 1 Multiple Axial
    - No tube integrity issues
    - In situ pressure testing not required
    - All ODSCC indications were plugged
  - Current Interim Guidance for tubes with potential elevated stress considered adequate

# Domestic Operating Experience

- Surry-1 PWSCC & In Situ Pressure Test
  - Surry-1 contains Model 51F SGs with A600TT tubing and has operated for 22.3 EFPY
  - Surry-1 Spring 2009 inspections detected a single axial PWSCC indication at the hot leg top of tubesheet expansion transition
    - SG 1A R9 C69 at TSH-0.02” and 0.62” in length
    - Previously identified tube with potential elevated stress
    - Original scope in +Point™ probe inspection program
  - In Situ Pressure Testing was performed on the flaw
    - No Leakage detected during leak and proof tests
  - Existing DA process for addressing OE is adequate

# Domestic Operating Experience

- Braidwood-1 FO Wear & In Situ Pressure Test
  - BWC Replacement SGs with A690TT tubing and has operated for 9.9 EFPY
  - Spring 2009 inspections detected a 73% TW flaw located just above the hot leg tubesheet, TSH+0.26”, SG B R89-C30
    - Historical data review identified this flaw in previous two inspections
      - Identified by Auto Analysis but discarded during editing process in both prior inspections
      - Associated with legacy object detected in 2003 that migrated. No change in flaw signal from 2007 to 2009
  - In Situ Pressure Testing was performed on the flaw
    - No Leakage detected during proof and leak tests
  - Data added to EPRIQ.com for industry use
  - Human Performance Issue
  - No additional guidance necessary

# International Operating Experience

- Fatigue Failures at EdF
  - Cruas
    - Preliminary investigation indicates that the chimney region in the EdF design was an important factor to the failure
      - No US SG has this design
    - Average of 26,000 Lbs/plant of deposits are being removed by Chemical cleaning in EdF units (CRU2, CRU3, BEL1, CAT1, CAT3, ChinonB3)
    - On-going EPRI SGMP projects are funded to investigate the level of deposits that could cause concerns
    - Deposit accumulation is second order effect
    - Potential for high cycle fatigue was added to draft revision of Integrity Assessment Guideline
    - Guidance in Secondary Water Chemistry GL to assess deposit loading

# International Operating Experience

- Fatigue Failures at EdF
  - Fessenheim
    - Bulletin 88-02 issue
    - Susceptible US plants evaluated this condition in late 80's and took corrective actions

# Divider Plate Cracking Project Update

# Divider Plate Cracking Project Update

- No progress since the last meeting
  - Work to be completed by end of 2009 pending Westinghouse resource availability due to H* PARC project
  - Remaining work involves wrap up and review
    - No safety issues are expected to result in the outstanding work

# Noise Monitoring

# Noise Monitoring

- EPRI Report 1016554 sent to the NRC
  - Describes methodology for measuring and monitoring noise in ECT data
  - Includes a specification for vendor software
- Palo Verde, Westinghouse, and EPRI piloted the Westinghouse software spring 2009
  - Demonstrated that the software performs well during a replacement SG inspection with some additional resources
  - Need other pilots
    - SGs with multiple degradation mechanisms
    - Utility that uses another inspection vendor

# Time Dependent Leak Rates

# Time Dependent Leak Rates

- EPRI and NRC working together to upgrade ANL's blowdown facility
  - Facility will be used to determine the leak rate threshold for the onset of leak jet/structure interactions that are of sufficient magnitude to produce fatigue crack growth with resultant time dependent increases in leak rates
  - Testing will be performed in 2010 to investigate conditions important to operating SGs
- This testing will not address in situ pressure test hold times at 3dP
  - Current test procedures reliably demonstrate structural integrity margins

# Time Dependent Leak Rates

- Under specialized conditions, time dependent plastic deformation can contribute to small increases in crack opening areas leading to time dependent leak rates
- Industry is developing the basis for revised leakage integrity in situ test requirements
- Testing is in progress to develop a correlation between increases in test pressure and equivalent hold times for leak rate tests at DBA pressures

# Examination Technique Equivalency

# Standardized Process for Determining Examination Technique Equivalency

- Technical update reports 1015126 and 1018557 have been sent to NRC
- Project Status:
  - Ongoing project proposes a process to show equivalency through ECT signal comparison of site technique to EPRI ETSS
  - Demonstrated several essential variable tolerances currently in Appendix H show little variability in POD
  - Final work (to be completed in 2010) should provide a recommended alternate to current process
  - Review of NRC Technical Letter Report (ML082960705) is supportive of EPRI equivalency methodology
  - Publish report in 2010

# Detection of Foreign Objects

# Detection & Sizing of Foreign Object Wear

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- Project update
  - Ability to detect foreign objects at varying distances from structures and tube surface researched for all three probe types
  - Effects of Foreign Objects on wear sizing shows little impact in many cases (typically conservative)
  - New ETSSs being developed for wear sizing with FO present
  - Continuing research on effects of structure/transition on volumetric wear detection
    - Should lead to ETSS development for detection and sizing of loose part wear at TTS expansion transition
  - Developing detection and sizing ETSSs for array probes (Intelligent Probe and X Probe)
  - Long term project; SGMP recommends closure of this item

# SGMP Website Access

# SGMP Website Access

- The NRC has access to the ETSS documents through each utility
- The NRC has access to the EPRI Charlotte office to review ETSS documents, backup information, and procedures upon request
- The NRC has visited the Charlotte office and reviewed ETSS documents on two separate occasions
- SGMP recommends closure of this item

# TSTF 510, Rev. 0

## "Revision to Steam Generator Program Inspection Frequencies and Tube Sample Selection"

# TSTF-510, Rev. 0

- Proposed changes revise ISTS, NUREGs 1430, 1431, and 1432
  - Specification 5.5.9, "Steam Generator (SG) Program”
  - Specification 5.6.7, "Steam Generator Tube Inspection Report“
  - Address implementation issues with the inspection intervals, and address other administrative changes and clarifications.
- Traveler & Fee Waiver Request transmitted to NRC on 3/26/09
- Fee Waiver Request Approved on 7/20/09 (ML092010534)
- NRC acceptance & schedule letter expected by 9/15/09

