UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 7, 1998

MEMORANDUM TO: Thomas H. Essig, Acting Chief
Generic Issues and Environmental Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

FROM: Stewart L. Magruder, Project Manager Stewart L. Magruder
Generic Issues and Environmental Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF THE DECEMBER 3, 1997, MEETING WITH NUCLEAR ENERGY INSTITUTE (NEI) REGARDING STEAM GENERATOR TUBE DATABASE FOR VOLTAGE-BASED ALTERNATE TUBE REPAIR CRITERIA

On December 3, 1997, representatives of the nuclear power industry met with members of the Nuclear Regulatory Commission (NRC) staff in Rockville, Maryland. The purpose of the meeting was to discuss issues related to the steam generator tube database for voltage-based alternate tube repair criteria for outside diameter stress corrosion cracking in Westinghouse plants with drilled hole tube support plates. The main topics of discussion were statistical techniques for simulation and treatment of steam generator tube data obtained from French nuclear plants. Meeting attendees are identified in Attachment 1. The agenda and staff's viewgraphs are included as Attachment 2.

The staff provided the following comments during the meeting:

With respect to statistical techniques for simulation, the staff commented that the currently adopted framework for performing conditional burst and leak calculations is Bayesian, which the staff and the industry both consider to be an appropriate model to address sampling uncertainty.

Any industry proposed modifications to the current statistical analysis framework need to be justified in terms of the goals of the analysis and the adopted analysis framework. In addition, the proposed modifications should be explicit with respect to the theoretical basis for the analysis framework; i.e., the formulation of the probabilistic problem and the model should be provided. This comment would also apply to the proposed alternative to the current probability of leak (POL) model or to the use of a Bootstrap approach. Calculations should be based on a consistent model and on applicable assumptions concerning data distributions and sampling uncertainty, i.e., the same analysis framework should be used for all the calculations. The assumptions made about the tail of the distributions should be conservative because the tail cannot be justified by the data.

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The staff commented that the proposed single sided p-test for the leak rate vs. voltage data correlation is acceptable. The industry representatives indicated that this approach results in a correlation and will be reflected in upcoming 90-day reports for plants with 7/8" tubing.

The staff commented that the industry proposed unbiased estimation for leak rate calculations as documented in section 6.3.2 of the EPRI report NP-7480-L is not acceptable for use in the current analysis framework because the approach has not demonstrated that the simulation will result in a conservative leak rate value at the 95% quantile.

With respect to the industry's proposal to modify the current statistical POL model, the staff believes that the industry needs to apply Goodness-of-Fit tests to the data to determine the applicability of the proposed model; and it needs to perform sensitivity studies to other statistical models to critically examine the proposed model.

With respect to the industry proposed exclusion of French data from the steam generator database, the staff noted that it is advantageous to include the French data in the database because the French data contain high voltage data points and have intergranular stress corrosion cracking (IGSCC) that has been in service for an extended time which is valuable for the future application to domestic plants. The staff commented that: (1) statistical tests cannot be used by themselves as a decision tool for excluding the data, (2) the primary bases for including or excluding the French data should rest on the experimental protocol, (3) the industry has not provided sufficient physical evidence to conclusively exclude the French data from the database, (4) the industry needs to perform a quality assurance review of the French data, (5) the quality assurance review will need to be performed expeditiously in order to satisfy the schedule requirement in the protocol for updating the database, and (6) any rules or criteria for including or excluding the French data should be applied consistently across the database.

With respect to the protocol for updating the steam generator database, NEI submitted the final version of the industry proposal in a letter dated October 28, 1997. The staff finds the proposal acceptable and will forward a letter to NEI to bring this issue to a closure.

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Project No. 689

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2. Agenda and Viewgraphs

cc w/att: See next page

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DISTRIBUTION: See attach page

OFFICE	PM:PGEB	EMCB	SC:PGEB
NAME	SMagruder:sw SLM	JTsao JCT	FAkstulewicz
DATE	1/5/98	1/6/98	1/7/98

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SDembek
ESullivan
JDavis
SCoffin
LAbramson, RES
JMuscara, RES

NRC-INDUSTRY MEETING REGARDING
STEAM GENERATOR DATABASE FOR
VOLTAGE-BASED ALTERNATE TUBE REPAIR CRITERIA
DECEMBER 3, 1997

