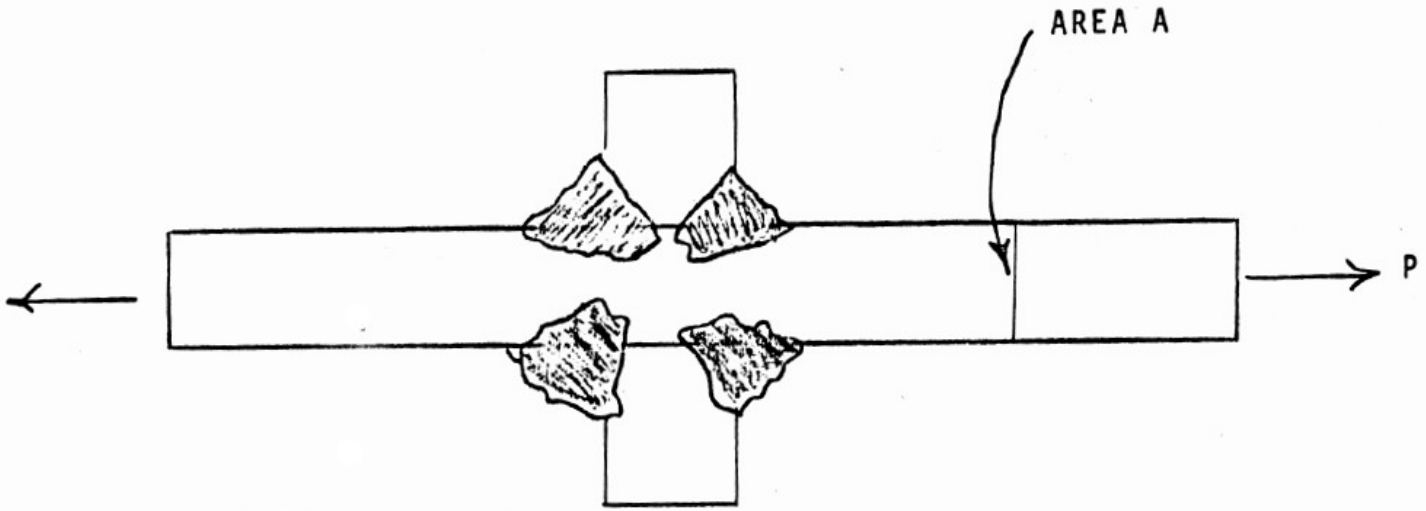
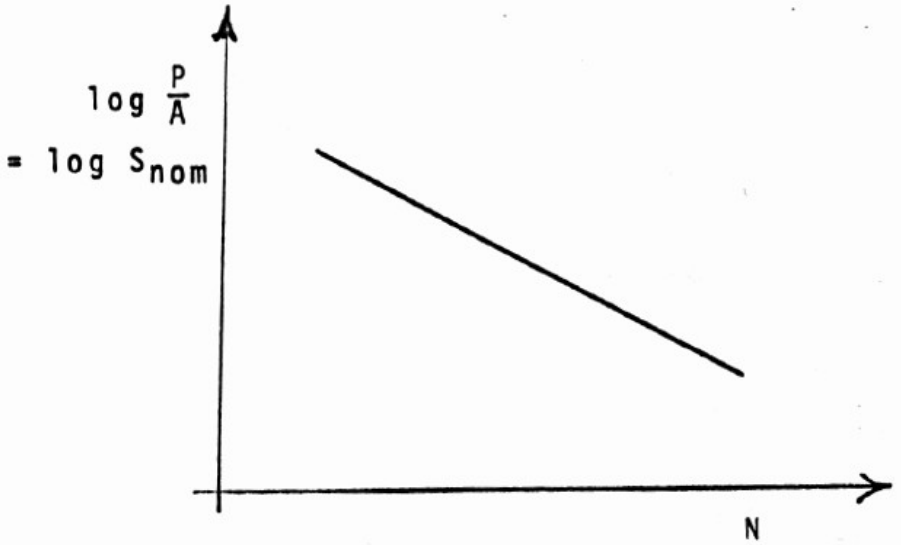
WELD FATIGUE TEST





