ASSUMPTIONS FOR THERMAL ANALYSIS OF PREAMPLIFIER UNIT

- CONTAINMENT TEMPERATURE VS. TIME USED AS A FORCING FUNCTION
- NUREG 0588 (EARLY VERSION) ITEMS
  USE LARGEST POSSIBLE Q

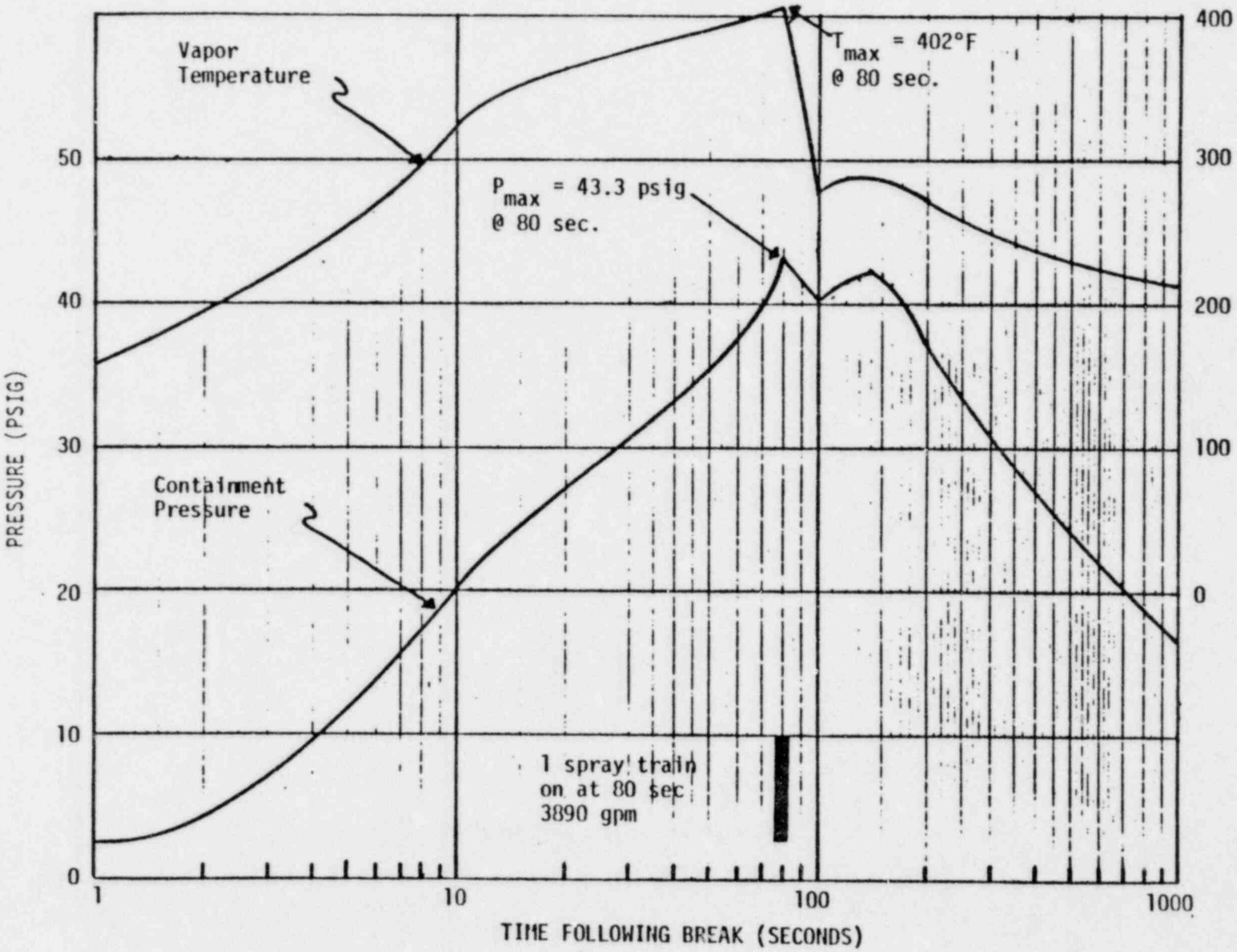
  $Q_{CONVECTION}$ = (AS PER NUREG 0588)

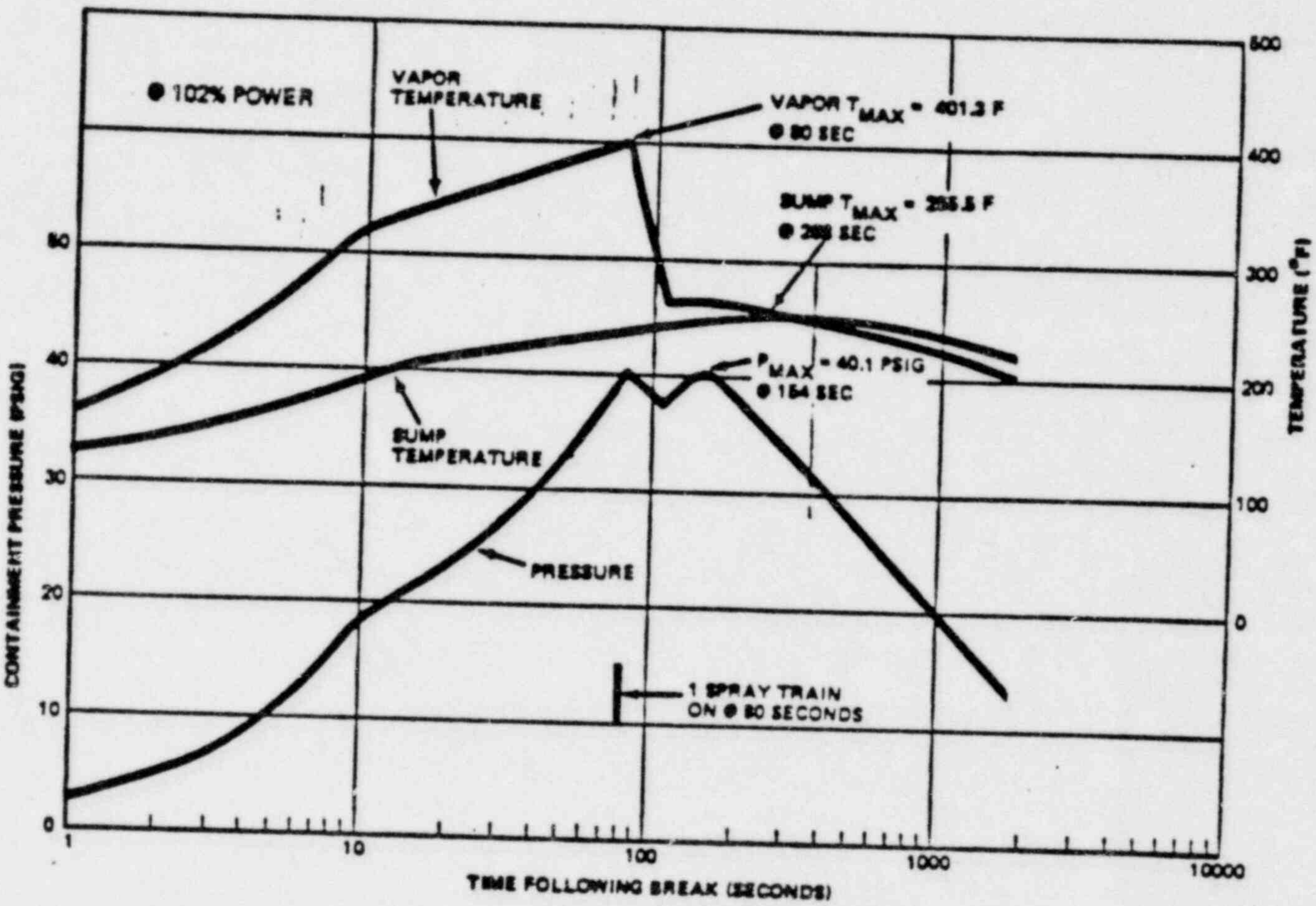
  $Q_{CONDUCTION}$ = 4*UCHIDA

  $Q_{CONDUCTION}$ = 4*TAGAMI
- HEAT CONDUCTION IN WALL VIA A SUBROUTINE IN CONTRANS CODE

CE calculated containment response
pressure and temperature vs. time
CESSARF generic mass/energy release
Arizona containment data