LIST OF ATTENDEES

NAME	ORGANIZATION
1. John Tsao	NRC/NRR
2. Rick Mullins	Southern Company
3. Steve Dembek	NRC/NRR
4. Stu Magruder	NRC/NRR
5. Brian Woodman	APTECH Engineering
6. Ron Gamble	Sartrex
7. Ted Sullivan	NRC/NRR
8. Jim Davis	NRC/NRR
9. Lee Abramson	NRC/RES
10. Joe Muscara	NRC/RES
11. Christopher Begley	APTECH Engineering
12. Robert Keating	Westinghouse
13. Patrick Heasler	Pacific Northwest National Lab.
14. Stephanie Coffin	NRC/NRR

Attachment 1

AGENDA
FOR NRC-INDUSTRY MEETING
REGARDING
STEAM GENERATOR DATABASE FOR
VOLTAGE-BASED ALTERNATE TUBE REPAIR CRITERIA

DECEMBER 3, 1997
8:00 AM - 2:30 PM
ONE WHITE FLINT NORTH
ROOM O-10B13

1. STATISTICAL TECHNIQUES FOR SIMULATION — 8:00 am

   A. TREATMENT OF UNCERTAINTIES IN PARAMETERS--STAFF
   B. DISTRIBUTION FOR LEAK RATES--STAFF
   C. UNBIASED ESTIMATION --STAFF
   D. PROBABILITY OF LEAK DATA--WESTINGHOUSE
   E. BOOTSTRAP APPROACH--WESTINGHOUSE

2. TREATMENT OF FRENCH DATA IN 7/8 TUBE DATABASE — 10:00 am

   A. STATISTICAL ANALYSIS OF BURST DATA--STAFF
   B. IMPLICATION ON LEAK RATE DATA--STAFF
   C. PHYSICAL EVIDENCE--WESTINGHOUSE

3. CAUCUS — 11:30 am

4. TREATMENT OF FACTIONAL INDICATIONS--WESTINGHOUSE — 1:30 pm

5. CAUCUS/SUMMARY — 2:30 pm

ATTACHMENT 2

SLB Leak Rate and Tube Burst Probability Models for ODSCC

Patrick G. Heasler
PNNL

Dec. 1997

Problem Formulation

- Objective is to estimate the 95% quantile on *Total Leak Rate* for an inspected Steam Generator.
- Total leak rate is leak rate the steam generator would experience during a pressure transient.
- The Total Leak Rate Distribution depends upon the inspection results.

Problem Formulation

Simplified Leak Rate Model:

$$T = \sum_{k=1}^{N} R_k Q_k \tag{1}$$

- $R_k Q_k$ is leak rate of tube k.
- Q_k is the conditional leak rate, with lognormal distribution $F_Q(q|\beta_3, \beta_4)$.
- R_k is binary variable with $Pr(R_k = 1) = logit(\beta_1 + \beta_2 V_k)$.
- Want to Calculate U_{95}, where $Pr(T < U_{95}) = .95$.

Problem Formulation

If unknown parameters β (alternatively $F_Q(\,)$ and $Pr(R_k = 1)$) are known, then problem has been solved:

- The distribution $F_T(\,)$ of T can be calculated numerically or by a Monte Carlo using the previous formulas.
- Result is $F_T(t|V, \beta) = Pr(T < t|V, \beta)$
- $F_T(\,)$ can be used to find U_{95}.

Parametric Uncertainty

Problem: We don't know β, but have data than can be used to estimate β. These estimates will contain substantial uncertainties. How can we modify the problem to account for this uncertainty?

Two solutions are available:

- Bayesian solution: Treat β as a random variable and describe uncertainty as a probability distribution.
- Frequentist solution: Put confidence bounds on U_{95}, which creates a tolerance bound or create a 95% prediction interval for T.

Parametric Uncertainty

Bayesian Solution:

- Use leak rate data X to calculate $f(\beta|X)$, the posterior distribution of β given the data.
- Note: for this problem $f(\beta|X)$ can be expressed as $f(\beta|\hat{\beta})$.
- Solution is 95% quantile of $F_T(t|V, X)$, which is:

$$F_T(t|V, X) = \int F_T(t|V, \beta) f(\beta|X) d\beta \qquad (2)$$

- $\hat{U}_{95}$ satisifies:

$$F_T(\hat{U}_{95}|V, X) = .95 \qquad (3)$$

Parametric Uncertainty

Bayesian Posterior:

$$f(\beta|X) = \frac{f(X|\beta)f(\beta)}{f(X)} \tag{4}$$

Important Point: posterior $f(\beta|X)$ is completely determined by data distribution $f(X|\beta)$ and prior $f(\beta)$. If standard non-informative priors are chosen, then $f(\beta|X)$ is completely determined by $f(X|\beta)$.