FN-238 3-77

GENERAL ELECTRIC

General Electric Company

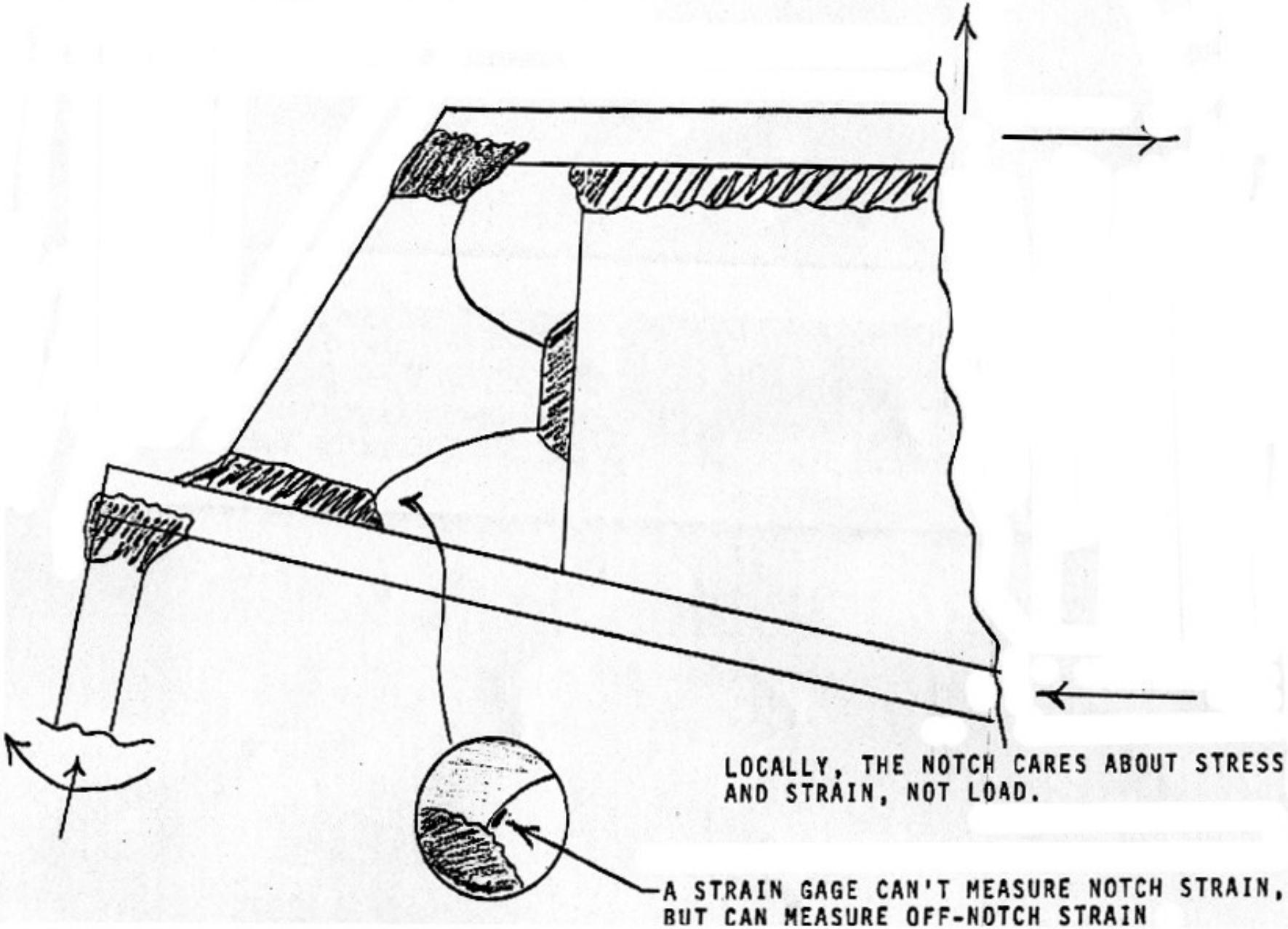
R. C. Leever

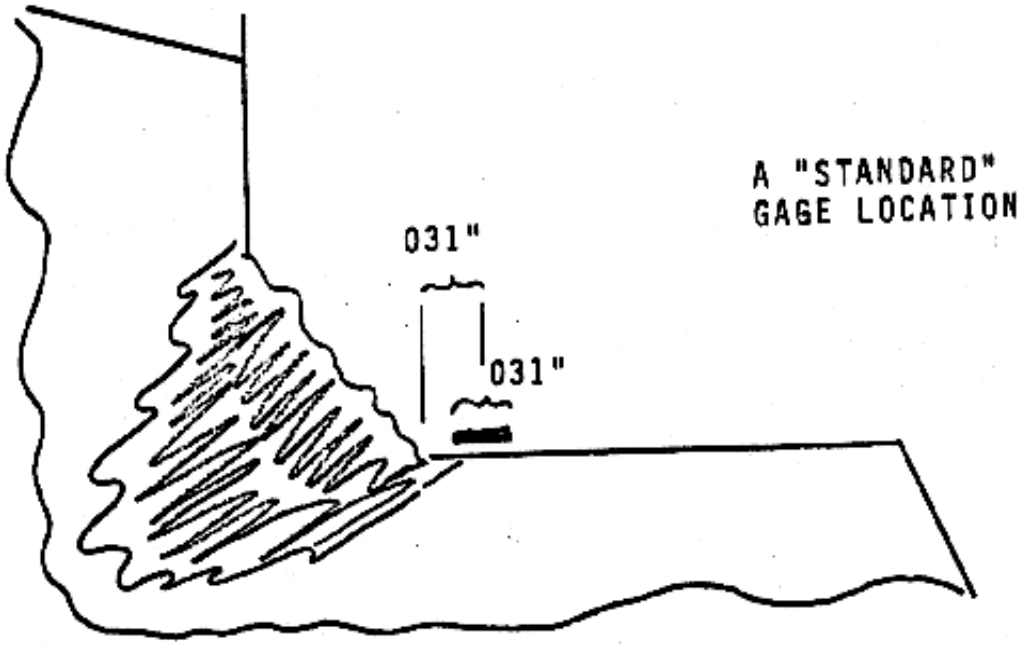