Generated by CE SGN/CONTRANS Codes



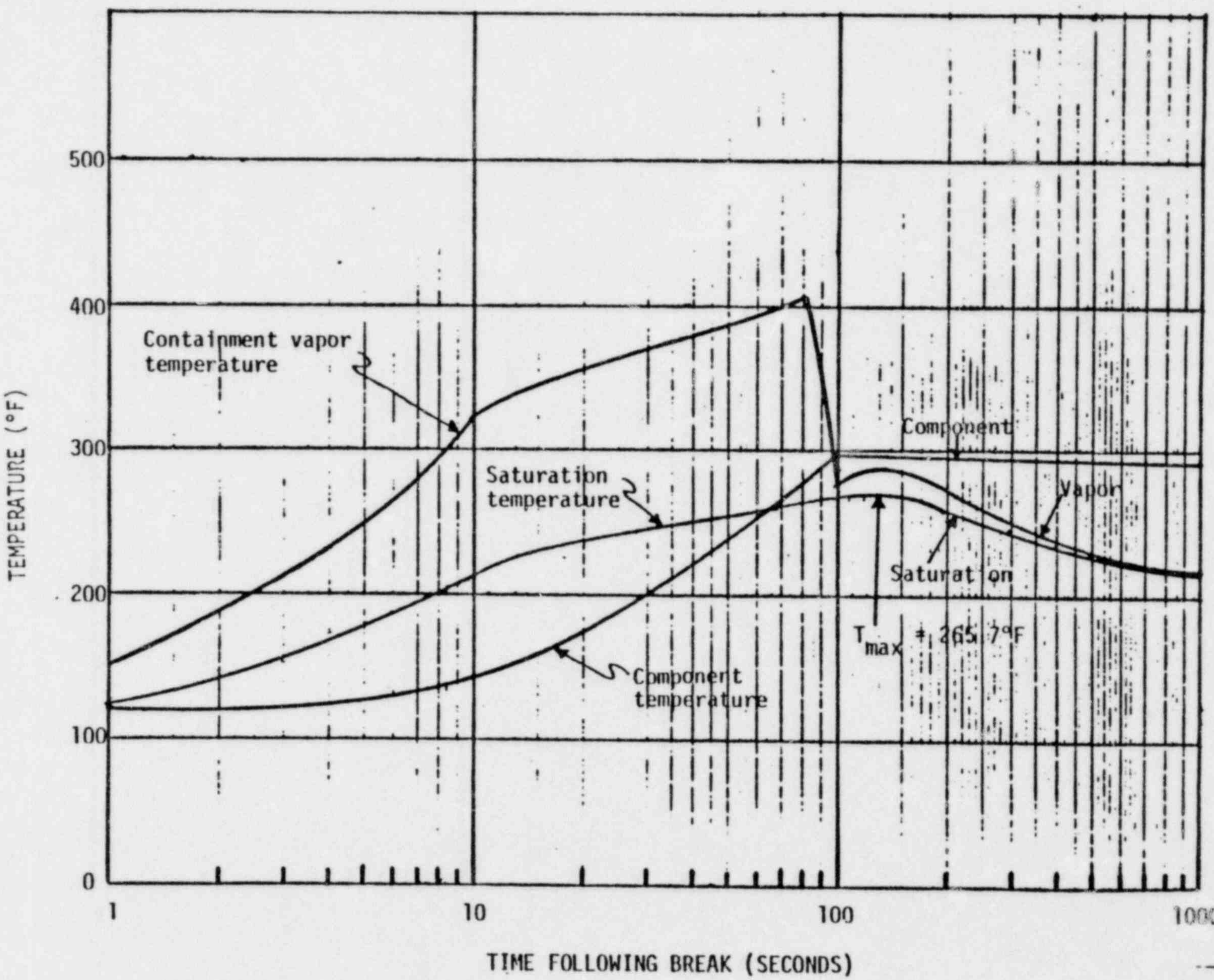


Bechtel

Palo Verde Nuclear Generating Station
FSAR

CONTAINMENT PRESSURE AND TEMPERATURE RESPONSE MSLB (SLOT) WITH LOSS OF ONE CONTAINMENT COOLING TRAIN

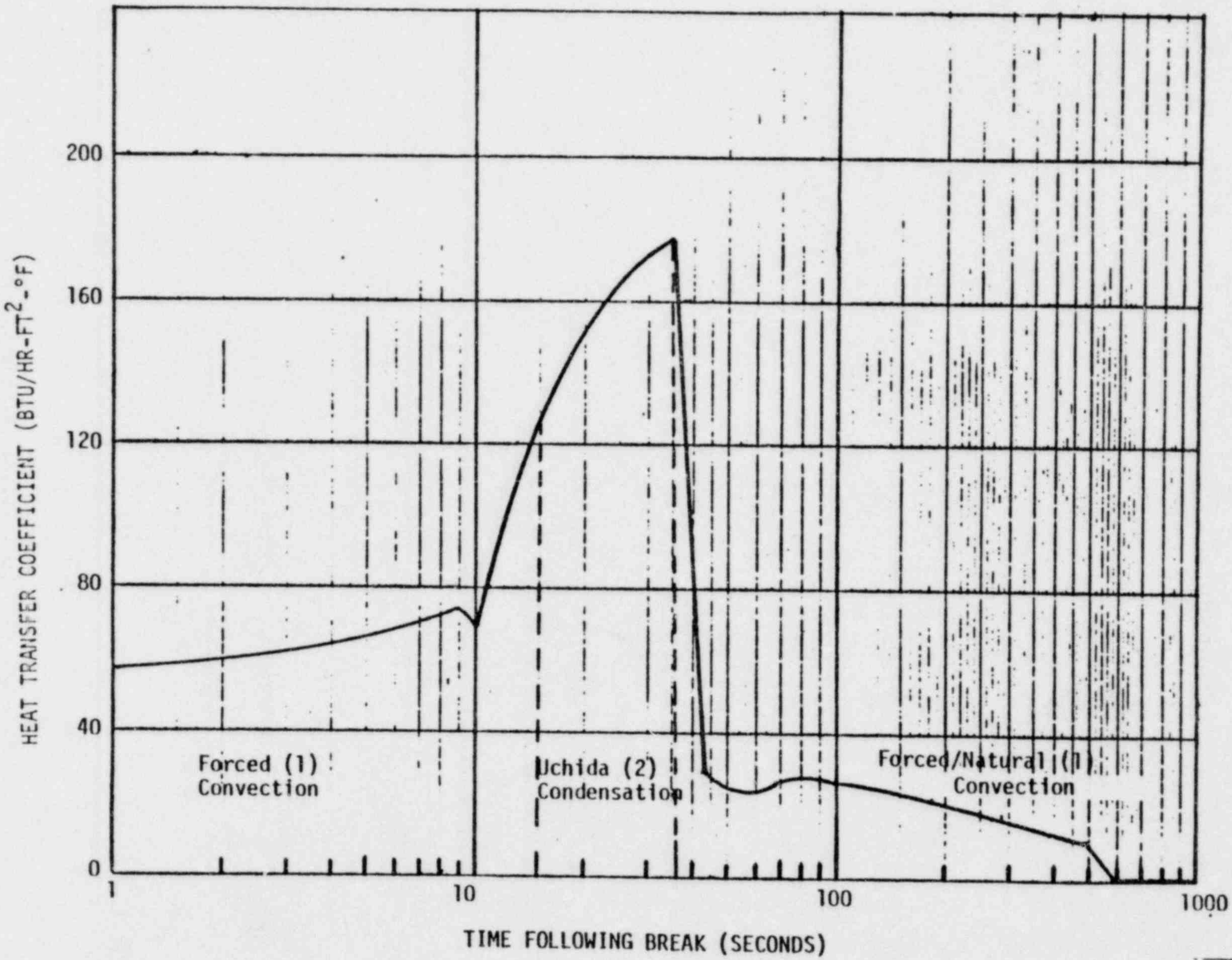
102% power
MSLB 8.78 ft^2 (worst case)
temperature vs time



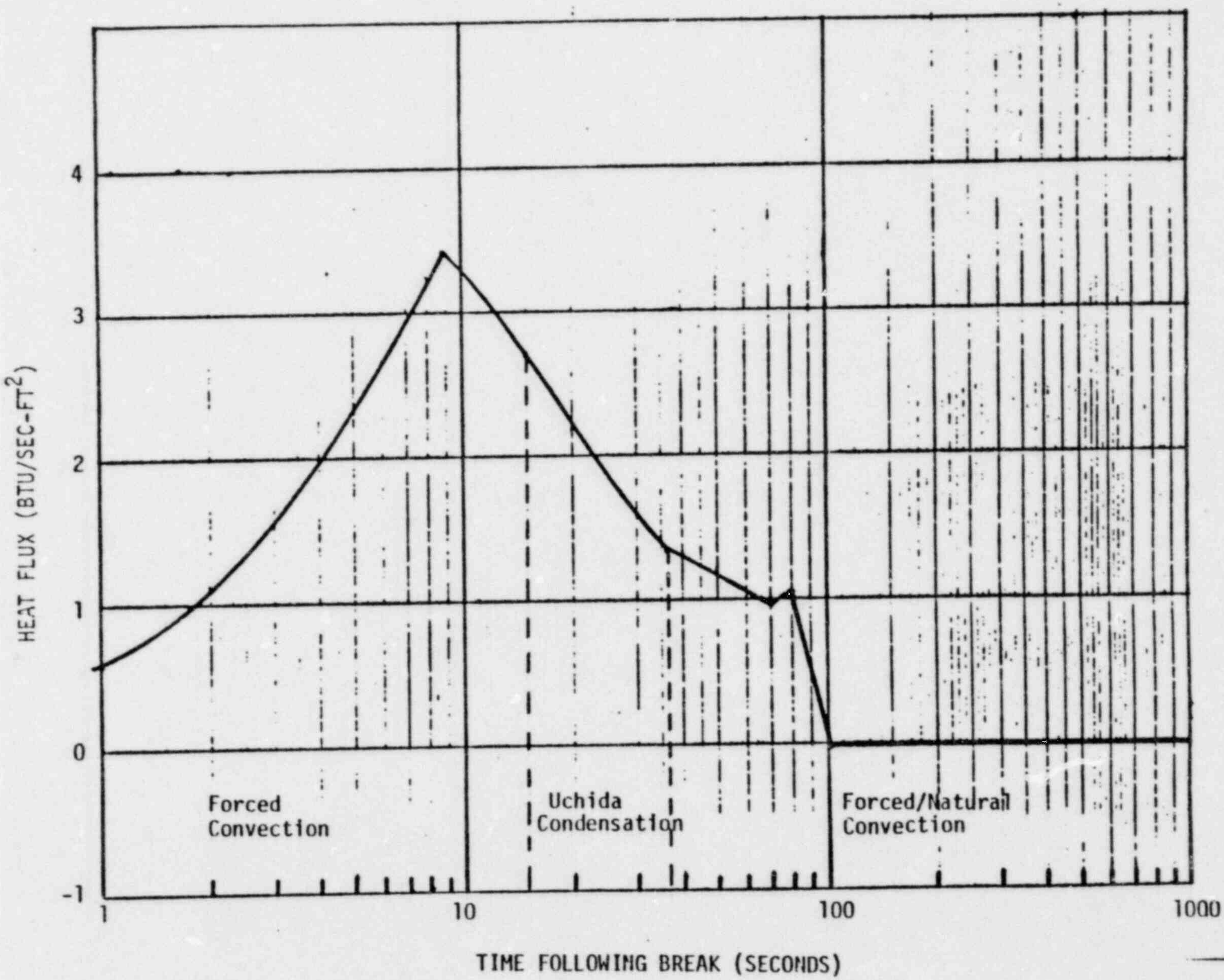
Heat transfer coefficient vs time
component thermal analysis

(1) per NUREG 0588

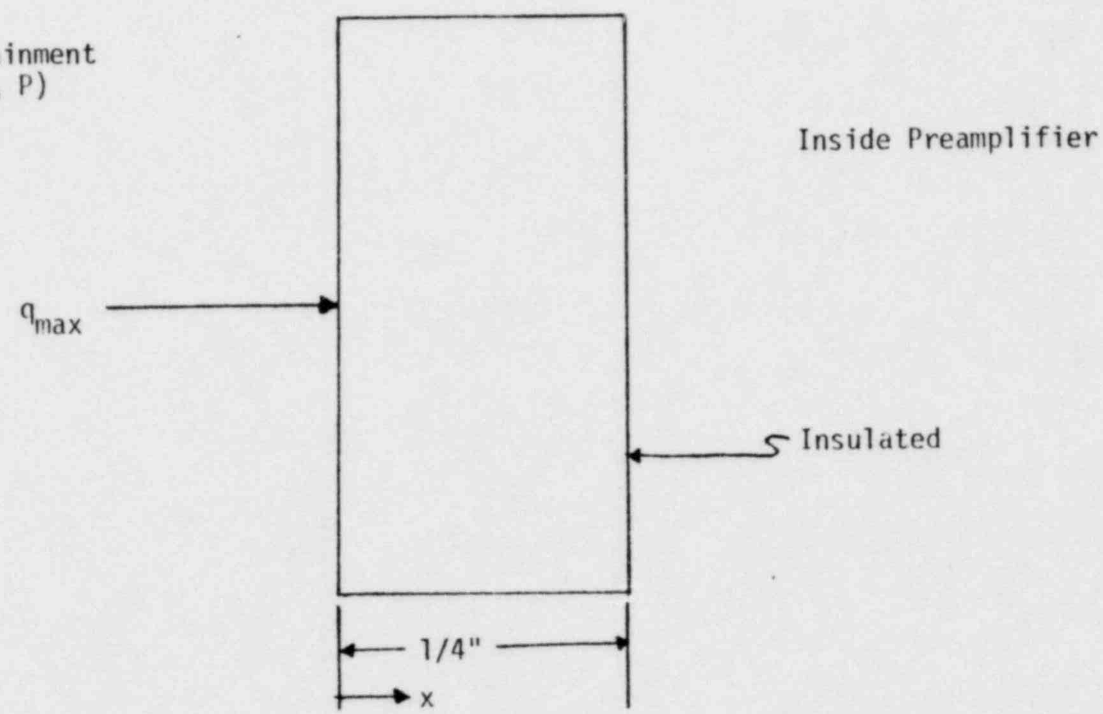
(2) with factor of 4



Component heat flux vs. time
NUREG 0588
(convection, Uchida condensation, Tagami condensation)