Parametric Uncertainty

Advantages of Bayesian Solution:

- Requires the least modification to present M.C. code to implement.
- Provides a coherent framework for dealing with all parametric uncertainty.
- Gives results that are asymptotically similar to frequentist results.
- Is a well-documented methodology.

Unbiased Estimation

Given the problem formulation, we are interested in the properties of an estimator of U_{95}, call it $\hat{U}_{95} = h(X)$. The properties of other estimators (that are not even used to construct $\hat{U}_{95}$) are not relevant.

- Bayesian Property: $F_T(\hat{U}_{95}|V, X) = .95$.
- Tolerance Bound Property:
  $Pr(U_{95} < \hat{U}_{95}) = .95$
- Prediction Bound Property:
  $Pr(T < \hat{U}_{95}) = .95$
- An estimate of the mean of Q_k is not even used to construct the present $\hat{U}_{95}$.
- Even if the mean of Q_k were used to construct $\hat{U}_{95}$, its acceptability should be determined by one of the three properties above.

Unbiased Estimation

If we were interested in estimating μ_Q, the mean of Q_k, EPRI's observations are correct with the following qualifications.

- There seems to be an error in "unbiased" estimation formula. If natural logs are used the formula is,

$$\hat{\mu}_Q = \exp(M_{lnQ})g(\frac{1}{2}S_{lnQ}^2) \quad (7)$$

so the formula for base-10 logs is,

$$\hat{\mu}_Q = \exp(ln(10)M_{logQ})g(\frac{1}{2}ln(10)^2S_{logQ}^2) \quad (8)$$

- Using the formula

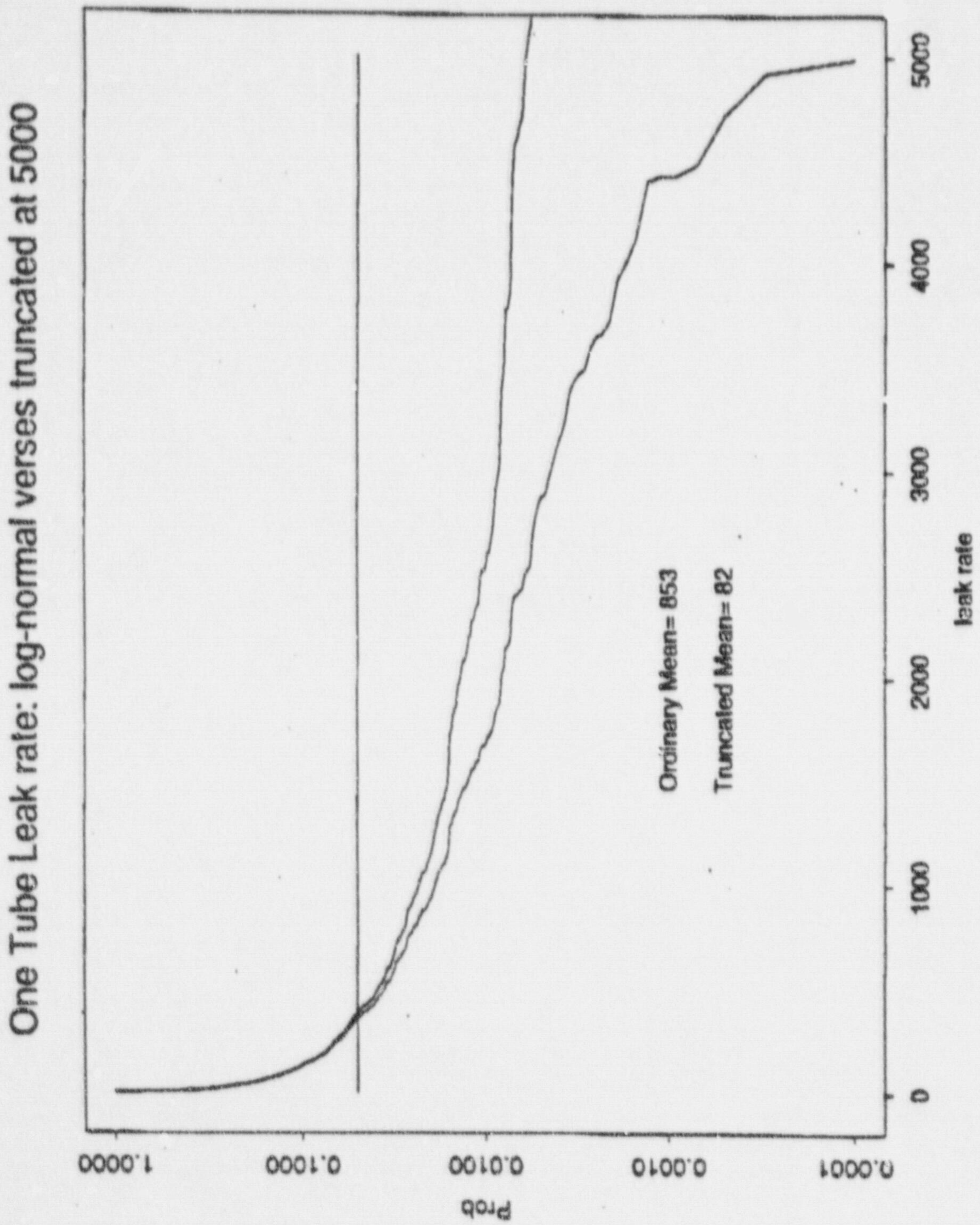
$$\hat{\mu}_Q = \exp(M_{lnQ} + \frac{1}{2}S_{lnQ}^2) \quad (9)$$

