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PROBABILITY ANALYSIS OF SURFACE RUPTURE OFFSET BENEATH GENERAL ELECTRIC TEST REACTOR REACTOR BUILDING

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ACRS Subcommittee Meeting

General Electric Test Reactor

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PURPOSE OF PROBABILISTIC ANALYSIS

1. To determine the probability of occurrence of a future surface rupture offset of any size greater than zero beneath the Reactor Building foundation

2. Then to determine whether the probability of occurrence is sufficiently low so that surface rupture offset should not be considered as a design basis event

PROBABILITY ACCEPTANCE CRITERION

". . . . a conservative calculation showing that the probability of occurrence of potential exposures in excess of the 10CFR Part 100 guidelines is approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower."

USNRC Standard Review Plan
Section 2.2.3

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RESULTS AND CONCLUSION OF ANALYSIS

RESULTS

- Calculated probability of occurrence of a future surface rupture offset of any size greater than zero beneath the Reactor Building foundation complies with the criterion
- Probabilistic analysis is conservative

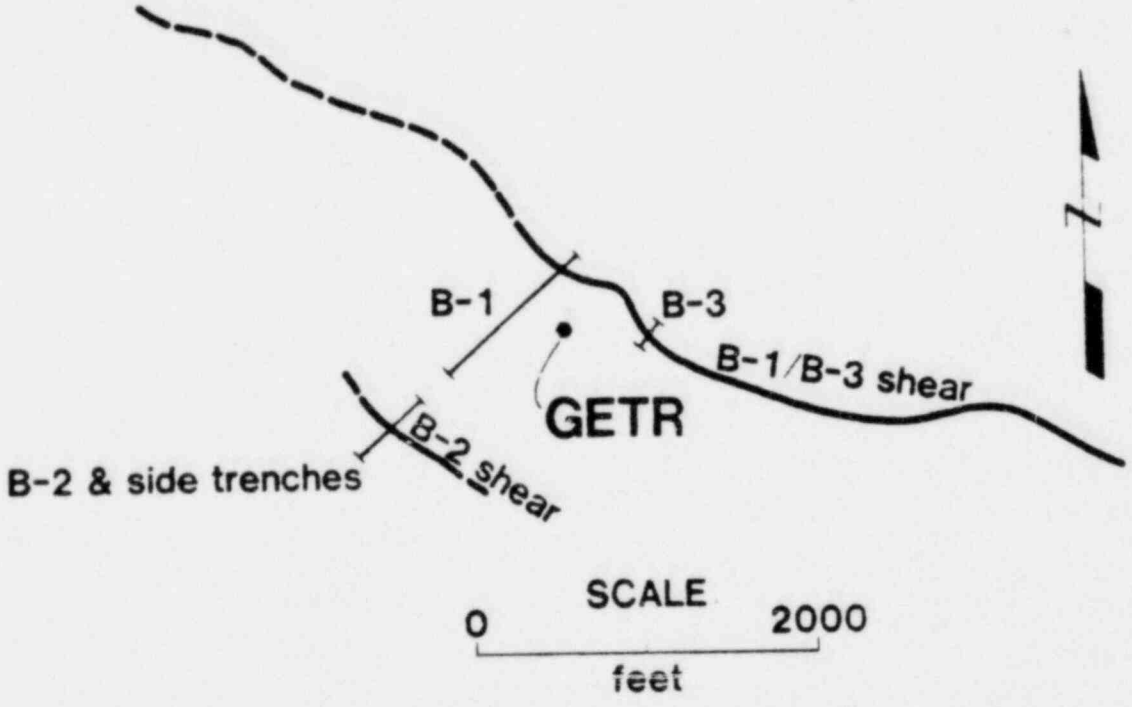
CONCLUSION

- Surface rupture offset should not be considered as a design basis event

OUTLINE OF PRESENTATION OF PROBABILISTIC ANALYSIS

- Simplified approach
- Confidence level probability analysis
- Detailed model analysis