PREAMPLIFIER MODEL INFORMATION



T(x, t) is via the Heat Conduction Equation

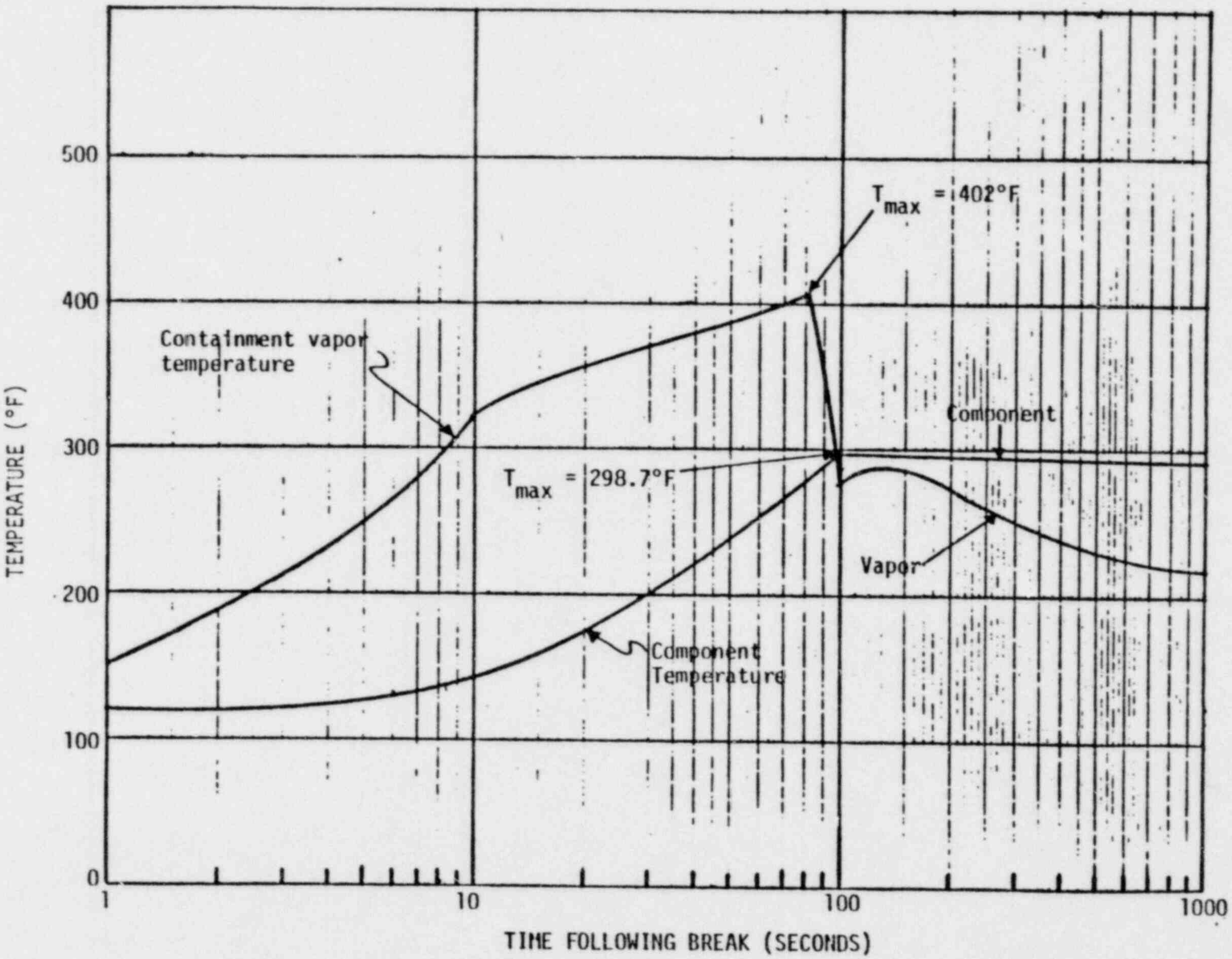
<u>Aluminum Proterties</u>

k = 121 Btu/hr-ft-°F

ρ = 169 lbm/ft^3

C_p = 0.208 Btu/lbm-°F

Containment vapor temperature,
component surface temperature
vs time



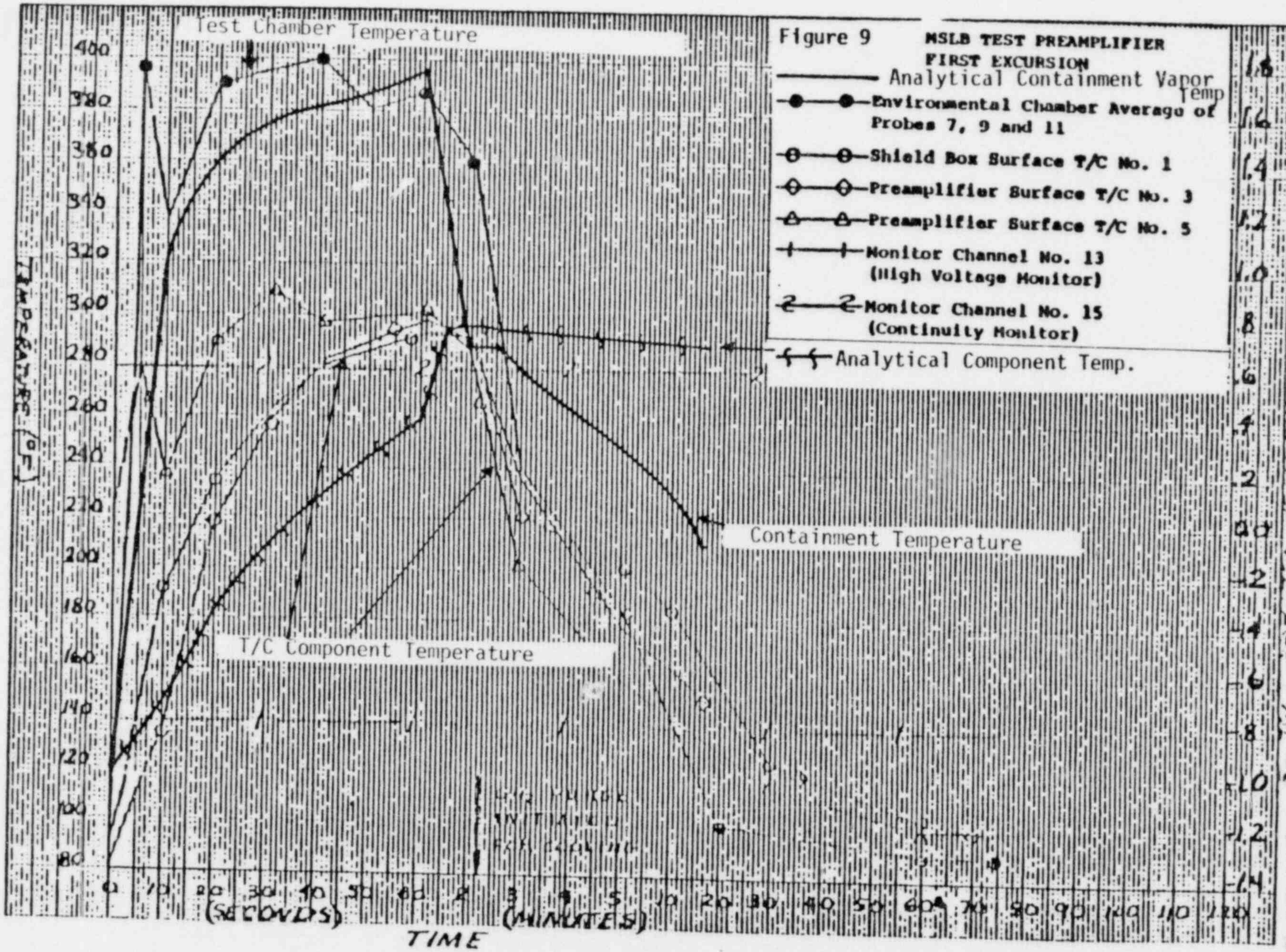


Figure 9
MSLB TEST PREAMPLIFIER
FIRST EXCURSION
Analytical Containment Vapor Temp
Environmental Chamber Average of Probes 7, 9 and 11
Shield Box Surface T/C No. 1
Preamplifier Surface T/C No. 3
Preamplifier Surface T/C No. 5
Monitor Channel No. 13 (High Voltage Monitor)
Monitor Channel No. 15 (Continuity Monitor)
Analytical Component Temp.
Test Chamber Temperature
Containment Temperature
T/C Component Temperature
TEMPERATURE (°F)
PREAMPLIFIER MONITOR VOLTAGE
(SECONDS)
(MINUTES)
TIME

SUMMARY OF THERMAL EQUIVALENCE

1) CONTAINMENT TEMPERATURE VS. TIME IS CONSERVATIVE: PEAK OF $\approx 400^{o}$F.

2) COMPONENT RESPONSE IN CONTAINMENT IS CONSERVATIVE: PEAK OF $\approx 298^{o}$F.

3) MEASURED TEST RESULTS: PEAK OF $\approx 300^{o}$F VIA THERMOCOUPLE MEASUREMENTS

4) CONCLUSION: THERMAL EQUIVALENCE HAS BEEN DEMONSTRATED IN THAT THE COMPONENT HAS PHYSICALLY BEEN HEATED AND TESTED TO THE CONSERVATIVELY CALCULATED CONTAINMENT RELATED TEMPERATURE

ADDITIONAL NOTES

1) THE WORST CASE HAS BEEN ANALYZED REGARDING THE COMPONENTS THERMAL RESPONSE (LARGEST BREAK AREA)

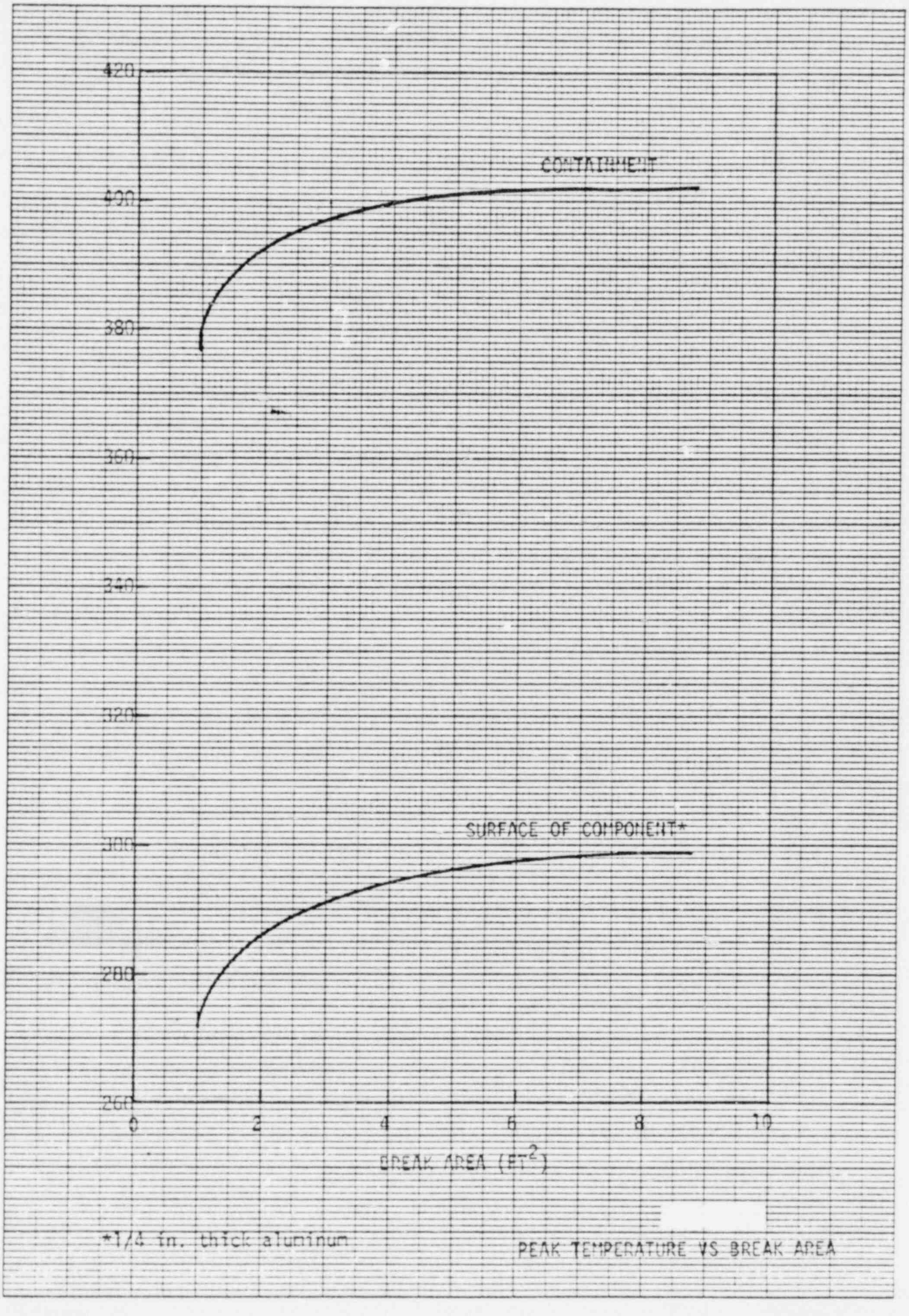
2) FOR THIS CASE A REACTOR TRIP OCCURRED AT ~3 SECONDS AT 6 PSIG

3) NOTE AT THE TIME OF 6 PSIG:

   - CONTAINMENT TEMPERATURE IS APPROXIMATELY 220°F

   - THERMAL LAG OF COMPONENT AT APPROXIMATELY 120°F

4) PREAMPLIFIER IS ENVIRONMENTALLY QUALIFIED AT APPROXIMATELY 300°F; 400°F IS ADDITIONAL CONSERVATISM



420
400
380
360
340
320
300
280
260
0
2
4
6
8
10
CONTAINMENT
SURFACE OF COMPONENT*
BREAK AREA (FT^2)
*1/4 in. thick aluminum
PEAK TEMPERATURE VS BREAK AREA

APPENDIX B

ANALYSIS OF UNCERTAINTIES
IN HARSH ENVIRONMENT
TEST RESULTS WITH RESPECT TO
TIME MARGINS

OBJECTIVE

SHOW THAT A HARSH ENVIRONMENT TEST PERIOD IS SUFFICIENT TO DEMONSTRATE THE CAPABILITY OF A COMPONENT TO REMAIN OPERATIONAL CONSIDERING SAMPLE SELECTION, PRODUCTION, AND PHYSICAL PROPERTY UNCERTAINTIES.