2901 E. Lake Rd. Bldg. 14-1

Erie, PA 16531

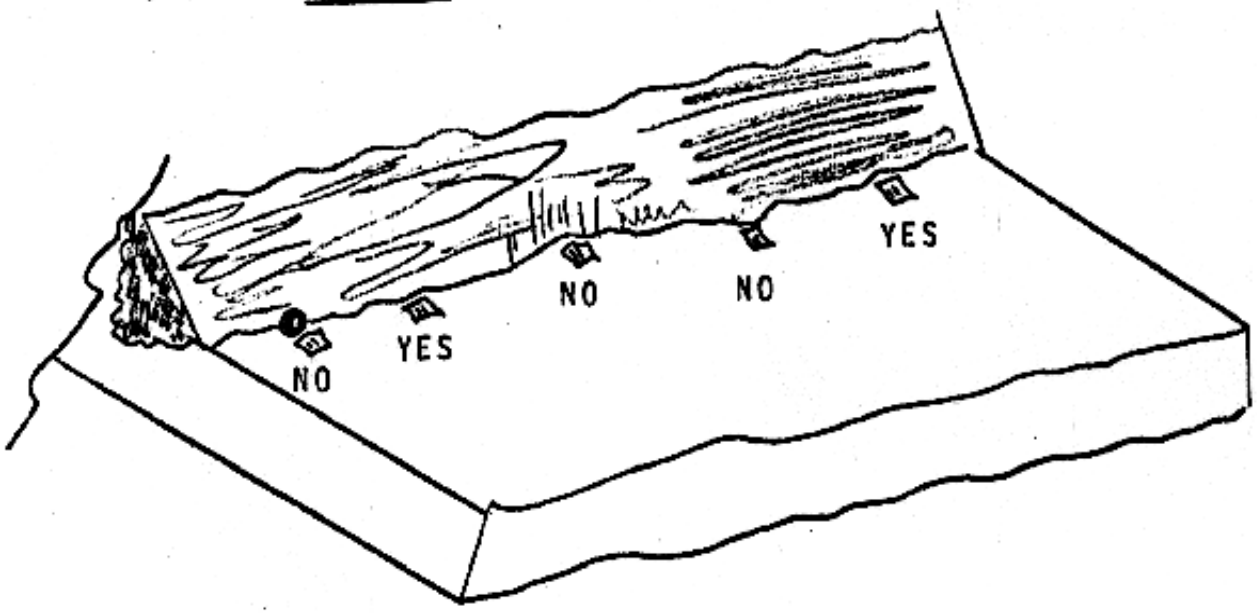
COMPLEX STRUCTURE

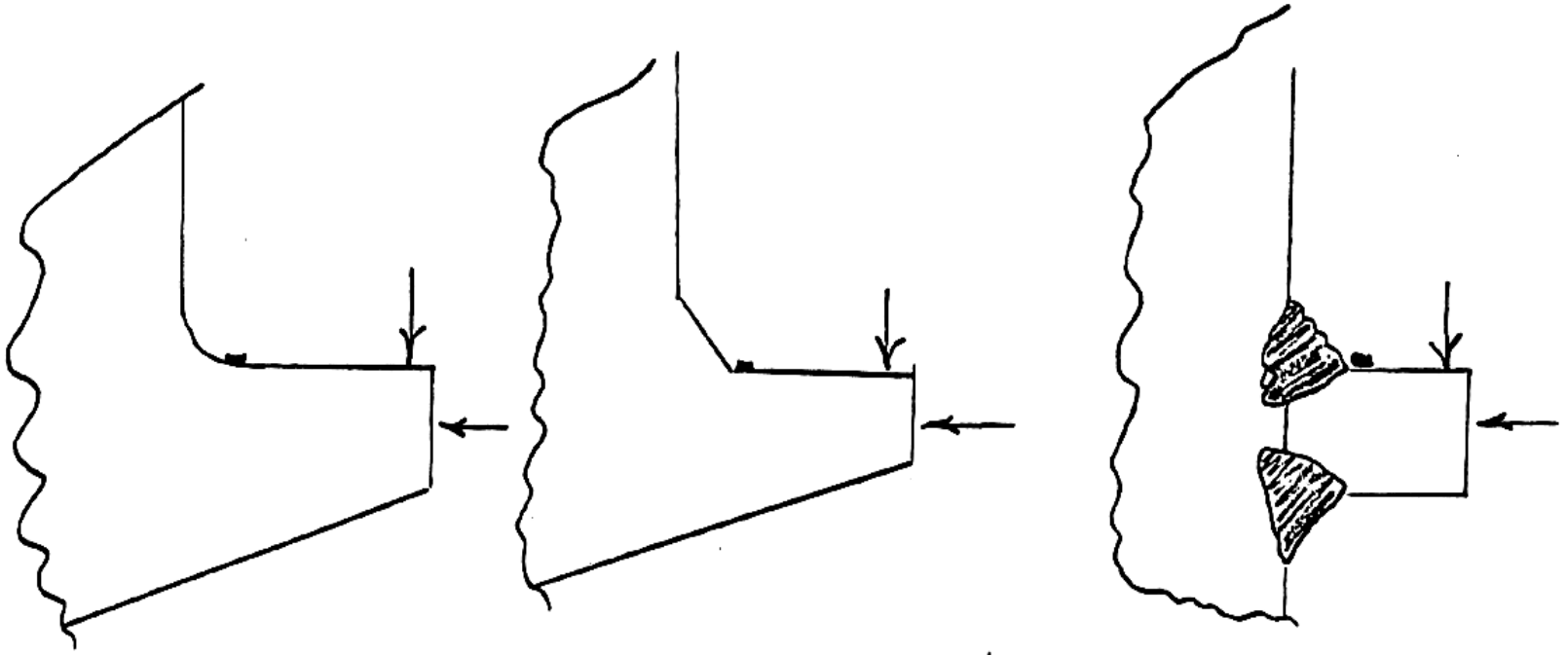
S_{nom} DOESN'T EXIST!