# TSTF-510, Rev. 0

| TSTF-510 STEAM GENERATOR TUBE INTEGRITY MILESTONE SCHEDULE | | | | |
|---|---|---|---|---|
| **Milestone Action** | **Original Target Date** | **Current Target Date** | **Responsible Individual** | **Comments/Status** |
| Draft of Technical Justification provided to SGTF & IIG for Comment | 8/8/2008 | | Boyers | Complete |
| SGTF & IIG Comments due | 8/15/2008 | | SGTF & IIG Members | None Received |
| Obtain NRR input on editorial items and clarifications desired | 8/15/2008 | | Melton | Received 8-21-08 |
| Resolve comments on Draft, address NRR list and provide final draft to SGTF and IIG | 8/22/2008 | | Boyers | Complete |
| Incorporate final comments into draft & transmit to Excel | 8/29/2008 | | Melton/Boyers | Complete |
| Create Traveler & distribute for PWROG & SGTF review | 9/15/2008 | | Excel | Draft issued 9-16-08 |
| Conduct pre-meeting with NRR to review proposed language & receive feedback | 9/30/2008 | 11/25/2008 | Excel & SGTF | Complete (Phone Conference) |
| ~~Broadbased Technical Review by SGTF, SGMP TAG and EOC~~ | ~~2/13/2009~~ | | ~~Melton/Boyers~~ | ~~Complete~~ |
| Resolve Broadbased Technical Review Comments | 2/28/2009 | | Melton/Boyers | Complete |
| Distribute updated Traveler to PWROG & SGTF | | 3/2/2009 | Excel | Complete |
| PWROG & SGTF provide comments | 10/15/2008 | 3/15/2009 | PWROG & SGTF | Complete |
| Resolve Owner Group Comments, Prepare Final Traveler, create transmittal letter, send to TSTF for Approval | 10/22/2008 | 3/22/2009 | Excel | Complete |
| TSTF review | 11/7/2008 | 3/15/2009 | Excel/NEI | Complete |
| Create Final Traveler, transmit to NRC & OGS, post | 11/15/2008 | 3/25/2009 | Excel/NEI | Complete |
| Submit TSTF Traveler to NRC | 1/1/2009 | 3/26/2009 | Excel/NEI | Complete |
| Receive NRC Acceptance & Schedule Letter | 3/1/2009 | 9/15/2009 | Excel/NEI | |
| Receive RAIs | 6/1/2009 | 12/1/2009 | Excel/NEI | |
| Respond to RAIs | 9/1/2009 | 3/1/2010 | Excel/NEI/SGTF | |
| Receive Notice for Comment | 12/1/2009 | 6/1/2010 | Excel/NEI | |
| Respond to Notice for Comment | 1/1/2010 | 7/1/2010 | Excel/NEI | |
| NRC Publish Notice of Availability | 4/1/2010 | 10/1/2010 | NRC | |

# EPRI SGMP Guideline Status and Revisions

# EPRI SGMP Guideline Status and Revisions

| Guideline Title | Current Rev # | Report # | Last Pub Date | Implement Date(s) | Interim Guidance | Review Date | Comments |
|---|---|---|---|---|---|---|---|
| Steam Generator Integrity Assessment Guidelines | 2 | 1012987 | Jul-06 | 1/2/2007<br>4/2/2007 | SGMP-IG-07-01 | n/a | Rev 3 to be published in 2009 |
| EPRI Steam Generator In Situ Pressure Test Guidelines | 3 | 1014983 | Aug-07 | 3/14/2008<br>6/14/2008 | none | n/a | Based on the 2009 review, a decision was made to initiate Rev 4 |
| PWR Steam Generator Examination Guidelines | 7 | 1013706 | Oct-07 | 9/1/2008 | SGMP-IG-08-04 | 2010 | |
| PWR Steam Generator Primary-to-Secondary Leakage Guidelines | 3 | 1008219 | Dec-04 | 7/17/2006<br>10/17/2006 | none | n/a | Rev 4 to be published in 2010 |
| PWR Primary Water Chemistry Guidelines | 6 | 1014986 | Dec-07 | 6/17/2008<br>9/17/2008 | SGMP-IG-09-01 | 2010 | |
| PWR Secondary Water Chemistry Guidelines | 7 | 1016555 | Feb-09 | 8/20/2009<br>11/20/2009 | none | 2011 | |
| Steam Generator Management Program Admin Procedures | 2 | 1015482 | Sep-07 | 1/3/2008<br>4/3/2008 | SGMP-IG-08-01, SGMP-IG-08-02, SGMP-IG-08-03 | n/a | Rev 3 to be published in 2010 |
| Steam Generator Degradation Specific Flaw Handbook | 0 | 1001191 | Jan-01 | n/a | SGMP-IG-06-01 | n/a | Rev 1 to be published in 2009 |

# EPRI SGMP Guideline Status and Revisions

- At the Jan 2009 SGTF meeting, the NRC requested a copy of Rev 7 of the PWR SG Examination Guidelines.
  - EPRI has provided the NRC with access to the requested guideline document.
- At the Jan 2009 SGTF meeting, the NRC agreed that they do not need draft copies of guideline documents and reports submitted on a routine basis.
  - If there is a specific draft that the NRC needs, then they will request it.
  - "Final" copies of approved guideline documents and interim guidance would continue to be provided to the NRC.