TEST CASE

A SAMPLE ANALYSIS TO JUSTIFY THE ADEQUACY OF THIS TEST PERIOD (AS SPECIFIED IN CENPD 255, REV. 3) WAS PERFORMED UTILIZING THE FOLLOWING UNCERTAINTY METHODOLOGY FOR AN ELECTRIC FILTER COMPONENT.

UNCERTAINTY METHODOLOGY

C-E HAS PERFORMED A STOCHASTIC SIMULATION OF THE TEST COMPONENT FAILURE MODELS IN ANTICIPATED OPERATION AND TESTING MODES. MARGIN TO FAILURE WAS QUANTITATIVELY EVALUATED IN EACH CASE.

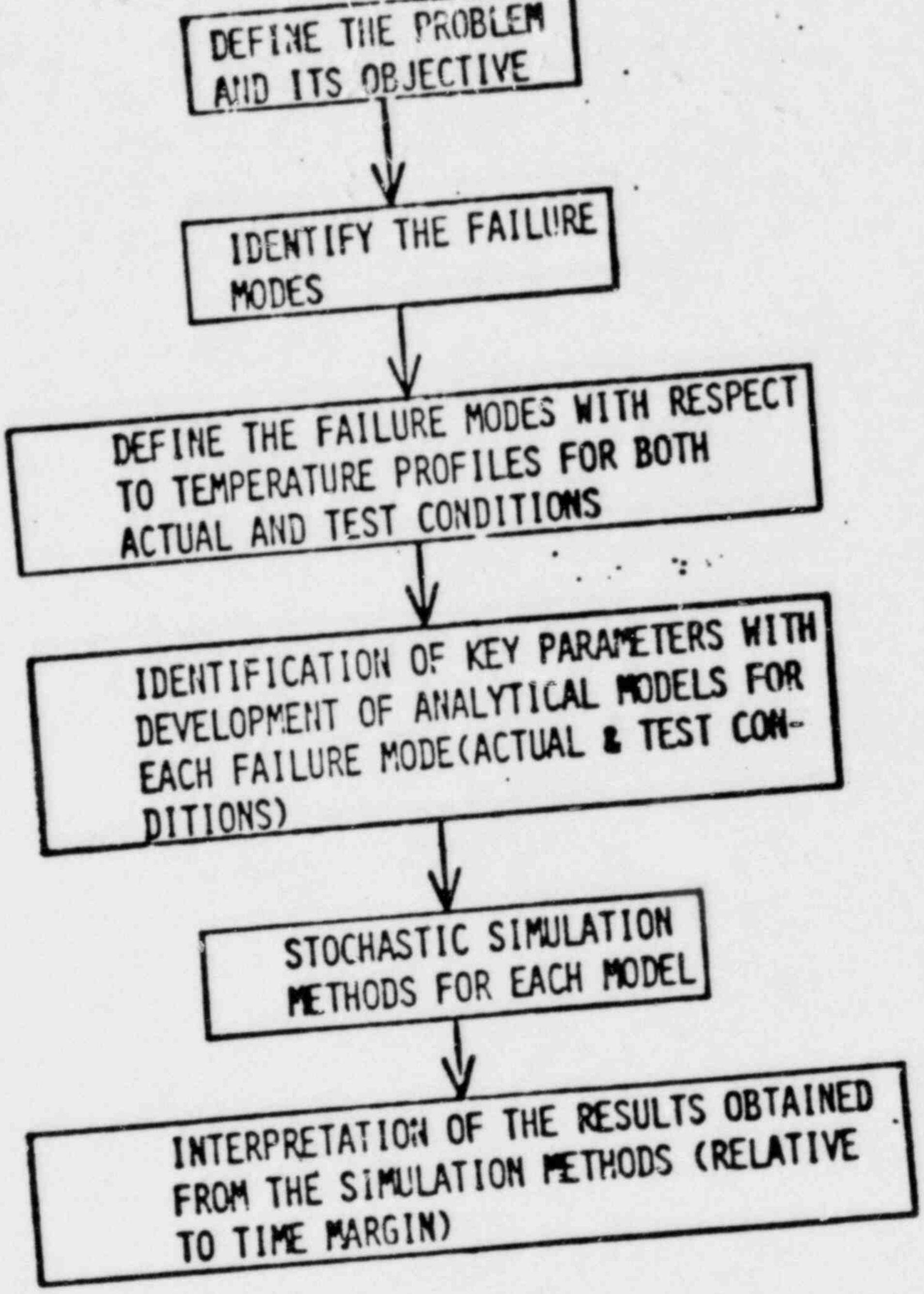
RESULTS

TEST PERIODS ON THE ORDER OF 10 MINUTES ARE MORE THAN ADEQUATE TO DEMONSTRATE THE SELECTED COMPONENT WILL FUNCTION AS REQUIRED.

FAILURE MODE MODEL DEVELOPMENT CRITERIA

1. CONSERVATIVE

2. CALCULABLE


DEFINE THE PROBLEM AND ITS OBJECTIVE
IDENTIFY THE FAILURE MODES
DEFINE THE FAILURE MODES WITH RESPECT TO TEMPERATURE PROFILES FOR BOTH ACTUAL AND TEST CONDITIONS
IDENTIFICATION OF KEY PARAMETERS WITH DEVELOPMENT OF ANALYTICAL MODELS FOR EACH FAILURE MODE(ACTUAL & TEST CONDITIONS)
STOCHASTIC SIMULATION METHODS FOR EACH MODEL
INTERPRETATION OF THE RESULTS OBTAINED FROM THE SIMULATION METHODS (RELATIVE TO TIME MARGIN)