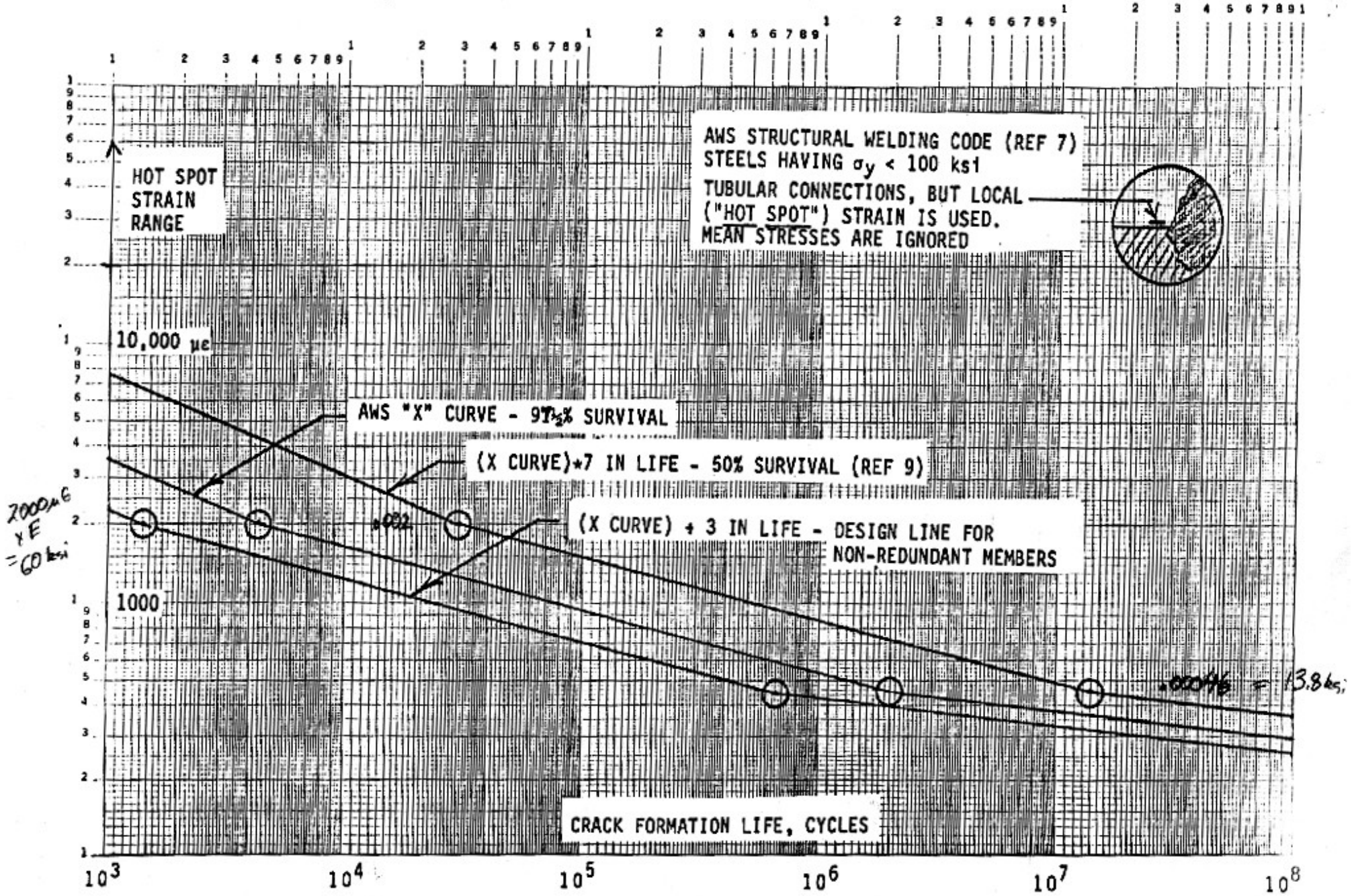


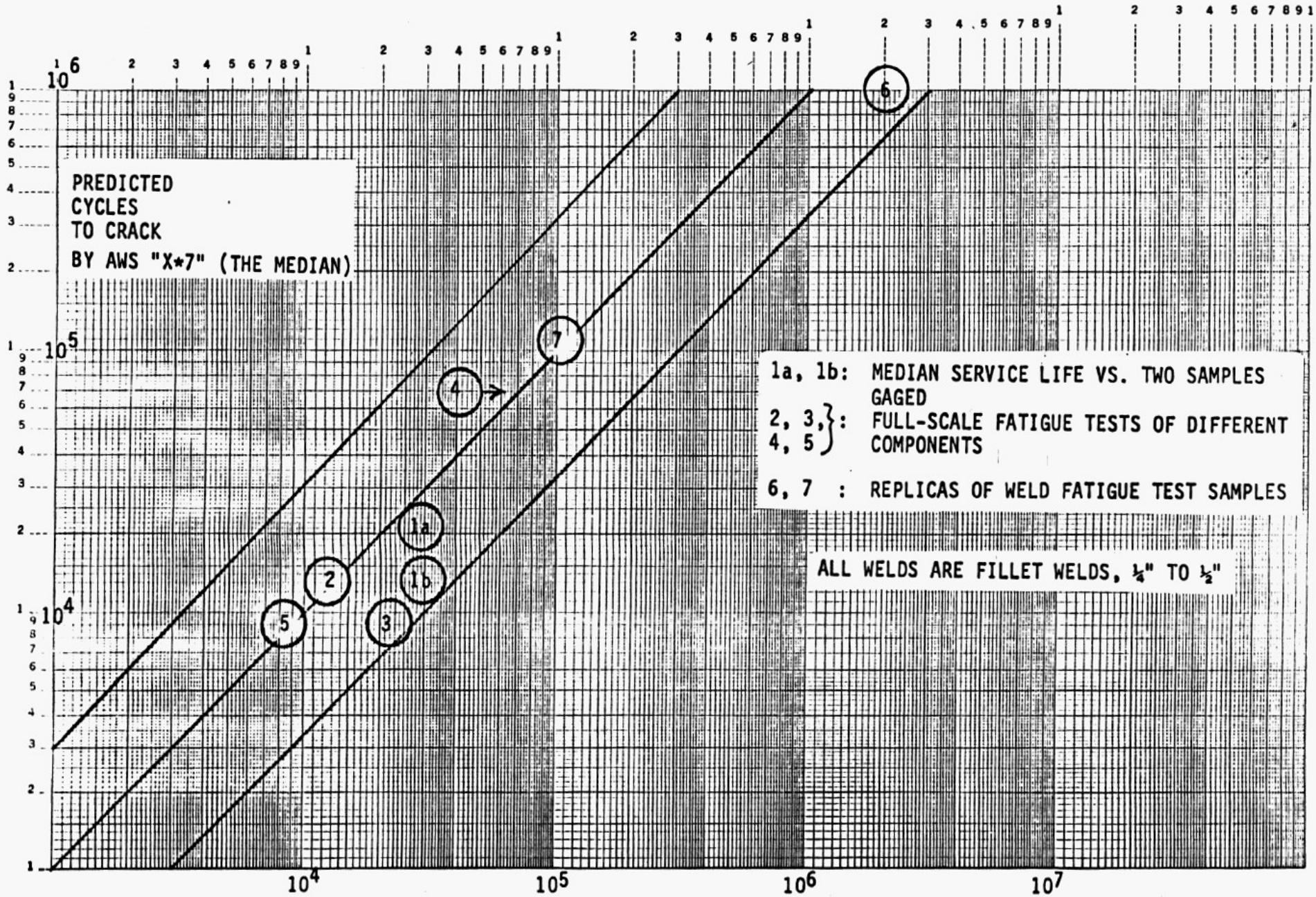
GAGE AT TYPICAL REGION AT FUSION LINE

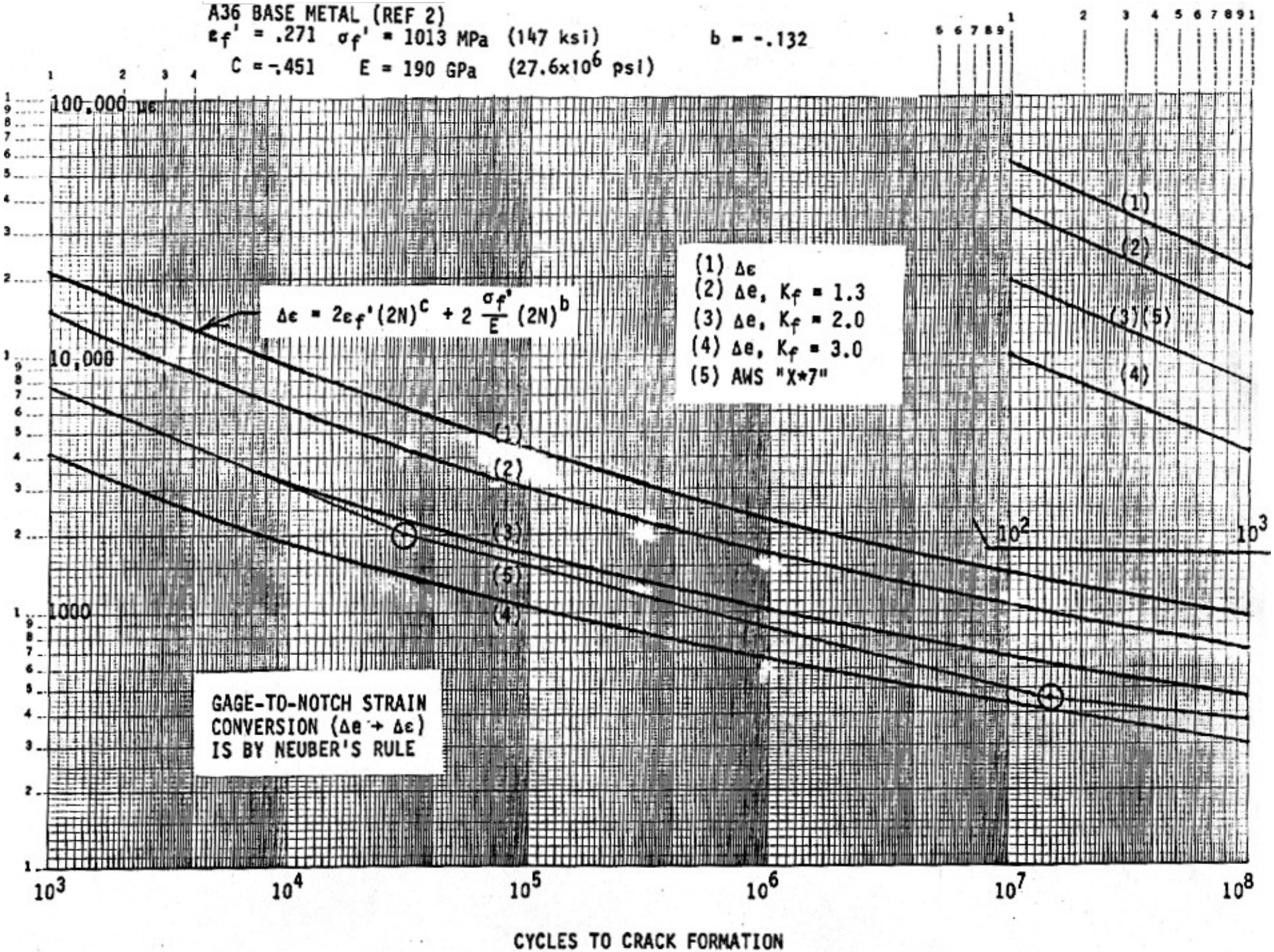


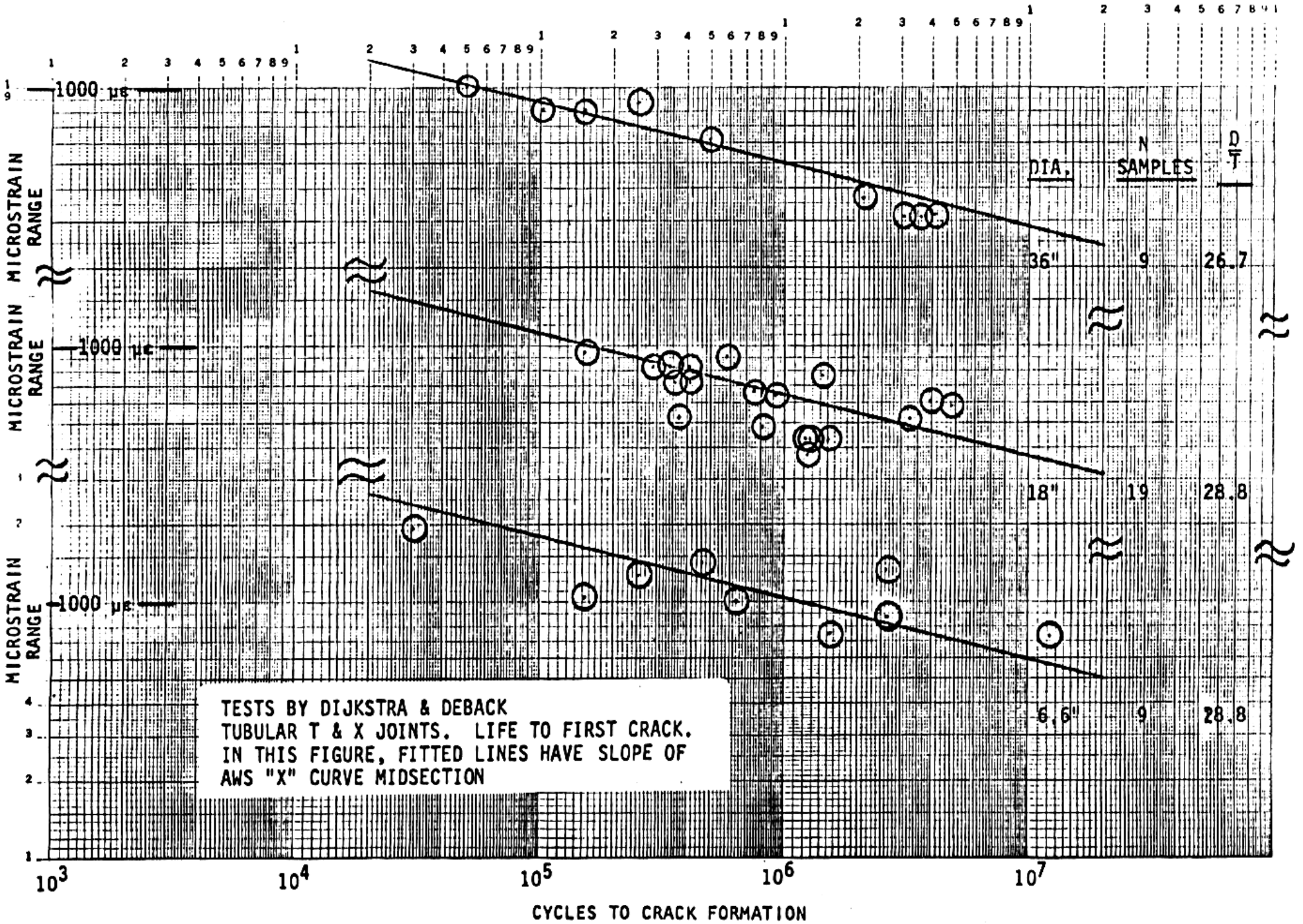


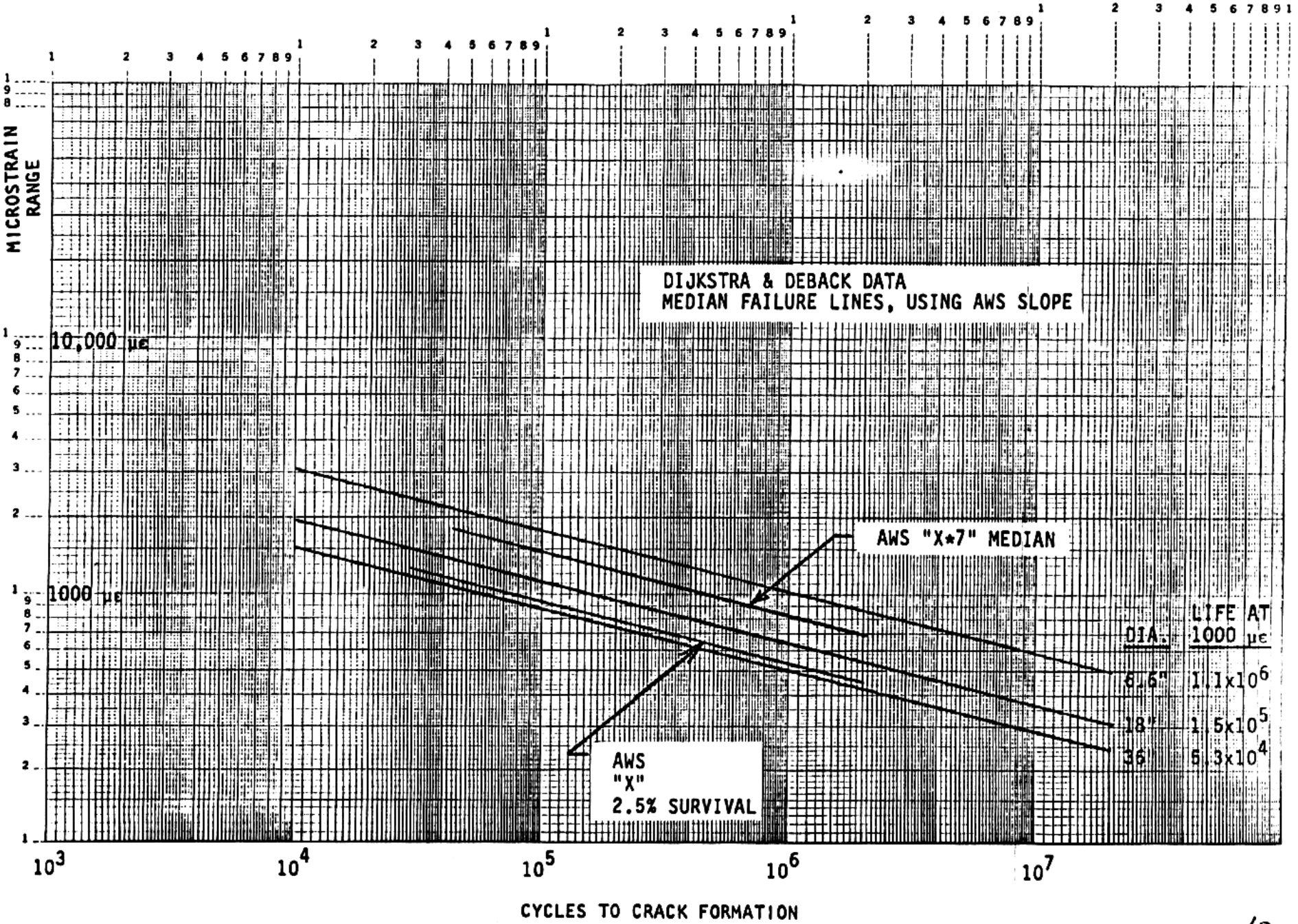
STRAIN CONCENTRATION:	GAGE MEASURES IT	GAGE GETS AS CLOSE AS YOU CAN GET WITH A STRAIN GAGE. NEED K_f GAGE-TO-NOTCH. NEED K_t IF CONCERNED WITH YIELDING.	
MATERIAL:	HOMOGENEOUS	HOMOGENEOUS	BASE METAL? WELD METAL? HEAT-AFFECTED ZONE?