is asymptotically correct.

Comments about log-normal distribution

- Fits existing data well (Fig. 6-8).
- Has a very heavy right-hand tail.
- Clearly is not bounded, as leak rate should be.
- Important information about right hand tail may exist.

Comments about log-normal



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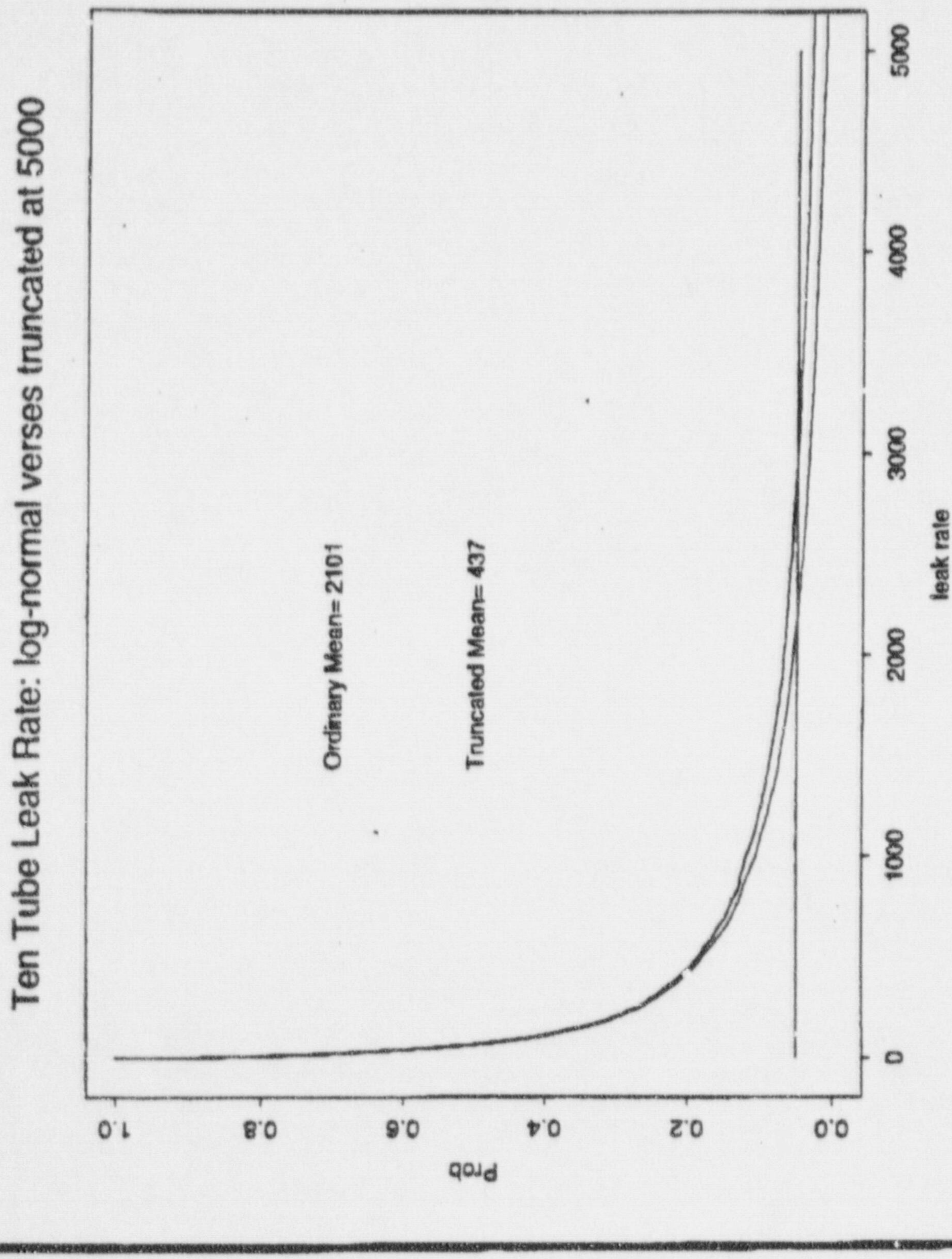