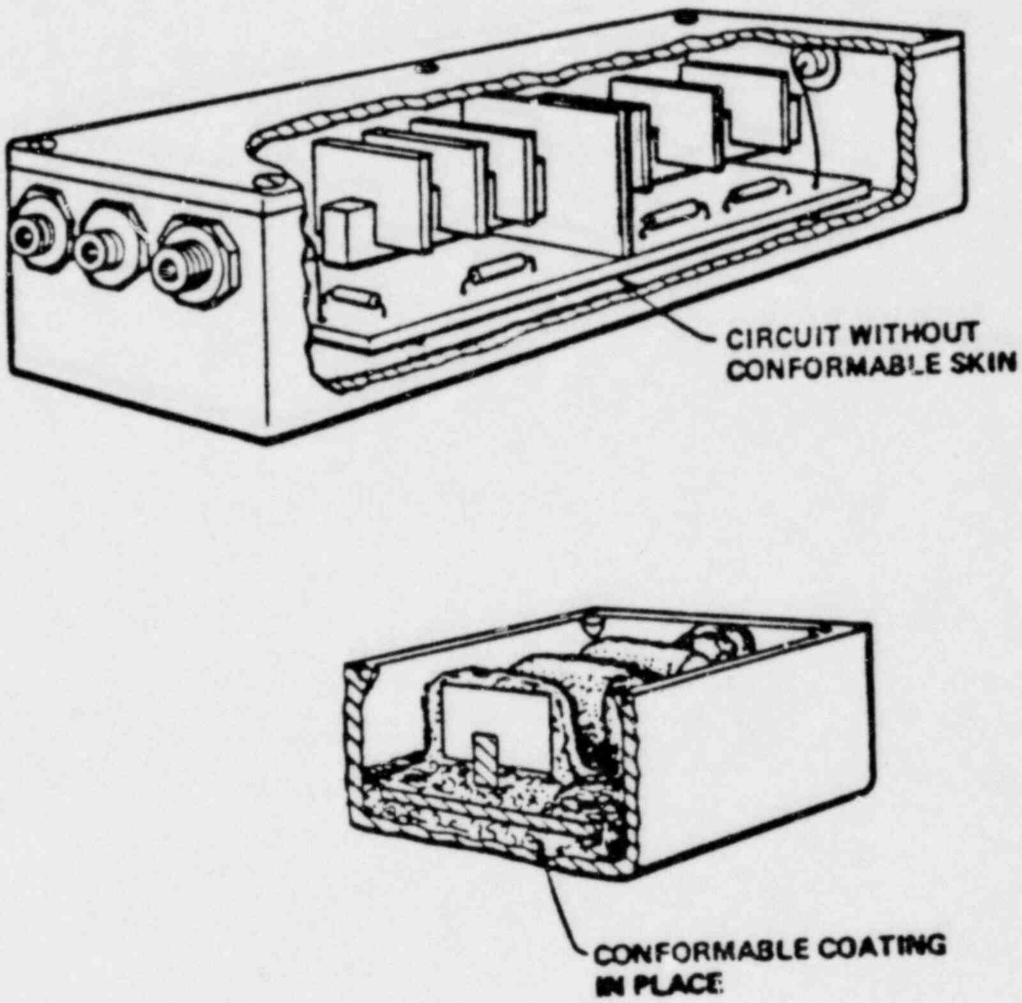


FIGURE 11

INTERIOR VIEWS OF THE CIRCUIT BOARD HOUSING

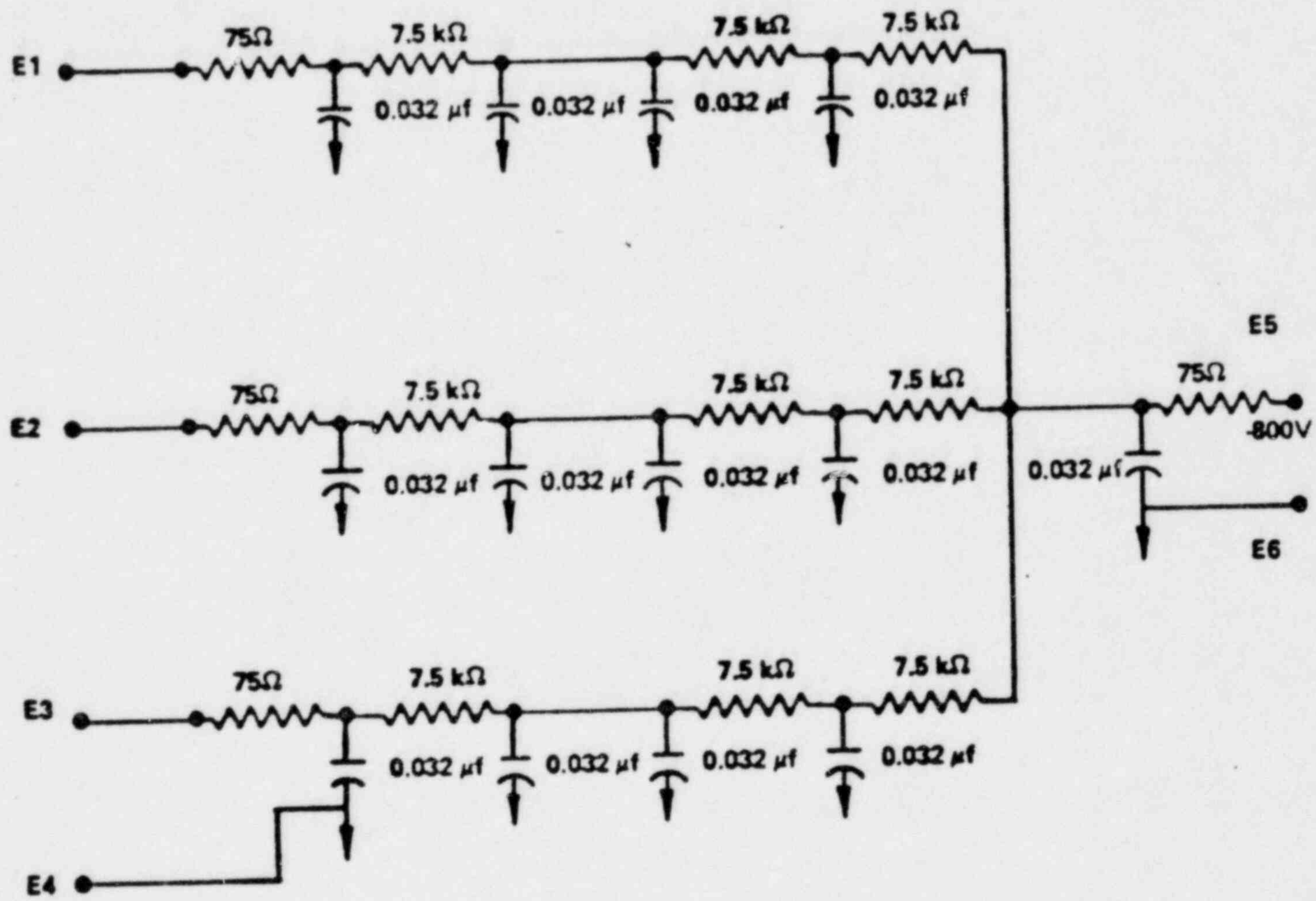


FIGURE 10
CIRCUIT SCHEMATIC FOR THE LOW PASS FILTER

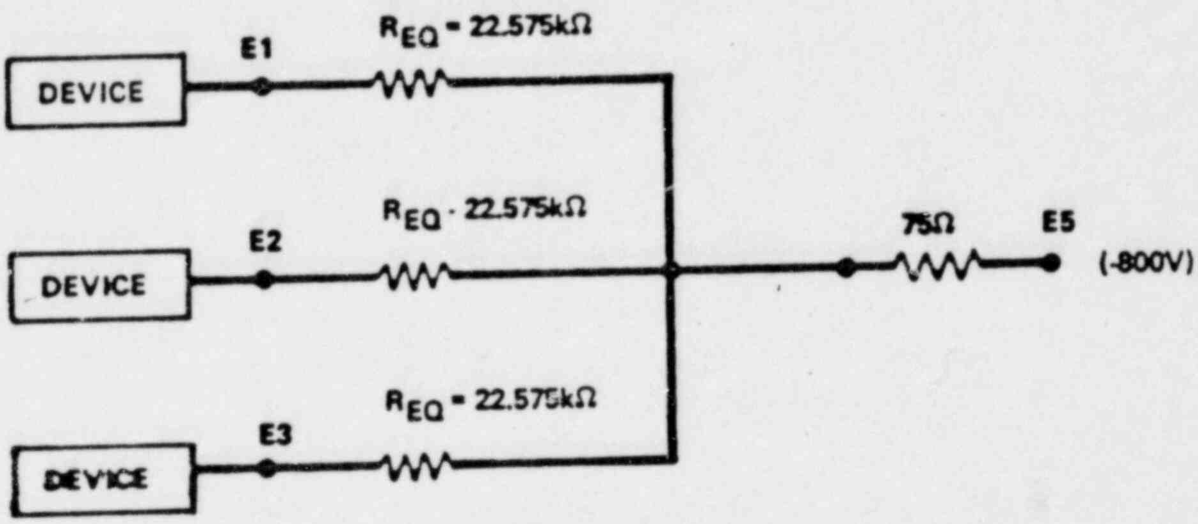


FIGURE 12

SIMPLIFIED HIGH VOLTAGE FILTER SCHEMATIC

TEMPERATURE EFFECTS ON ELECTRICAL PROPERTIES

MODEL INFORMATION

FAILURE CRITERION	CIRCUIT OUTPUT VOLTAGE DROPS BENEATH 500
CONSERVATIVE ASSUMPTIONS	1. CIRCUIT COMPONENTS OPERATE AT THE SURFACE TEMPERATURE EXPERIENCED BY THE COMPONENT ENCLOSURE BOX. NO CONDUCTION OR CONVECTION LOSSES ARE INCORPORATED IN THE ANALYSIS.
	2. UNCERTAINTIES UTILIZED ARE CONSISTENT WITH MAXIMUM VALUES SUPPLIED BY THE MANUFACTURER OVER THE ENVIRONMENTAL CONDITIONS CONSIDERED IN THE ANALYSIS.
	3. THE THERMAL RESISTANCE OF THE ENCLOSURE OUTSIDE THE CIRCUIT BOX IS NOT INCORPORATED.
	4. THE THERMAL CAPACITANCE OF THE STRUCTURE TO WHICH THE COMPONENT ENCLOSURE BOX IS ATTACHED IS NOT INCORPORATED.
	5. THE THERMAL CAPACITANCE OF THE CONFORMABLE COATING AND THE RESISTANCE TO HEAT FLOW ARE CONSIDERED NEGLIGIBLE.

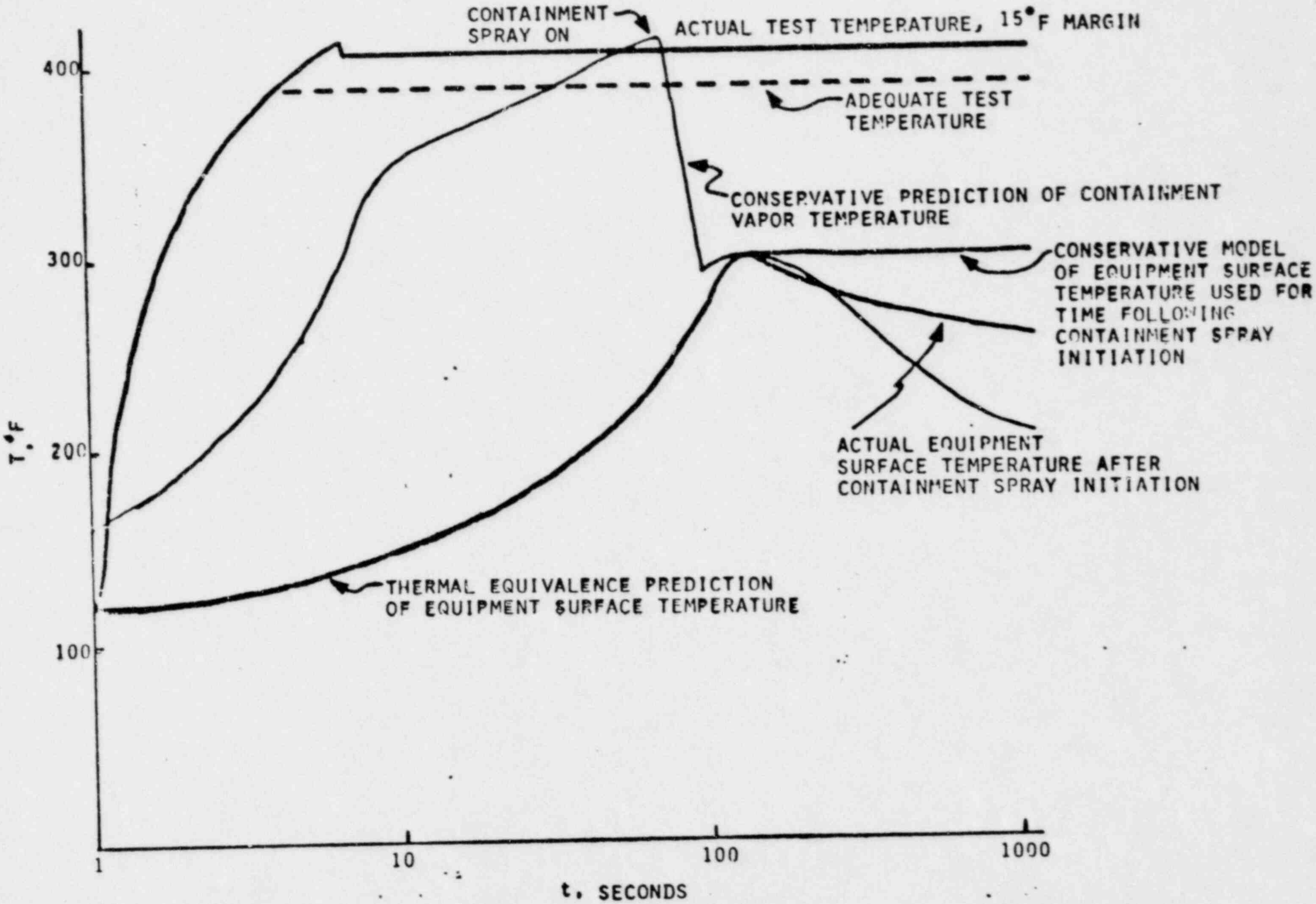


FIGURE 2

TYPICAL TEMPERATURE PROFILES FOR ENVIRONMENTAL QUALIFICATION TESTS

MOISTURE EFFECTS ON CIRCUIT OPERATION

MODEL INFORMATION

FAILURE CRITERION	CIRCUIT BOARD TEMPERATURE DROPS BENEATH DEW POINT TEMPERATURE IN CAVITY.
CONSERVATIVE ASSUMPTIONS	1. FAILED OUTER SEAL ASSUMED ON COMPONENT ENCLOSURE BOX.
	2. ALL MOISTURE DIFFUSION THROUGH CONFORMABLE COATING BARRIER GOES INTO CIRCUIT BOARD CAVITY.
	3. NO BENEFIT FOR THE OUTER ENCLOSURE AROUND THE COMPONENT ENCLOSURE BOX WAS INCORPORATED.

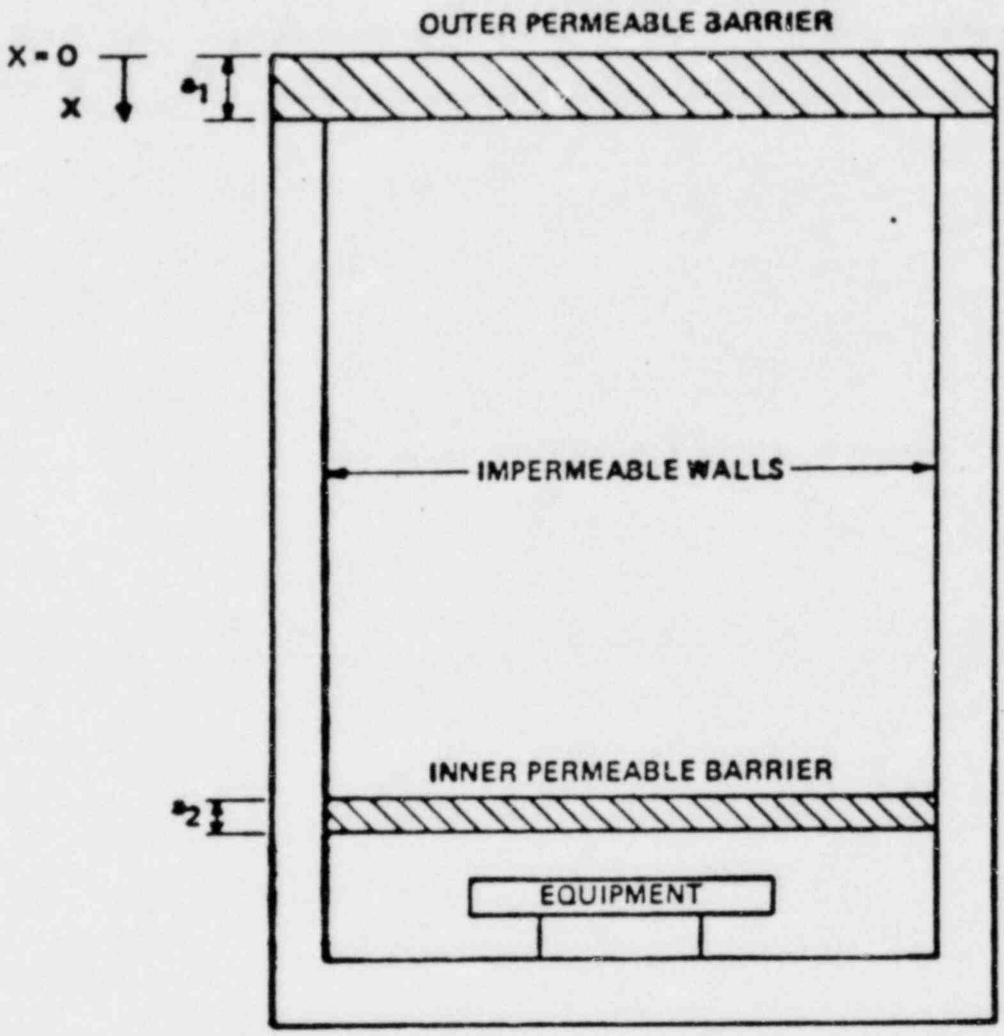


FIGURE 3

SIMPLIFIED MODEL OF EQUIPMENT PROTECTION AGAINST MOISTURE DIFFUSION

TEMPERATURE EFFECTS ON INDUCED MECHANICAL STRAIN, MODEL INFORMATION

FAILURE CRITERION — A STRAIN LEVEL OF 1%

CONSERVATIVE ASSUMPTIONS

1. ANY STRAIN OVER THE FAILURE STRAIN CAUSES CIRCUIT FAILURE, IN REALITY EVEN IF CIRCUIT BOARD TEARS AT STANDOFFS - NO CIRCUIT FAILURE IS ANTICIPATED.