# EPRI SGMP Guideline Status and Revisions Planned Changes

- Steam Generator Integrity Assessment Guidelines
  - Changes in design parameters shall be assessed and included if they result in primary to secondary pressure differences that are greater than the values used in the evaluation of SIPC
    - Deleted the last phrase (by more than 50 psi)
  - Added a requirement to assess each design basis accident when determining AILPC limit
  - Added an explanation of “worst case degraded tube”

# EPRI SGMP Guideline Status and Revisions Planned Changes

- Steam Generator Integrity Assessment Guidelines
  - Added a requirement to use Appendix I ETSSs or site specific ETSSs developed to the rigor of Appendix I for the assessment of tube integrity as they become available
  - Added a discussion about proactive inspections not being characterized as inspections for potential degradation in Degradation Assessments

# EPRI SGMP Guideline Status and Revisions Planned Changes

- Steam Generator Integrity Assessment Guidelines
  - Updated operational experience section to include cracking in Alloy 600TT tubing, high row U-Bends, wear in replacement SGs, and recent fatigue failures
  - New section on dispositioning late breaking OE
  - Requirement to evaluate forms of degradation that have been found at prior inspections but not observed at the current inspection
  - Requirement to consider the uninspected population if less than 100% inspection is being performed and degradation is detected

# EPRI SGMP Guideline Status and Revisions Planned Changes

- Steam Generator Integrity Assessment Guidelines
  - Rewrote Chapter 9, Leakage Assessments
    - Brought this up to date with latest information and methodologies for leakage assessments
      - Added requirements to consider loads other than pressure loads
      - Added requirement to consider pop-through

# NEI 03-08 Overview

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- NEI issued Rev 4 to Implementation Protocol on July 07, 2009 effective August 1, 2009
  - Clarifies & provides more detail for processing deviations
- Deviation Process
  - IP Notification within 45 days after approval with NRC notification at about the same time
  - Notification to Document Control Desk with copies to the NRC Plant Project Manager, the NRC Project Manager responsible for the IP, NRC Site Resident Office and NRC Regional Office
    - NRC Project Manager responsible for the IP?

# NEI 03-08 Overview
## SGMP Deviations to date in 2009

- Deviation to Steam Generator sodium concentration action levels during startup
  - One plant took a deviation to two needed requirements from Secondary Water Chemistry guidelines on 3 separate occasions
  - Sodium <100 ppb prior to escalating power & to S/D plant if sodium >250 ppb when power >5%
  - Plant had no blowdown at hot shutdown conditions and had concerns for thermal cycling the SG to effect a drain and fill
  - SG tubing made from Alloy 690TT

# Performance Standard for SG Tube Integrity

# Performance Standard for SG Tube Integrity

- Past performance standard  90/50
- Present performance standard 95/50
- What benefit is a 95/95 requirement?

# Past Performance Standard 90/50
# IAGL Rev. 1

- Operational assessment requires that the most limiting projected defects or indication sizes, as determined by an appropriate analysis, do not exceed the appropriate operational assessment limit for each defect type.
- Considering all significant uncertainties, a defect or indication size measured to be at the operational assessment limit will satisfy the performance criterion with a probability of 90% at 50% confidence.
- Probabilistic Criterion
  - < 0.1 for the burst of one or more tubes
- It should be noted that this criterion is equivalent to the requirement that structural integrity be maintained at 3NOPD (or 1.4 LADP if higher) with a probability of 90% at a confidence level of 50%.

# Past Performance Standard 90/50 IAGL Rev. 1

- Computational hierarchy "dependent on the available margin and the pedigree of the input data"
  - Arithmetic
  - Simplified Statistical
  - Monte Carlo
- Arithmetic
  - All input at worst case 90$^{th}$ percentile values (stacked worst case)
- Simplified Statistical
  - Combine 90$^{th}$ percentile material, burst equation and NDE sizing uncertainties
  - Upper 90$^{th}$ percentile growth rate
  - For plug on detection worst case BOC flaw depth equal to depth at POD = 0.95
- Monte Carlo
  - Fully probabilistic "full bundle analysis"

# Past Performance Standard 90/50
# IAGL Rev. 1

- Performance standard met on a per degradation mechanism basis
- Arithmetic and Simplified Statistical techniques are based on “worst case flaw”
- Arithmetic and Simplified Statistical techniques are assumed to be bounding
- Monte Carlo fully probabilistic approach used if bounding techniques are unsuccessful

# Present Performance Standard 95/50
# IAGL Rev. 2

- During actual operation of a given SG in a given cycle, for the degradation mechanism of interest, one tube has the lowest structural performance parameter associated with it.
- However, this is one of many possible outcomes for the given starting condition. A fully probabilistic analysis leads to a distribution of possible outcomes of SG operation.
- The “projected worst case degraded tube” is defined as the degraded tube with the 5th percentile structural performance parameter at 50% confidence of the distribution of lower extreme values of structural performance parameters.
- Using the definition of the projected worst case degraded tube to perform the OA is mathematically equivalent to demonstrating that the probability of violating the structural performance criteria is no greater than 0.05 at 50% confidence.
- Conversely, the probability of meeting the performance criteria is at least 0.95 at 50% confidence.

# Present Performance Standard 95/50 IAGL Rev. 3 Additions

- A fully probabilistic analysis leads to a distribution of possible outcomes of SG operation for all degradation sites both detected and undetected for a given degradation mechanism.
- An illustration of a fully probabilistic treatment of the tube bundle for a given mechanism is shown in Figure 8-1.
- In this illustration, a Monte Carlo analysis for the tube bundle is used to establish the distribution of the tubes that produce the lowest burst pressure for the given degradation mechanism.
- Figure 8-1, the “projected worst case degraded tube” is defined as the degraded tube with the 5th percentile structural performance parameter at 50% confidence of the distribution of lower extreme values of structural performance parameters.