Statistical Analysis of French Data

- The GOF tests are performed correctly.
- The tests have NOT been interpreted correctly.
- From the results presented, I would favor retaining the French data, and it would be to industry's advantage to do this.

comparison	1	2	3	4	5	6	7
null Hyp	model 4	model 4	model 6	model 4	model 11	model 14	model 16
Alt Hyp	model 1	model 5	model 7	model 8	model 12	model 15	model 17
N-H SSE	66.94	66.94	52.12	66.94	52.118	20.83	54.36
N-H DOF	91	91	72	91	72	47	61
A-H SSE	62.47	65.96	52.11	60.203	49.849	19.971	50.586
A-H DOF	89	89	70	87	70	45	59
F Stats	3.183	0.662	0.00806	2.434	1.594	0.967	2.2
F stats DOF	2, 89	2, 89	2, 70	4, 87	2, 70	2, 45	2, 59
P value, %	4.6	51.83	99.2	5.32	21.1	38.8	12
comments	reject NH accept AH	accept NH	accept NH	need more tests	accept NH	accept NH	accept NH

model 1 US and MB data are from a different population than that of Edf data

model 4 All (US, MB & Edf) data are from the same population.

model 5 All (US, MB, & Edf) data that are less than 3 volts and data that are greater than 3 volts are from different populations.

model 6 US+MB data less than 3 volts and greater than 3 volts are from the same population.

model 7 US+MB data less than 3 volts and greater than 3 volts are from different populations.

model 8 US data, MB data, and Edf data are from three separate populations.

model 11 US data and MB data are from the same population.

model 12 US data and MB data are from different populations.

model 14 MB data and EDF data are from the same population.

model 15 MB data and Edf data are from different populations.

model 16 Edf data and US data are from the same population.

model 17 Edf data and US data are from different populations.

Interpretation of Tests

- A significant F-test implies (1) the model does not fit, or (2) something is "wrong" with the data.
- Original reason for conducting such tests was to evaluate (1), because validity of model is very important.
- These tests can be used to prove (1), but not (2).
- (2) can only be concluded if compelling external proof can be found that the data is "in error."

Interpretation of Tests

If Tests are significant:

1 MODEL DOES NOT FIT RELEVANT DATA: ITS VALIDITY IS IN DOUBT!!!!

2. Model can only be saved if we can PROVE that some of the data is not relevant.

3. Must show that the "type" of ODSCC that occurs in French generators can't occur in US generators.

cc:

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ATTACHMENT 2

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Patrick G. Heasler
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Dec. 1997

Problem Formulation

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Problem: We don't know β, but have data than can be used to estimate β. These estimates will contain substantial uncertainties. How can we modify the problem to account for this uncertainty?

Two solutions are available:

- Bayesian solution: Treat β as a random variable and describe uncertainty as a probability distribution.
- Frequentist solution: Put confidence bounds on U_{95}, which creates a tolerance bound or create a 95% prediction interval for T.