2. STANDOFFS ARE ASSUMED NOT TO BEND OR DEFORM.

3. TOLERANCE ON CIRCUIT BOARD PENETRATIONS FOR STANDOFFS ARE ASSUMED NOT TO EXIST.

4. CREDIT IS NOT TAKEN FOR THE THERMAL CAPACITANCE OF THE STRUCTURE TO WHICH THE COMPONENT ENCLOSURE IS FIXED.

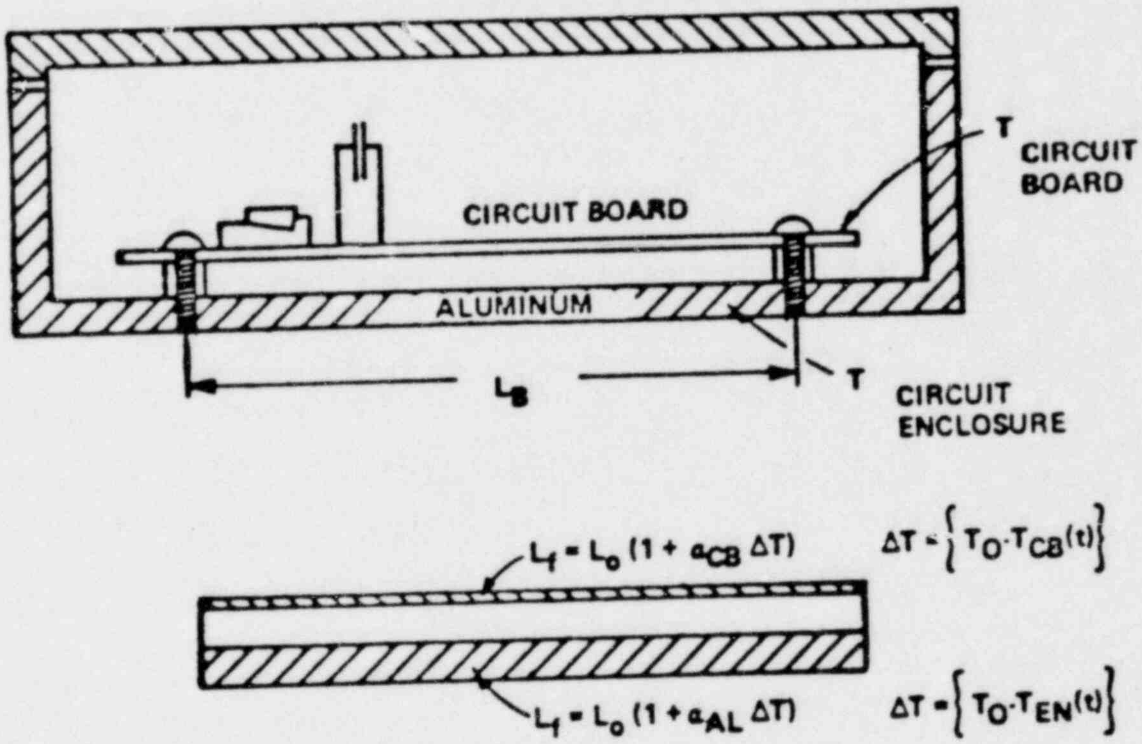
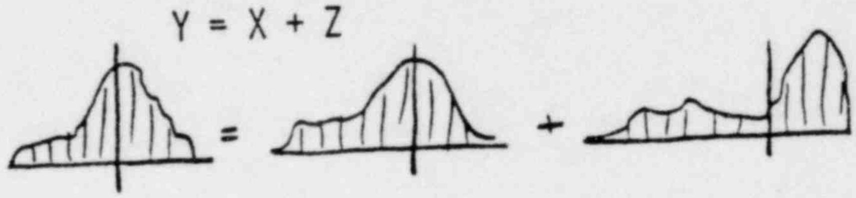


FIGURE 5
SIMPLIFIED THERMAL STRAIN SCHEMATIC

STOCHASTIC SIMULATION TECHNIQUES EMPLOYED

$$Y = X + Z$$



BENEFITS

1. REALISTIC RESULTS
2. NO SENSITIVITY ASSUMPTIONS ARE REQUIRED
3. NO LIMITATIONS ON FUNCTION FORM

APPLICATIONS TO LICENSED UNCERTAINTY ANALYSES

1. CALVERT CLIFFS RELOAD FUEL SAFETY ANALYSIS
2. ST. LUCIE RELOAD FUEL SAFETY ANALYSIS
3. ARKANSAS RELOAD FUEL SAFETY ANALYSIS
4. ROD BOW TOPICAL REPORT