# Where are we now? 95/50
# IAGL Rev. 3 Additions cont.

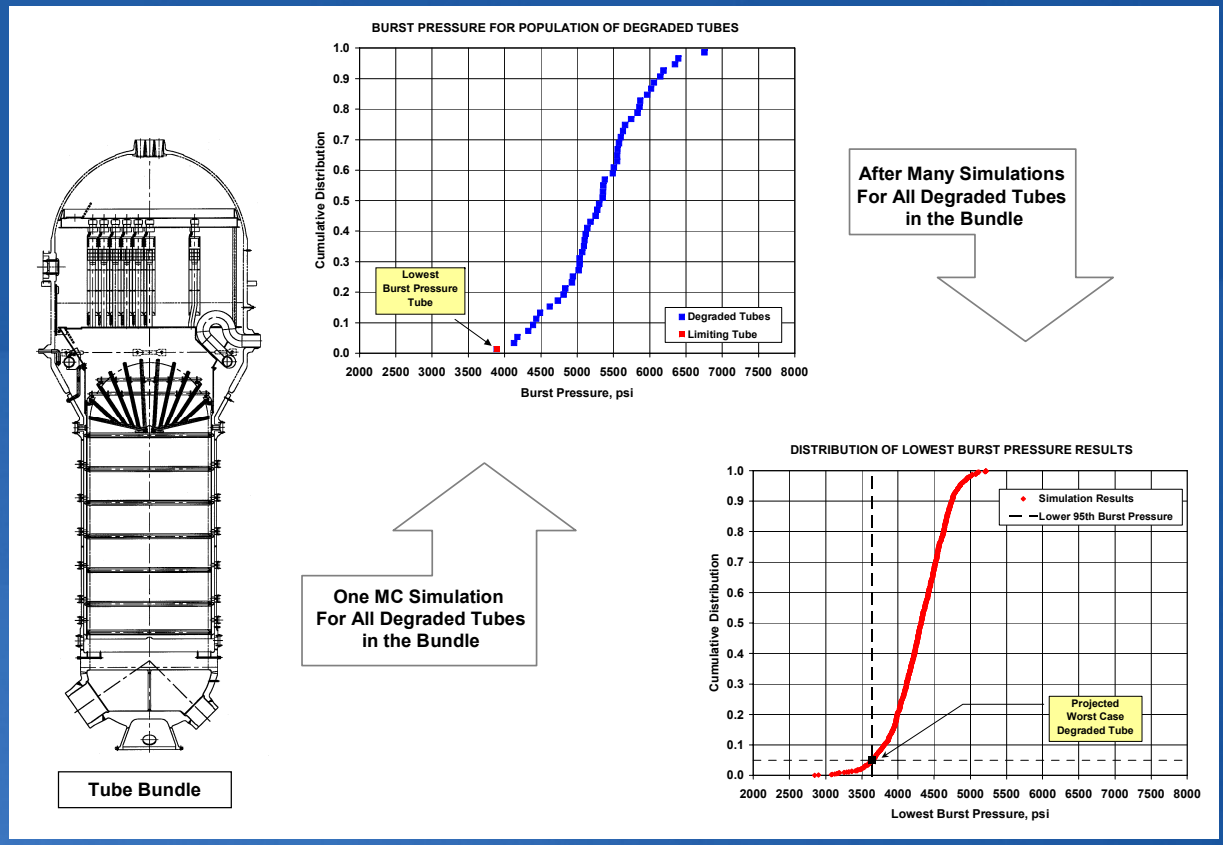



**Figure 8-1**
**Fully Probabilistic Monte Carlo Simulation to Establish Worst-Case Degraded Tube – Full Bundle Analysis**

## Present Performance Standard 95/50 Degradation Mechanisms

- Degradation Mechanism
  - Degradation geometry
  - POD curve
  - Distribution of growth rates
- Most severely degraded SG's in past had at most two degradation mechanisms that truly challenged tube integrity performance criteria

## Present Performance Standard 95/50 "Worst Case Degraded Tube"

- Condition Monitoring
  - Evaluate all degradation sites
  - "Worst case" will be included
  - Each site must individually meet limiting SIPC at 95/50
- Operational Assessment
  - "Projected worst case degraded tube" is necessarily a probabilistic concept
  - What is the basis for selecting a probability of meeting the limiting SIPC?

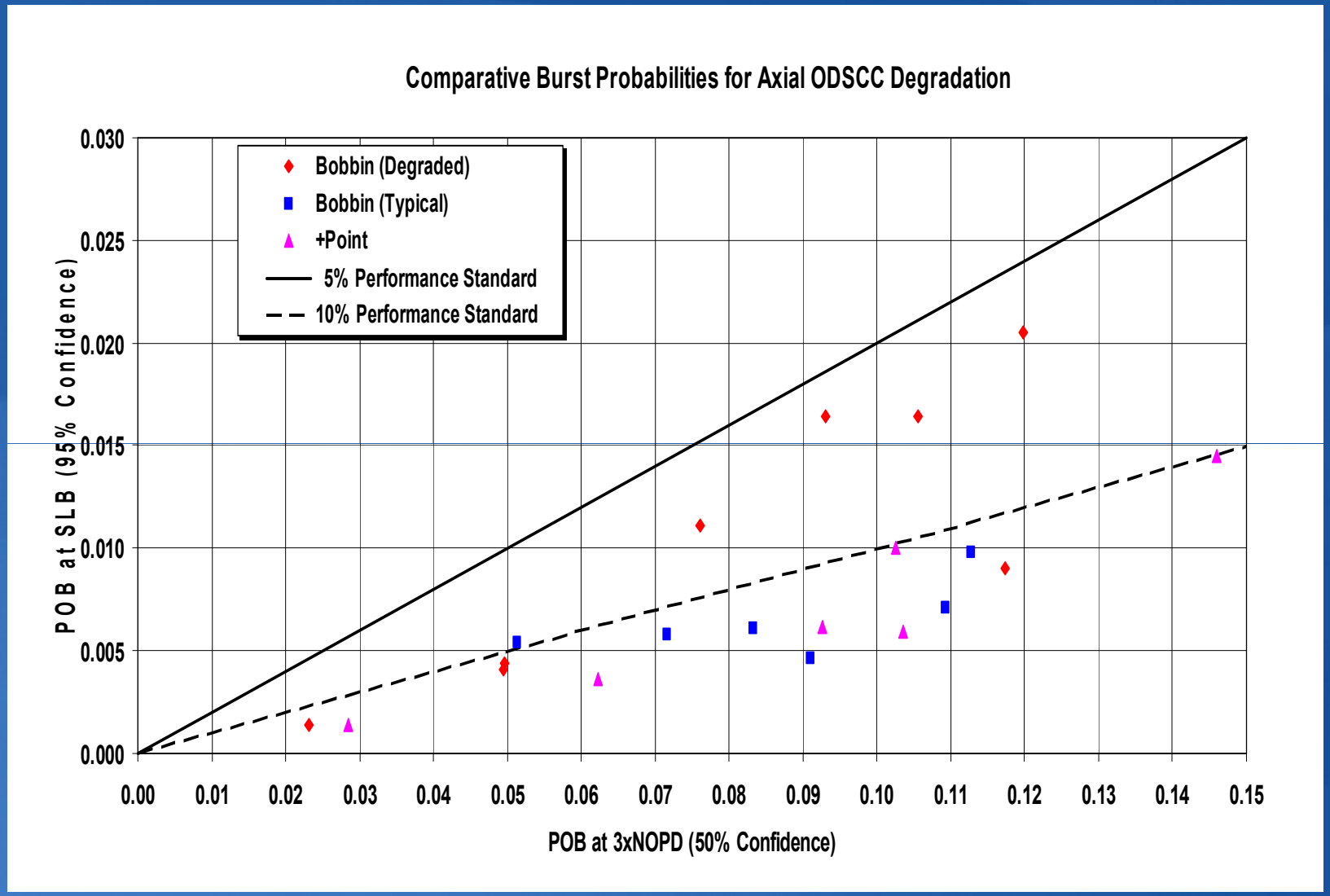
## Present Performance Standard 95/50 Probabilistic Figure of Merit