Parametric Uncertainty

Bayesian Solution:

- Use leak rate data X to calculate $f(\beta|X)$, the posterior distribution of β given the data.
- Note: for this problem $f(\beta|X)$ can be expressed as $f(\beta|\hat{\beta})$.
- Solution is 95% quantile of $F_T(t|V, X)$, which is:

$$F_T(t|V, X) = \int F_T(t|V, \beta) f(\beta|X) d\beta \qquad (2)$$

- $\hat{U}_{95}$ satisifies:

$$F_T(\hat{U}_{95}|V, X) = .95 \qquad (3)$$

Parametric Uncertainty

Bayesian Posterior:

$$f(\beta|X) = \frac{f(X|\beta)f(\beta)}{f(X)} \tag{4}$$

Important Point: posterior $f(\beta|X)$ is completely determined by data distribution $f(X|\beta)$ and prior $f(\beta)$. If standard non-informative priors are chosen, then $f(\beta|X)$ is completely determined by $f(X|\beta)$.

Parametric Uncertainty

Advantages of Bayesian Solution:

- Requires the least modification to present M.C. code to implement.
- Provides a coherent framework for dealing with all parametric uncertainty.
- Gives results that are asymptotically similar to frequentist results.
- Is a well-documented methodology.

Unbiased Estimation

Given the problem formulation, we are interested in the properties of an estimator of U_{95}, call it $\hat{U}_{95} = h(X)$. The properties of other estimators (that are not even used to construct $\hat{U}_{95}$) are not relevant.

- Bayesian Property: $F_T(\hat{U}_{95}|V, X) = .95$.
- Tolerance Bound Property: $Pr(U_{95} < \hat{U}_{95}) = .95$
- Prediction Bound Property: $Pr(T < \hat{U}_{95}) = .95$
- An estimate of the mean of Q_k is not even used to construct the present $\hat{U}_{95}$.
- Even if the mean of Q_k were used to construct $\hat{U}_{95}$, its acceptability should be determined by one of the three properties above.

Unbiased Estimation

If we were interested in estimating μ_Q, the mean of Q_k, EPRI's observations are correct with the following qualifications.

- There seems to be an error in "unbiased" estimation formula. If natural logs are used the formula is,

$$\hat{\mu}_Q = \exp(M_{lnQ})g(\frac{1}{2}S^2_{lnQ}) \quad (7)$$

so the formula for base-10 logs is,

$$\hat{\mu}_Q = \exp(ln(10)M_{logQ})g(\frac{1}{2}ln(10)^2 S^2_{logQ}) \quad (8)$$