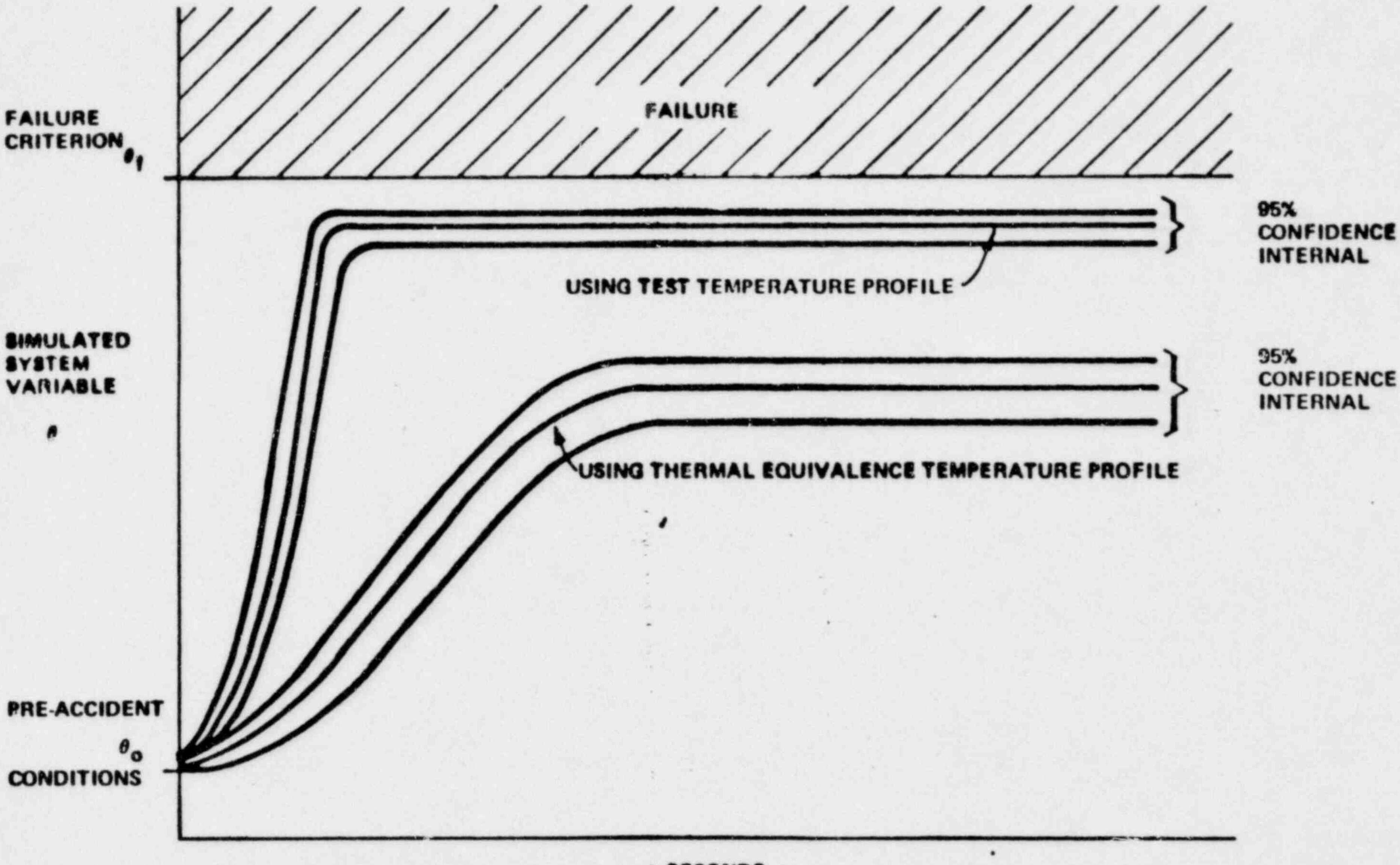


FIGURE 9

PROFILES OF A TYPICAL EQUIPMENT CHARACTERISTIC FOR THERMAL EQUIVALENCE AND TEST TEMPERATURE PROFILES

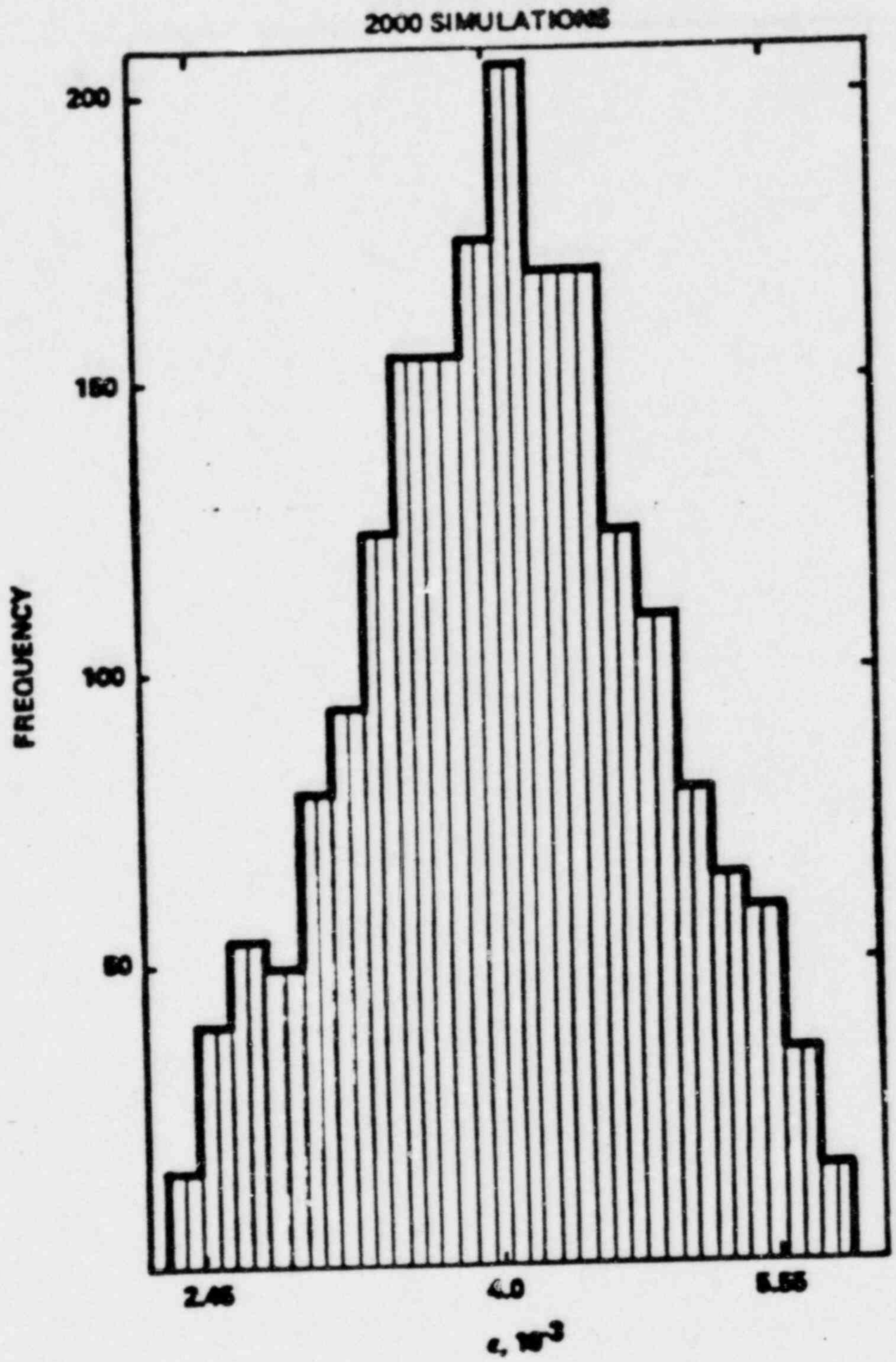


FIGURE 29

TYPICAL HISTOGRAM OUTPUT FROM SIGMA

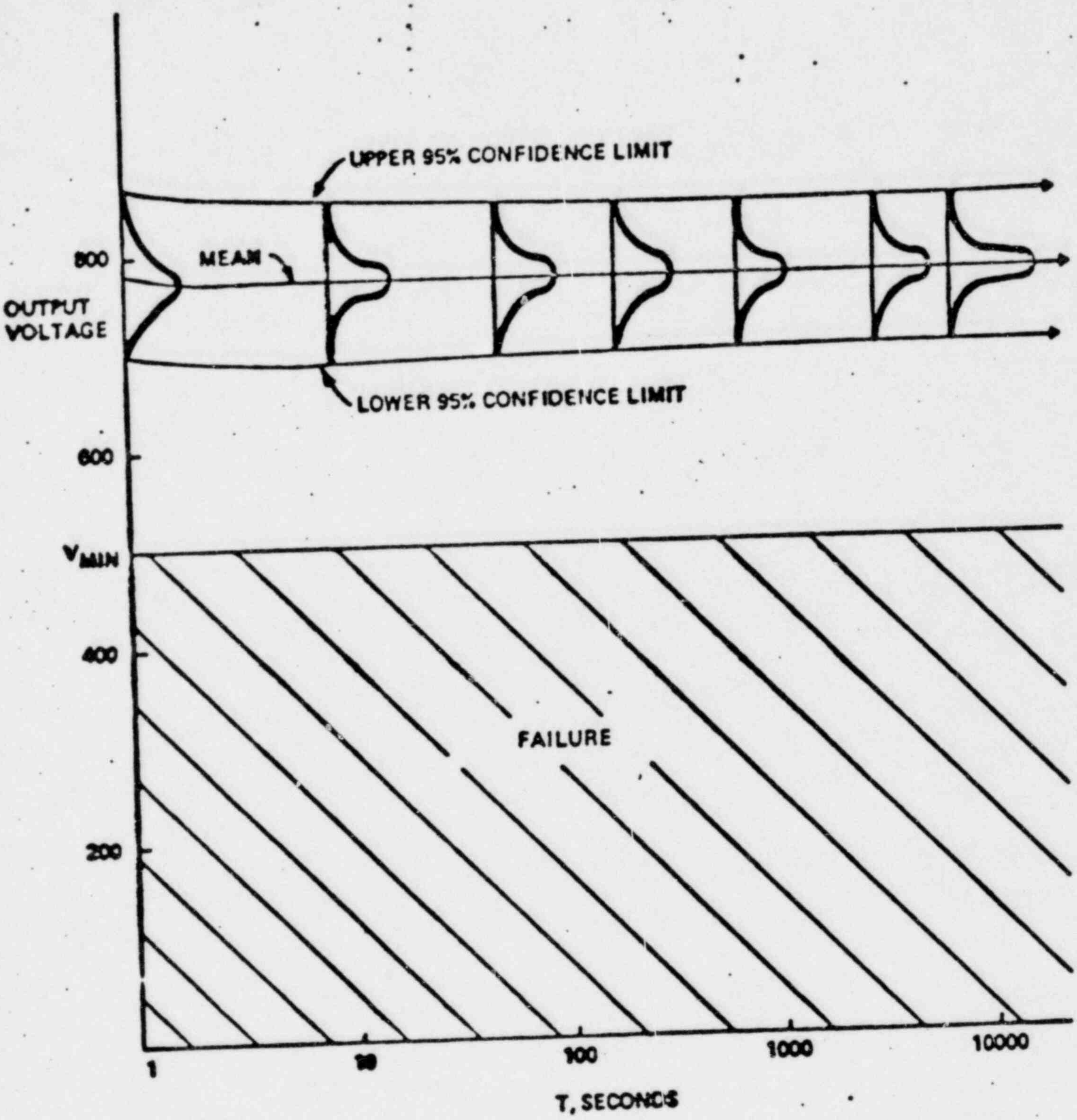


FIGURE 14

SIMULATED OUTPUT VOLTAGE AS A FUNCTION OF TIME

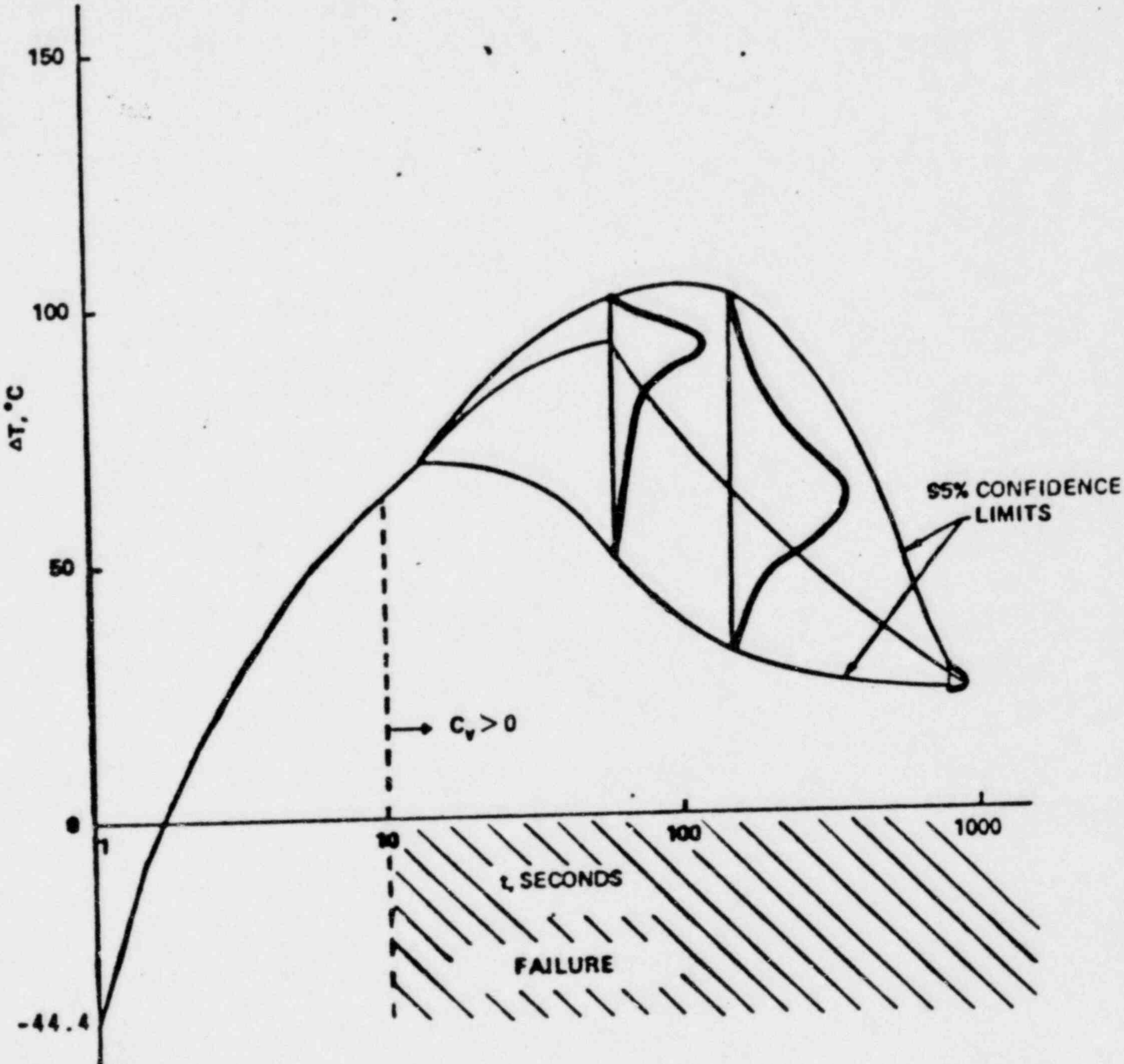


FIGURE 16

SIMULATED DISTRIBUTION OF MOISTURE EFFECTS (ΔT) AS A FUNCTION OF TIME
(ONE MOISTURE BARRIER – THERMAL EQUIVALENCE TEMPERATURE MODEL)

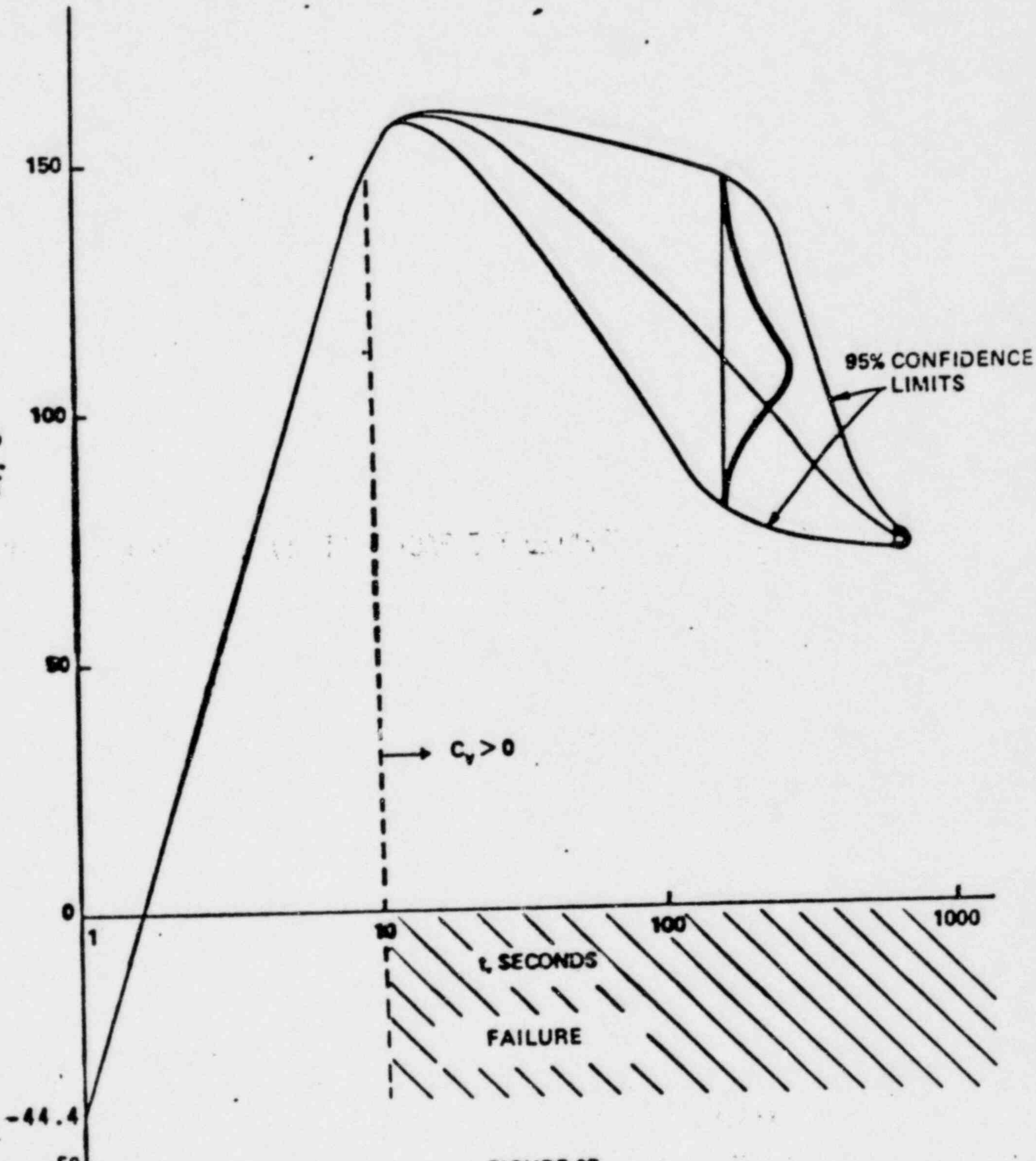


FIGURE 17

SIMULATED DISTRIBUTION OF MOISTURE EFFECTS (ΔT) AS A FUNCTION OF TIME (ONE MOISTURE BARRIER – TEST TEMPERATURE MODEL)