- Regulatory precedent
  - Bobbin Voltage ARC
- Probability of Burst at MSLB
  - Less than or equal to 0.01
- What is the probability of burst (POB) at 3$\Delta$P when the POB at MSLB is 0.01?
- Industry Study
  - EPRI Report 1012984

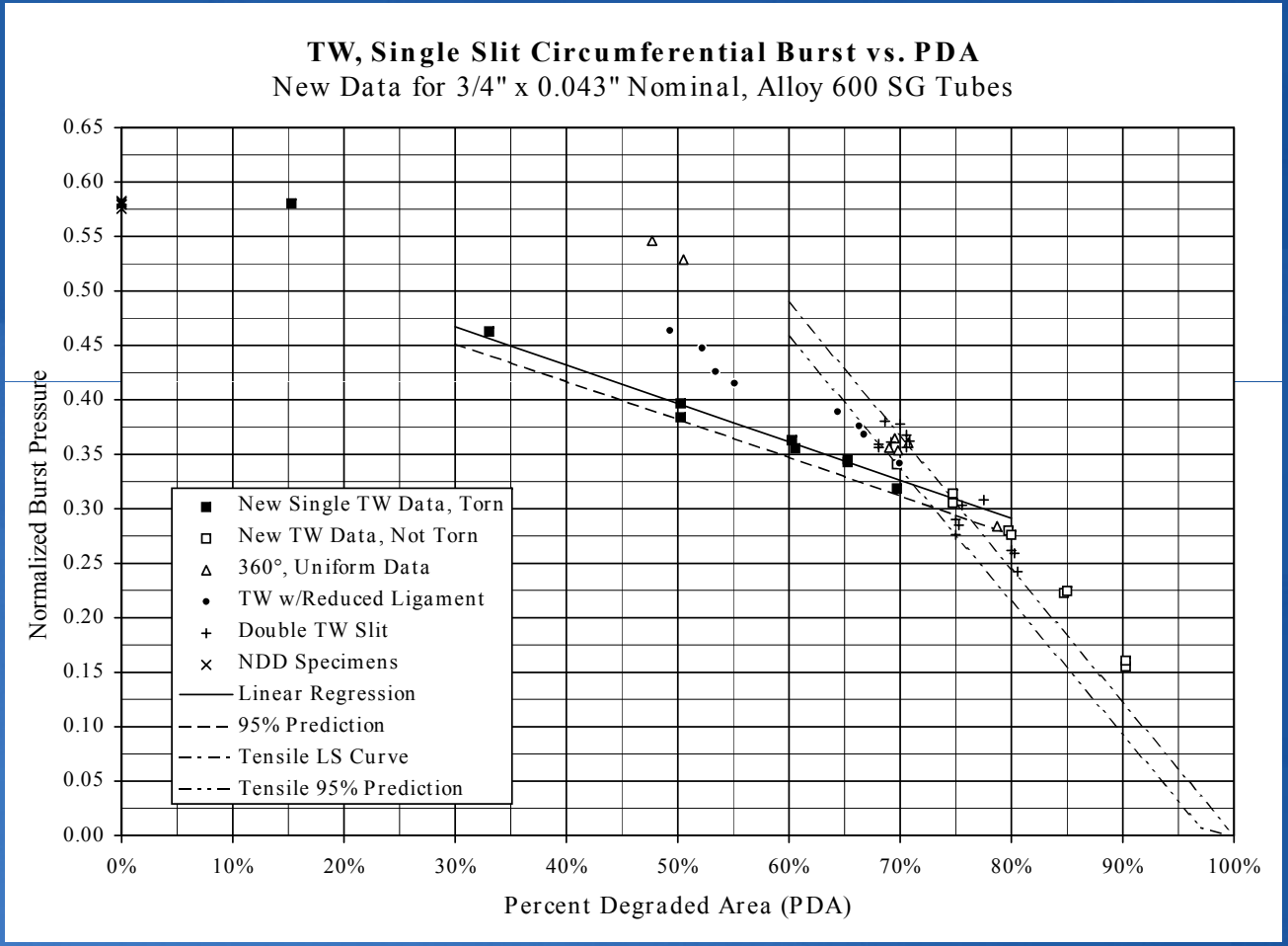
## Present Performance Standard 95/50 Probabilistic Figure of Merit cont.