AWS STRUCTURAL WELDING CODE (REF 7)
STEELS HAVING σ_y < 100 ksi
TUBULAR CONNECTIONS, BUT LOCAL ("HOT SPOT") STRAIN IS USED.
MEAN STRESSES ARE IGNORED
HOT SPOT STRAIN RANGE
10,000 με
1000
AWS "X" CURVE - 97½% SURVIVAL
(X CURVE)*7 IN LIFE - 50% SURVIVAL (REF 9)
(X CURVE) ÷ 3 IN LIFE - DESIGN LINE FOR NON-REDUNDANT MEMBERS
CRACK FORMATION LIFE, CYCLES
10^3
10^4
10^5
10^6
10^7
10^8


PREDICTED
CYCLES
TO CRACK
BY AWS "X*7" (THE MEDIAN)
1a, 1b: MEDIAN SERVICE LIFE VS. TWO SAMPLES GAGED
2, 3, 4, 5: FULL-SCALE FATIGUE TESTS OF DIFFERENT COMPONENTS
6, 7 : REPLICAS OF WELD FATIGUE TEST SAMPLES
ALL WELDS ARE FILLET WELDS, ¼" TO ½"
10^6
10^5
10^4
10^4
10^5
10^6
10^7
ACTUAL CYCLES TO CRACK FORMATION


A36 BASE METAL (REF 2)
$\varepsilon_f' = .271$ $\sigma_f' = 1013$ MPa (147 ksi)
$C = -.451$ $E = 190$ GPa (27.6×10^6 psi)
$b = -.132$
100,000 με
10,000
1000
$\Delta\varepsilon = 2\varepsilon_f'(2N)^c + 2\frac{\sigma_f'}{E}(2N)^b$
(1) Δε
(2) Δe, $K_f = 1.3$
(3) Δe, $K_f = 2.0$
(4) Δe, $K_f = 3.0$
(5) AWS "X*7"
GAGE-TO-NOTCH STRAIN CONVERSION (Δe → Δε) IS BY NEUBER'S RULE
10^2
10^3
10^3
10^4
10^5
10^6
10^7
10^8
CYCLES TO CRACK FORMATION


1000 με
MICROSTRAIN RANGE
1000 με
MICROSTRAIN RANGE
1000 με
MICROSTRAIN RANGE
DIA.
N SAMPLES
D/T
36"
9
26.7
18"
19
28.8
6.6"
9
28.8
TESTS BY DIJKSTRA & DEBACK
TUBULAR T & X JOINTS. LIFE TO FIRST CRACK.
IN THIS FIGURE, FITTED LINES HAVE SLOPE OF
AWS "X" CURVE MIDSECTION
10^3
10^4
10^5
10^6
10^7
CYCLES TO CRACK FORMATION