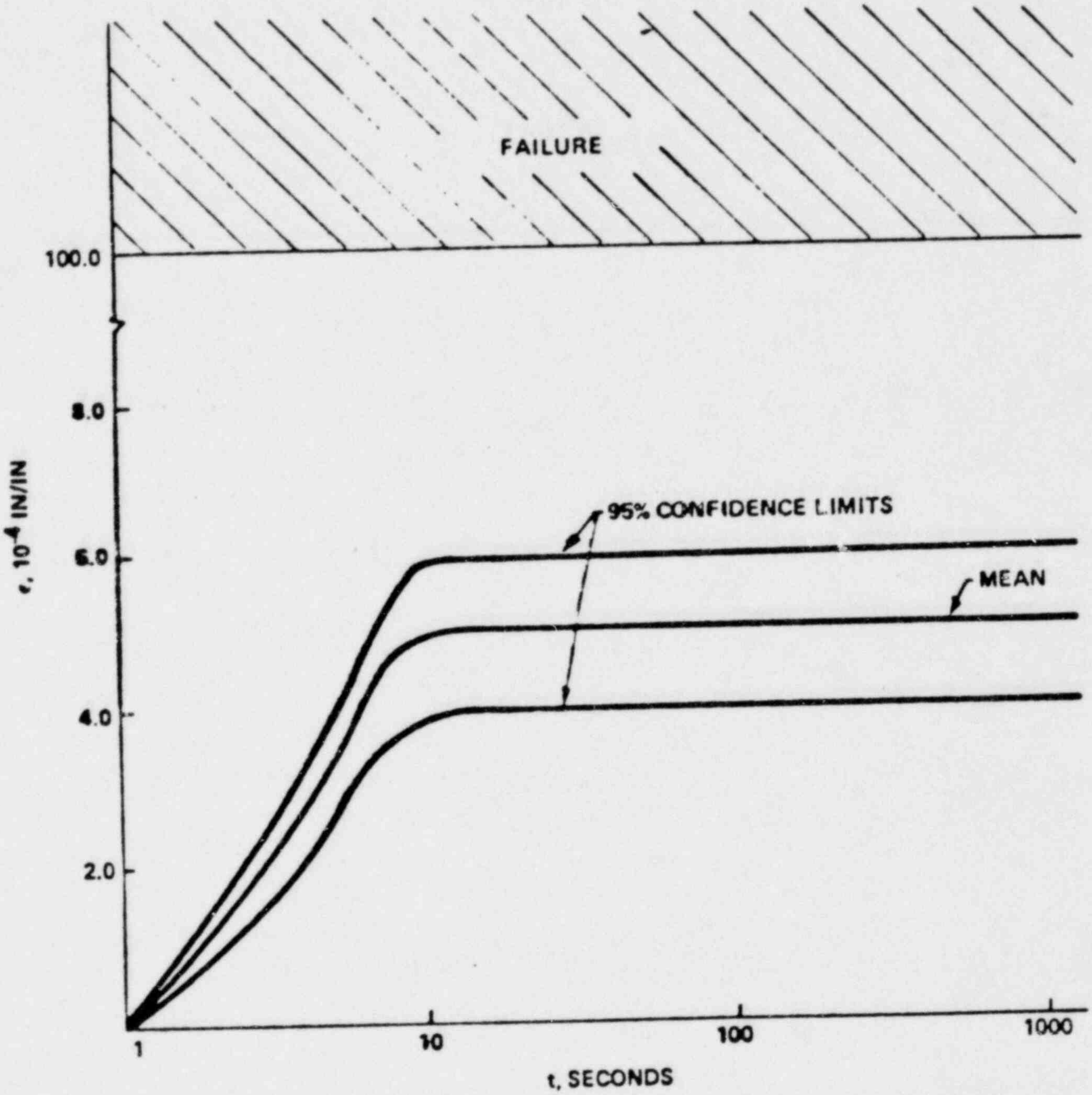


FIGURE 22

SIMULATED CIRCUIT BOARD STRAIN AS A FUNCTION OF TIME
(2000 SIMULATIONS – TEST TEMPERATURE PROFILE)

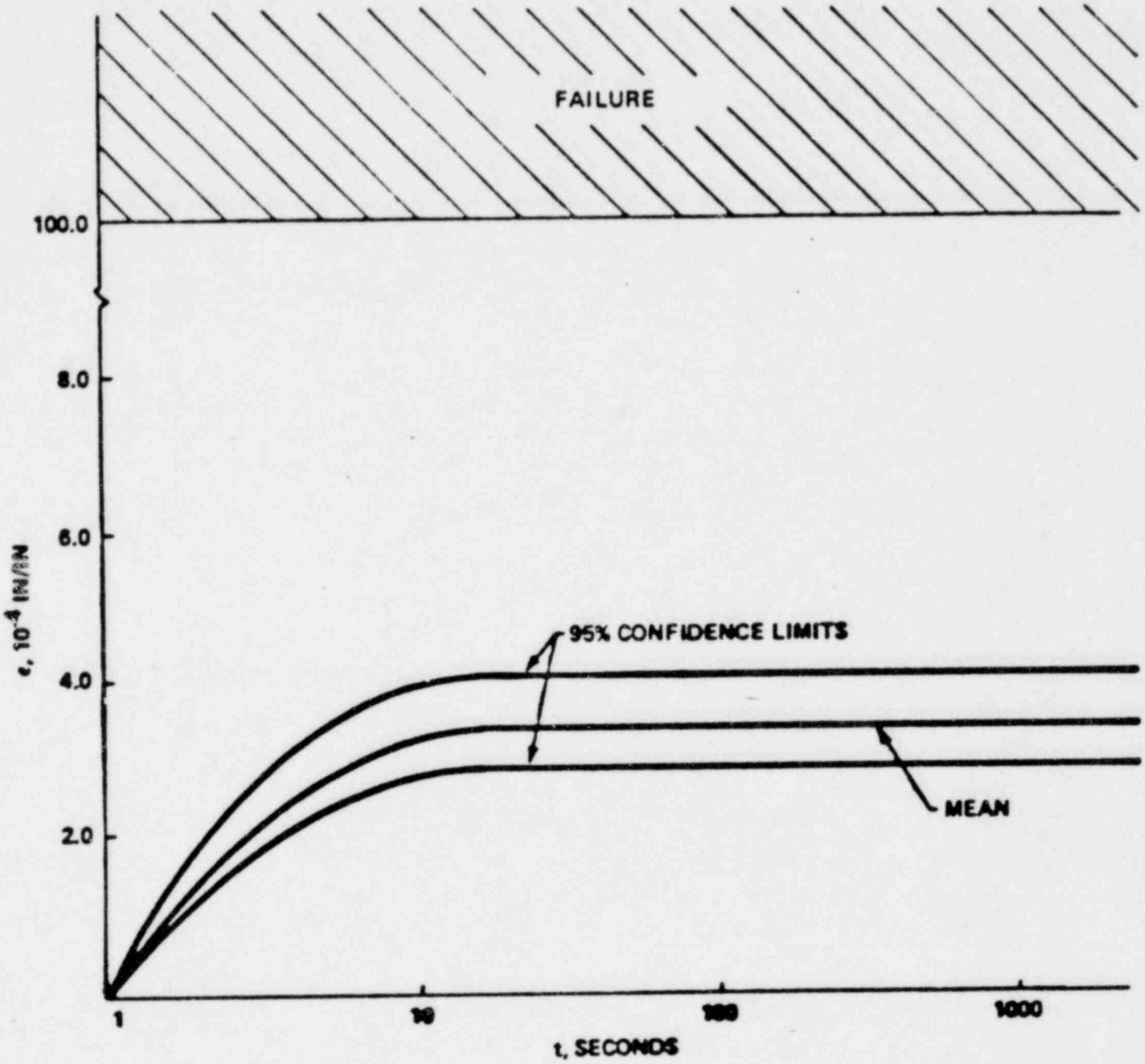


FIGURE 21

SIMULATED CIRCUIT BOARD STRAIN AS A FUNCTION OF TIME
(2000 SIMULATIONS – THERMAL EQUIVALENCE TEMPERATURE PROFILE)

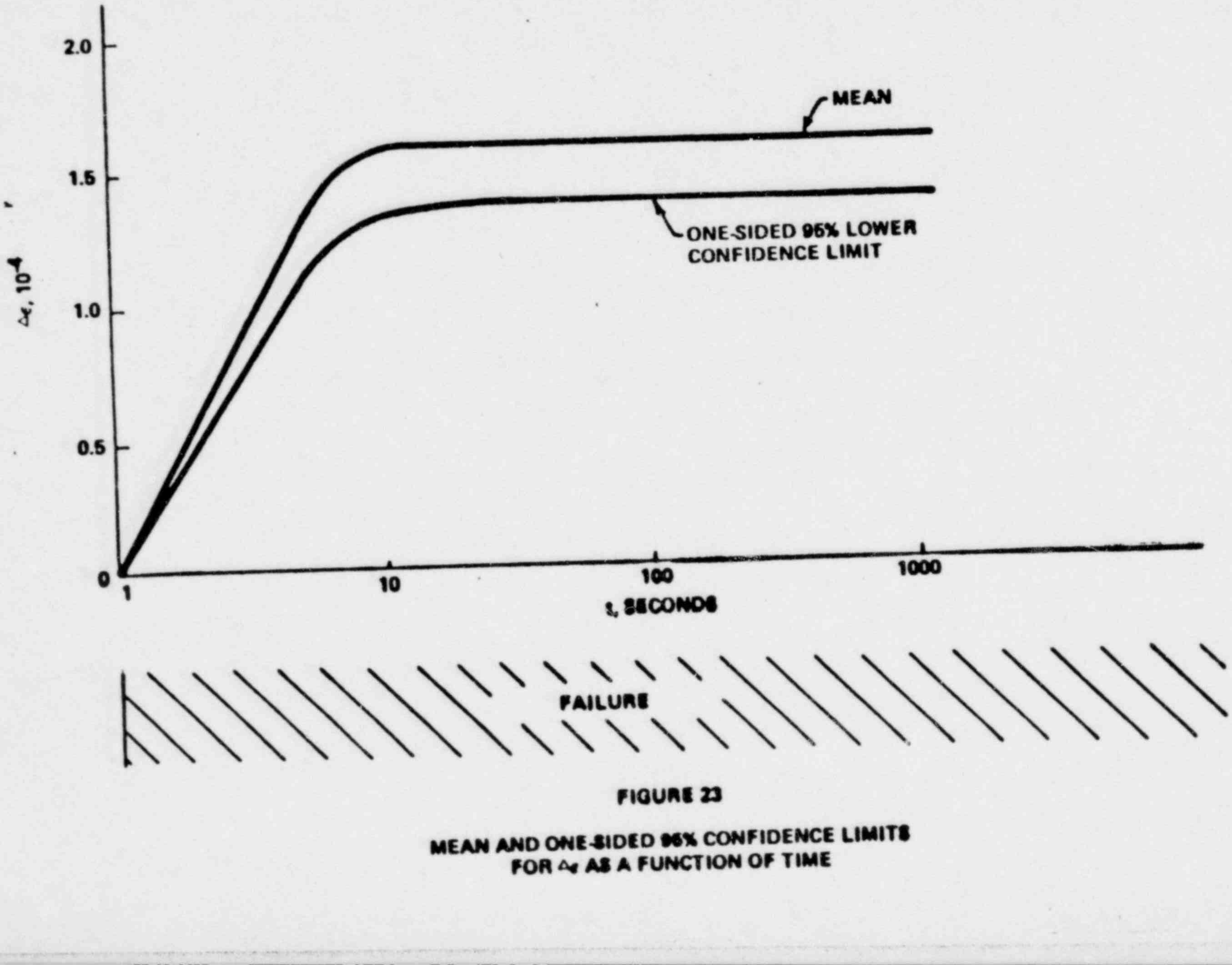


FIGURE 23

MEAN AND ONE-SIDED 95% CONFIDENCE LIMITS FOR $\Delta\epsilon$ AS A FUNCTION OF TIME

CONCLUSIONS

1. THE ANALYSIS FORMS THE BASIS FOR JUSTIFYING THE ENVIRONMENTAL TEST CONDITIONS AND THE TEST PERIOD UTILIZED.

2. EACH ANALYTICAL TEST RESULT WAS SUBSTANTIATED BY ACTUAL COMPONENT TEST DATA IN HARSH ENVIRONMENTAL CONDITIONS.

3. THE ANALYSIS ILLUSTRATED THE FACT THAT REALITY WAS ENVELOPED BY THE TEST CONDITIONS UTILIZED.

4. TEST CONDITIONS WERE MORE SEVERE THAN EVEN A CONSERVATIVE CALCULATION OF REALITY WOULD INDICATE.