- Axial Cracking
  - In most cases POB <= 0.1 at 3ΔP ensures POB at MSLB < 0.01
  - Several cases require POB <= 0.05 at 3ΔP to result in POB at MSLB < 0.01
- Circumferential Cracking
  - POB <= 0.05 at 3ΔP typically required to meet POB at MSLB < 0.01

# Present Performance Standard 95/50



# Present Performance Standard 95/50 Probabilistic Figure of Merit cont.



## Present Performance Standard 95/50

- Industry requirement
  - Considering all degradation sites for a given degradation mechanism, the projected probability of meeting the limiting SIPC must be 0.95 or greater at 50% confidence
  - “Full bundle requirement”
  - Shortcut techniques provided in IAGL such that fully probabilistic analyses are not typically required

# What Benefit is a 95/95 Requirement

- No significant need
- No significant technical benefit compared to present practice
- Increase in complexity of analyses can, in practice, lead to increased uncertainty

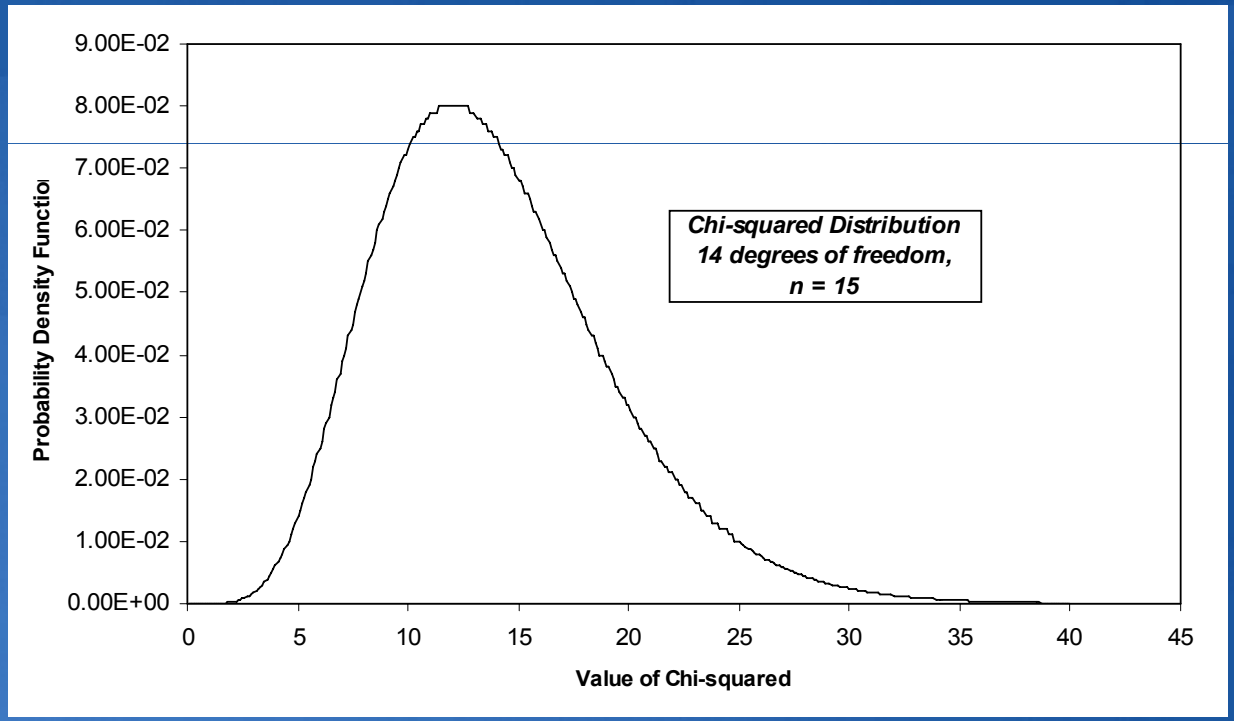
# Statistical Confidence Statements

- For a given sample of input data a mathematical statement made using this data is true X% of the time.
- Confidence interval is a confidence statement about a distribution parameter, such as average value or standard deviation
- For a normal distribution, the average values of samples of size "n" are distributed according to Student's "t" distribution with "n-1" degrees of freedom
- The shape of the "t" distribution depends on "n-1"
- For n > 50 the "t" distribution is about equal to the standard normal distribution

$$\mu = \bar{Y} \pm \frac{S}{\sqrt{n}} \bullet t_{n-1,\alpha/2}$$

# Statistical Confidence Statements cont.

- For a Normal Distribution, the Standard Deviations of Samples of Size "n" are Distributed According to Chi-squared Distribution ($X^2_{n-1}$) with "n-1" Degrees of Freedom



# Statistical Confidence Statements cont.

- Standard Deviation of Normal Parent Population, (σ)

$$\sigma = S \bullet \sqrt{\frac{(n-1)}{\chi^2_{n-1}}}$$

- For Lower Confidence Limit Select $X^2_{n-1}$ at Percentile of Interest
- For Upper Confidence Limit Select $X^2_{n-1}$ at Percentile of Interest
- For n = 15, Upper 95% Confidence Limit $X^2_{n-1}$ is 6.571

$$\sigma = S \bullet \sqrt{\frac{14}{6.571}} = 1.46 \bullet S$$

# Statistical Confidence Statements cont.

A Tolerance Interval is a Confidence Statement about Some Percentile of a Parent Population