- Using the formula

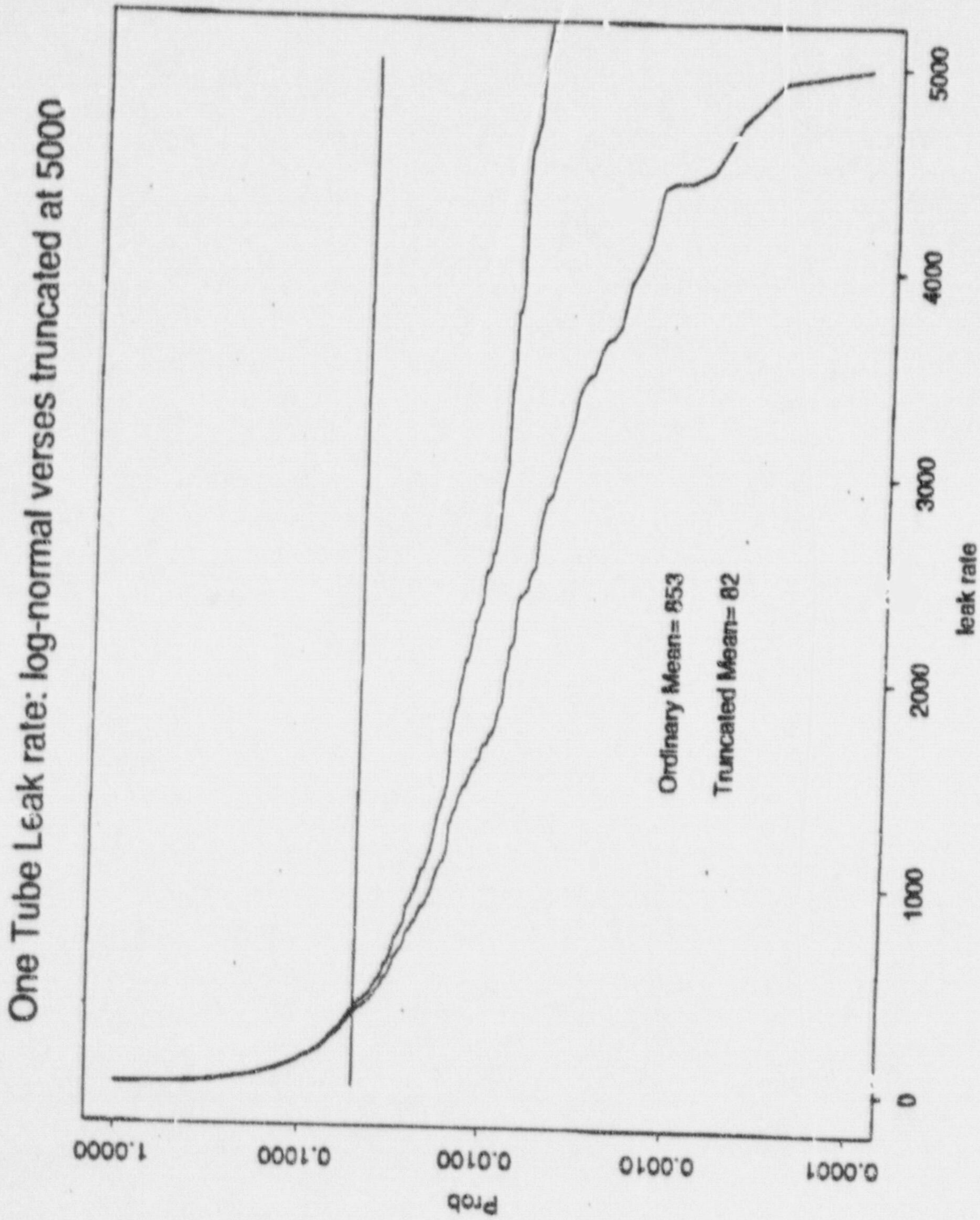
$$\hat{\mu}_Q = \exp(M_{lnQ} + \frac{1}{2}S^2_{lnQ}) \quad (9)$$

is asymptotically correct.