LOCATION OF SHEARS IN RELATION TO GETR



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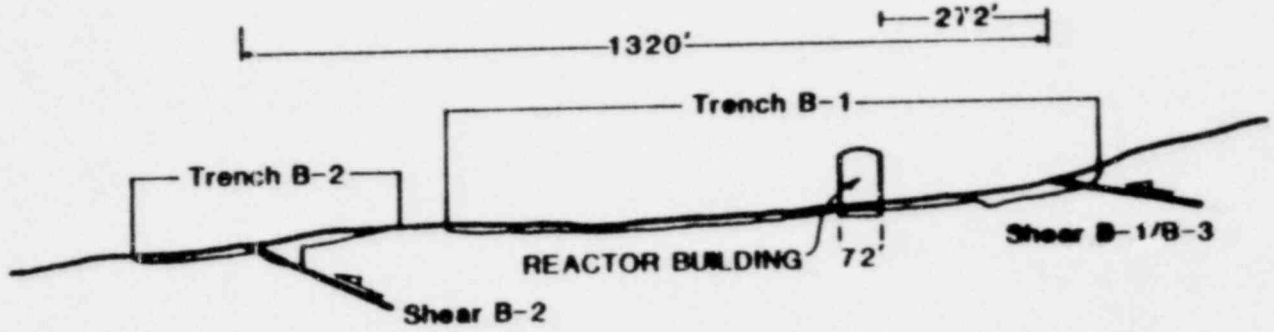
CROSS-SECTION OF GETR SITE



SCALE: Horizontal = Vertical

0 200 400 600 800 1000

feet

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OBSERVED OFFSET DATA

Time Period (Before Present in Years)	Maximum Offset During Time Period (ft)	
	Shear B-2	Shear B-1/B-3
0 – 8,000 to 15,000	0	0
8,000 to 15,000 – 17,000 to 20,000	3	2
17,000 to 20,000 – 70,000 to 125,000	5	10
70,000 to 125,000 – 128,000 to 195,000 or greater	80+	40+

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BASIC PROBABILITY PARAMETERS

Annual probability of occurrence of an offset beneath Reactor Building foundation, P:

$$P = P_1 \times P_2$$

Where:

P_1 = annual probability that an offset will occur between shears B-2 and B-1/B-3

P_2 = probability that an offset will occur beneath the Reactor Building foundation, given that an offset occurs between the shears

SIMPLIFIED APPROACH

t = 128,000 years	t = 195,000 years
$P_1 \cong 1/128{,}000$	$P_1 \cong 1/195{,}000$
$P_2 \cong 72/1320$	$P_2 \cong 72/1320$

$$P = P_1 \times P_2$$

$P = 1/128{,}000 \times 72/1320$	$P = 1/195{,}000 \times 72/1320$
$\boxed{P = 4.3 \times 10^{-7}}$	$\boxed{P = 2.8 \times 10^{-7}}$

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CONFIDENCE LEVEL PROBABILITY ANALYSIS

$$P_1 = -\ell n\,(1-C)/t$$

Where:

- C = Confidence level probability
- t = Number of years without an offset between the shears

$$P_2 = (\ell+b)/(L-b)$$

Where:

- ℓ = Width of Reactor Building
- L = Distance between two existing shears
- b = Width of offset at ground surface

$$P = P_1 \times P_2$$

PROBABILITY OF OFFSET OCCURRING BENEATH REACTOR BUILDING FOUNDATION

Confidence Level Probability	No. of yrs. without an event	
	t = 128,000 yrs	t = 195,000 yrs
0.95	1.4×10^{-6}	8.9×10^{-7}
0.90	1.0×10^{-6}	6.8×10^{-7}
0.50	3.1×10^{-7}	2.1×10^{-7}

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DETAILED MODEL ANALYSIS

$$P_1 = \phi \lambda e^{-\lambda}$$

Where:

λ = Mean time rate of occurrence of offsets

ϕ = Probability that an offset will occur between the two shears given that an offset occurs

$$P_2 = (\ell + b)/(L - b)$$

Where the parameters are the same as the confidence level probability analysis

$$P = P_1 \times P_2$$

METHOD FOR OBTAINING PROBABILITY DENSITY FUNCTION FOR λ AND ϕ

$$p(\lambda,\phi) = \psi\, L(\lambda,\phi|\text{data}) \cdot p'(\lambda,\phi)$$

Where:

ψ = normalizing constant

$p'(\lambda,\phi)$ = prior probability density function

$$L(\lambda,\phi|\text{data}) = \prod_{i=1}^{4} \frac{(\lambda t_i)^{n_i} e^{-\lambda t_i}}{n_i!} (1-\phi)^{n_i}$$

t_i = time period (years)

n_i = number of events in time period t_i

$$p(\lambda,\phi) = \frac{t^{n+1} \lambda^n e^{-\lambda t}}{n!} (n+1)(1-\phi)^n \quad \text{for } 0 \leq \phi \leq 1,\ \lambda \geq 0$$

Where:

$$t = \sum_{i=1}^{4} t_i$$

$$n = \sum_{i=1}^{4} n_i$$

ESTIMATED VALUES FOR PROBABILITY P_1

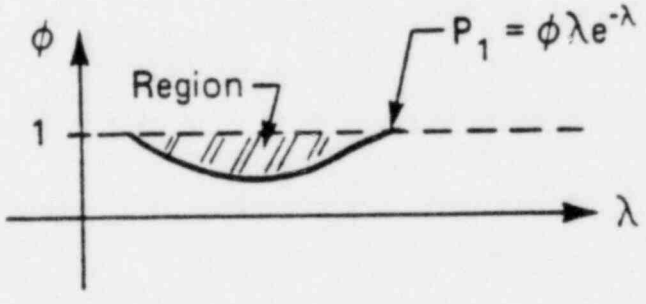
Weighted estimate

$$\breve{P}_1 = \int_0^1 \int_0^\infty \phi \lambda e^{-\lambda} p(\lambda,\phi)\, d\lambda\, d\phi$$

$$\breve{P}_1 = \left(\frac{t}{t+1}\right)^{n+2} \cdot \frac{n+1}{n+2} \cdot \frac{1}{t}$$

$$\boxed{\breve{P}_1 < \frac{1}{t}}$$

Confidence limits



PROBABILITIES OF OFFSET BENEATH REACTOR BUILDING FOUNDATION

Analysis Basis	Detailed Model*		Confidence Level Prob. Analysis	
	t = 128,000 yrs.	t = 195,000 yrs.	t = 128,000 yrs.	t = 195,000 yrs.
Weighted estimate	4.5×10^{-7}	3.0×10^{-7}	NA	NA
0.95 Confidence level	1.3×10^{-6}	8.4×10^{-7}	1.4×10^{-6}	8.9×10^{-7}
0.90 Confidence level	1.0×10^{-6}	6.7×10^{-7}	1.0×10^{-6}	6.8×10^{-7}
0.50 Confidence level	2.9×10^{-7}	1.9×10^{-7}	3.1×10^{-7}	2.1×10^{-7}

*Based on n = 15

CONFIDENCE LEVELS FOR OFFSET BENEATH REACTOR BUILDING FOUNDATION FOR 10^{-6} CRITERION PROBABILITY VALUE

Detailed Model*		Confidence Level Prob. Analysis	
t = 128,000 yrs	t = 195,000 yrs	t = 128,000 yrs	t = 195,000 yrs
0.91	0.97	0.89	0.96

*Based on n = 15

EVALUATION OF CONSERVATISM

- Probability of potential consequences are at least one order of magnitude lower
- Offsets can occur outside of area between the two shears
- Conclusion is based on t = 128,000 years. An average value between 128,000 years and 195,000 years is more appropriate. Furthermore, the age of unfaulted soil material is probably older than 195,000 years
- Prior distribution for λ and ϕ was conservatively assumed in Detailed Model
- Two-dimensional geometric model is conservative

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SUMMARY AND CONCLUSION

- Weighted estimate probability value is less than 10^{-6}
- 0.90 Confidence level value is essentially equal to 10^{-6}
- Probabilistic analysis is conservative
- Analysis and results comply with criterion

Hence

- Surface rupture offset of any size should not be considered as a design basis event