Double Sided Tolerance Limit - I am 95% Confident that 95% of the Population is Between

$$\bar{Y} - K \bullet S \quad \text{and} \quad \bar{Y} + K \bullet S$$

Single Sided Tolerance Limit – I am 95% Confident that 95% of the Population is Above

$$\bar{Y} - k \bullet S$$

K and k Depend on Both Confidence and Percentile

# Statistical Confidence Statements cont.

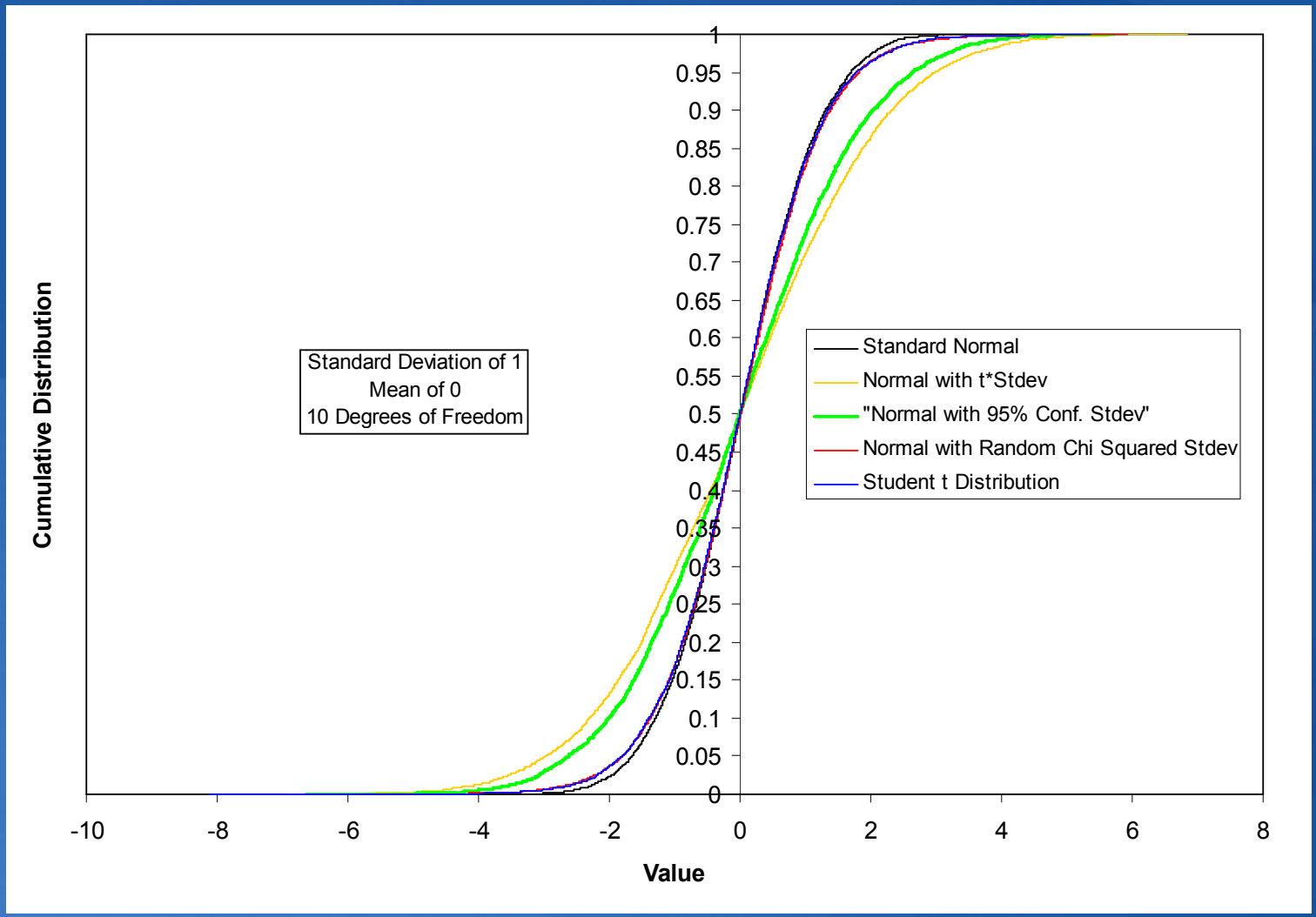
- The steam generator world typically reverses the order of percentile and confidence.
- Here a 95/50 one sided lower tolerance limit is considered to mean that 95% of the population is greater than some number with 50% confidence
- A percentile of a population is also a probability statement