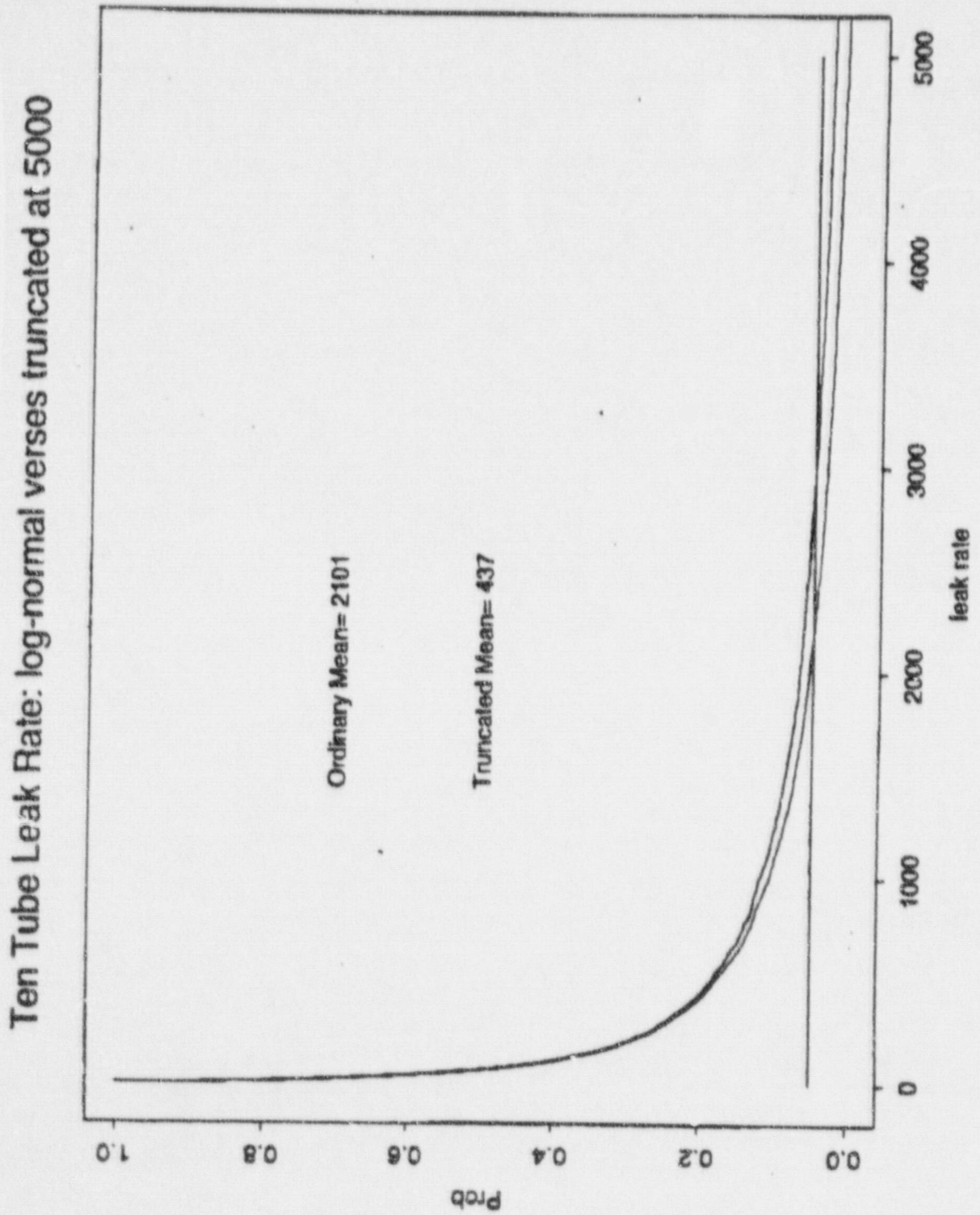
Comments about log-normal distribution

- Fits existing data well (Fig. 6-8).
- Has a very heavy right-hand tail.
- Clearly is not bounded, as leak rate should be.
- Important information about right hand tail may exist.

Comments about log-normal



Comments about log-normal



Statistical Analysis of French Data

- The GOF tests are performed correctly.
- The tests have NOT been interpreted correctly.
- From the results presented, I would favor retaining the French data, and it would be to industry's advantage to do this.

comparison	1	2	3	4	5	6	7
null Hyp	model 4	model 4	model 6	model 4	model 11	model 14	model 16
Alt Hyp	model 1	model 5	model 7	model 8	model 12	model 15	model 17
N-H SSE	66.94	66.94	52.12	66.94	52.118	20.83	54.36
N-H DOF	91	91	72	91	72	47	61
A-H SSE	62.47	65.96	52.11	60.203	49.849	19.971	50.586
A-H DOF	89	89	70	87	70	45	59
F Stats	3.183	0.662	0.00806	2.434	1.594	0.967	2.2
F stats DOF	2. 89	2. 89	2. 70	4. 87	2. 70	2. 45	2. 59
P value, %	4.6	51.83	99.2	5.32	21.1	38.8	12
comments	reject NH accept AH	accept NH	accept NH	need more tests	accept NH	accept NH	accept NH

model 1 US and MB data are from a different population than that of Edf data

model 4 All (US, MB & Edf) data are from the same population

model 5 All (US, MB, & Edf) data that are less than 3 volts and data that are greater than 3 volts are from different populations.

model 6 US+MB data less than 3 volts and greater than 3 volts are from the same population.

model 7 US+MB data less than 3 volts and greater than 3 volts are from different populations.

model 8 US data, MB data, and Edf data are from three separate populations.

model 11 US data and MB data are from the same population.

model 12 US data and MB data are from different populations.

model 14 MB data and EDF data are from the same population.

model 15 MB data and Edf data are from different populations.

model 16 Edf data and US data are from the same population.

model 17 Edf data and US data are from different populations.

Interpretation of Tests

- A significant F-test implies (1) the model does not fit, or (2) something is "wrong" with the data.
- Original reason for conducting such tests was to evaluate (1), because validity of model is very important.
- These tests can be used to prove (1), but not (2).
- (2) can only be concluded if compelling external proof can be found that the data is "in error."

Interpretation of Tests

If Tests are significant:

1. MODEL DOES NOT FIT RELEVANT DATA: ITS VALIDITY IS IN DOUBT!!!!
2. Model can only be saved if we can PROVE that some of the data is not relevant.
3. Must show that the "type" of ODSCC that occurs in French generators can't occur in US generators.

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