# Statistical Confidence Statements cont.

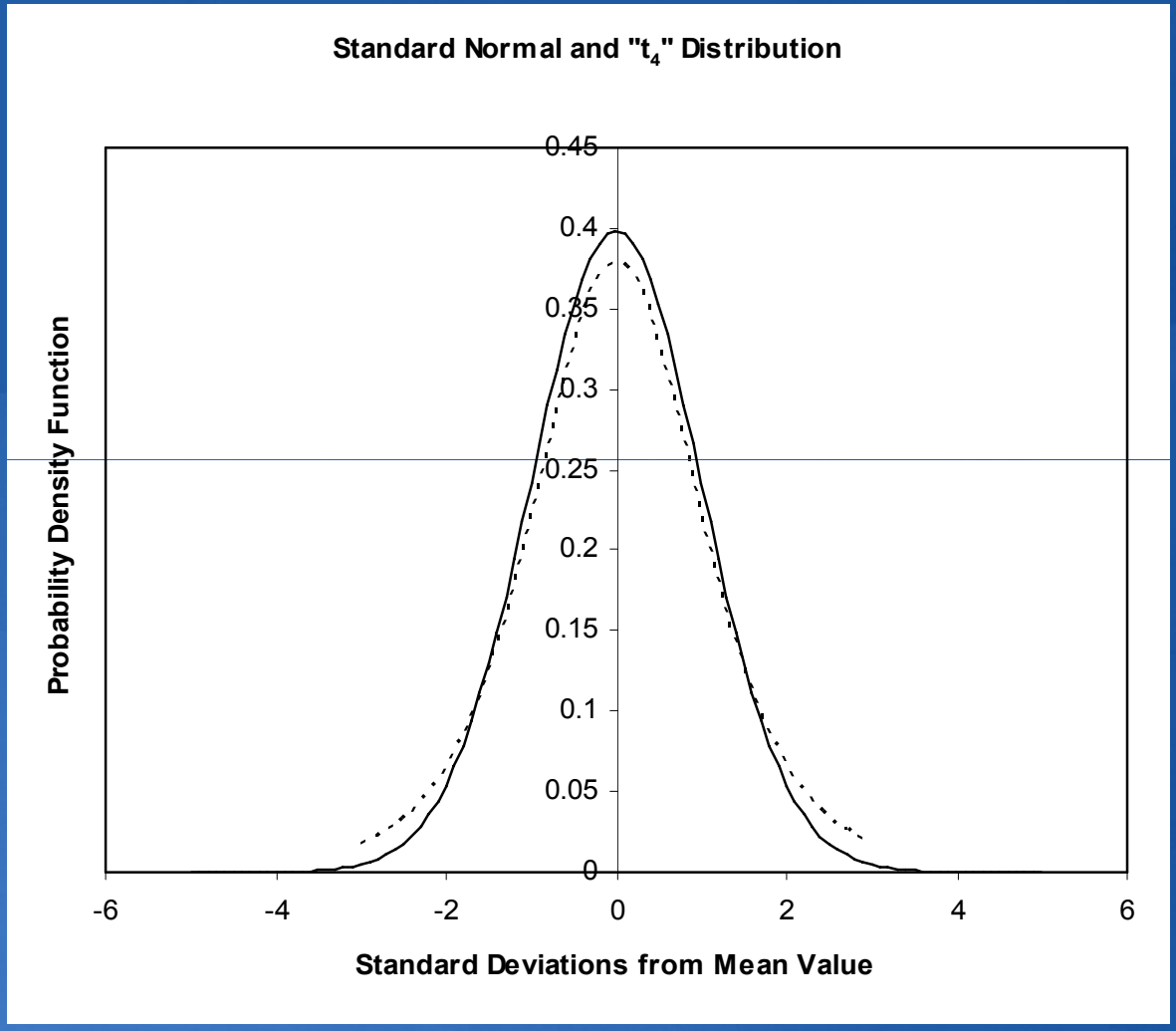
- Looking for the 95$^{th}$ percentile at 95% Confidence
  - Sample size of 59, take the largest one
  - Sample size of 1000, take the 961$^{st}$ largest
  - Sample size of 10000, take the 9547$^{th}$ largest

- What if you have to calculate the numbers in the sample?
  - Use all input adjusted to 95% confidence = NO

# Statistical Confidence Statements cont.

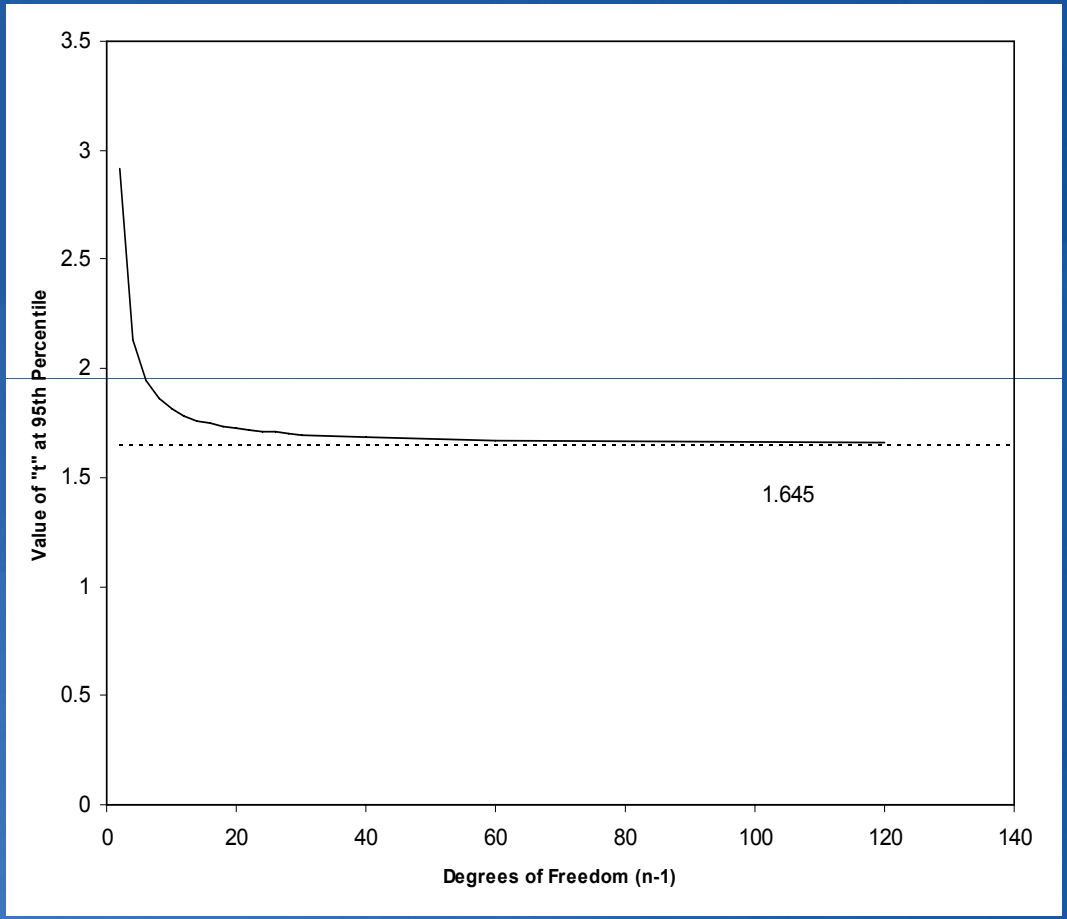


# Statistical Confidence Statements cont.



# Statistical Confidence Statements cont.

- Values of “t” at 95th Percentile as a function of the degrees of freedom



# Summary

- Tube integrity evaluations typically deal with datasets with populations of 100 or more.
- Going to a 95% confidence requirement is no significant benefit.
- Increasing the complexity of evaluations would likely be detrimental rather than an increase in conservatism.

**NRC Summary Comments**

**Public Questions/Comments**

**Action Item Review**

**Adjourn**