DIJKSTRA & DEBACK DATA
MEDIAN FAILURE LINES, USING AWS SLOPE
AWS "X*7" MEDIAN
AWS
"X"
2.5% SURVIVAL
10,000 με
1000 με
DIA.
LIFE AT 1000 με
8.6"
1.1x10^6
18"
1.5x10^5
36"
5.3x10^4
MICROSTRAIN RANGE
CYCLES TO CRACK FORMATION
10^3
10^4
10^5
10^6
10^7

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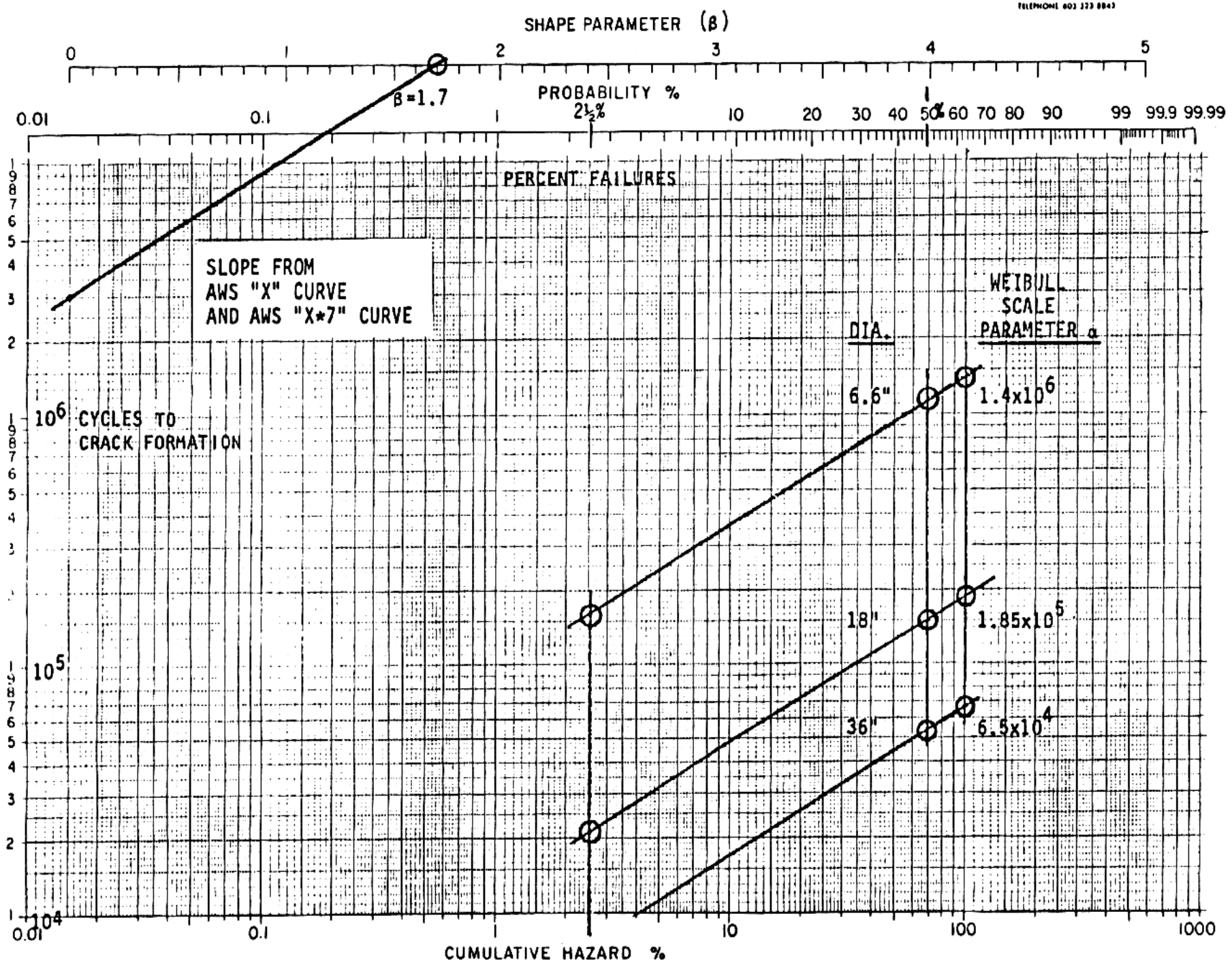


11

WEIBULL MODEL - "SERIES SYSTEM"
- "WEAK LINK SYSTEM"

SCALE PARAMETER WITH ONE COMPONENT = α

SCALE PARAMETER WITH m COMPONENTS = α'; β IS UNCHANGED

$$\alpha' = \frac{\alpha}{m^{1/\beta}}$$

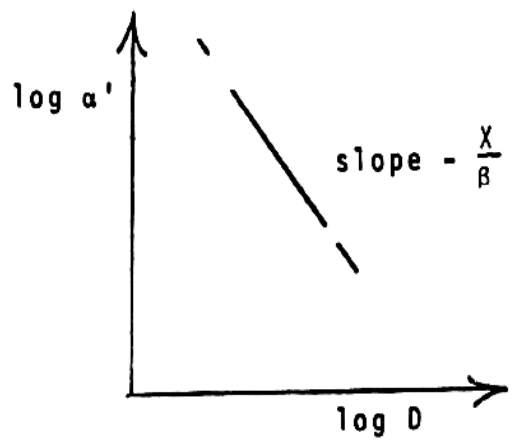
IF A GIVEN WELD IS ONE COMPONENT, WHAT IS TWO COMPONENTS?

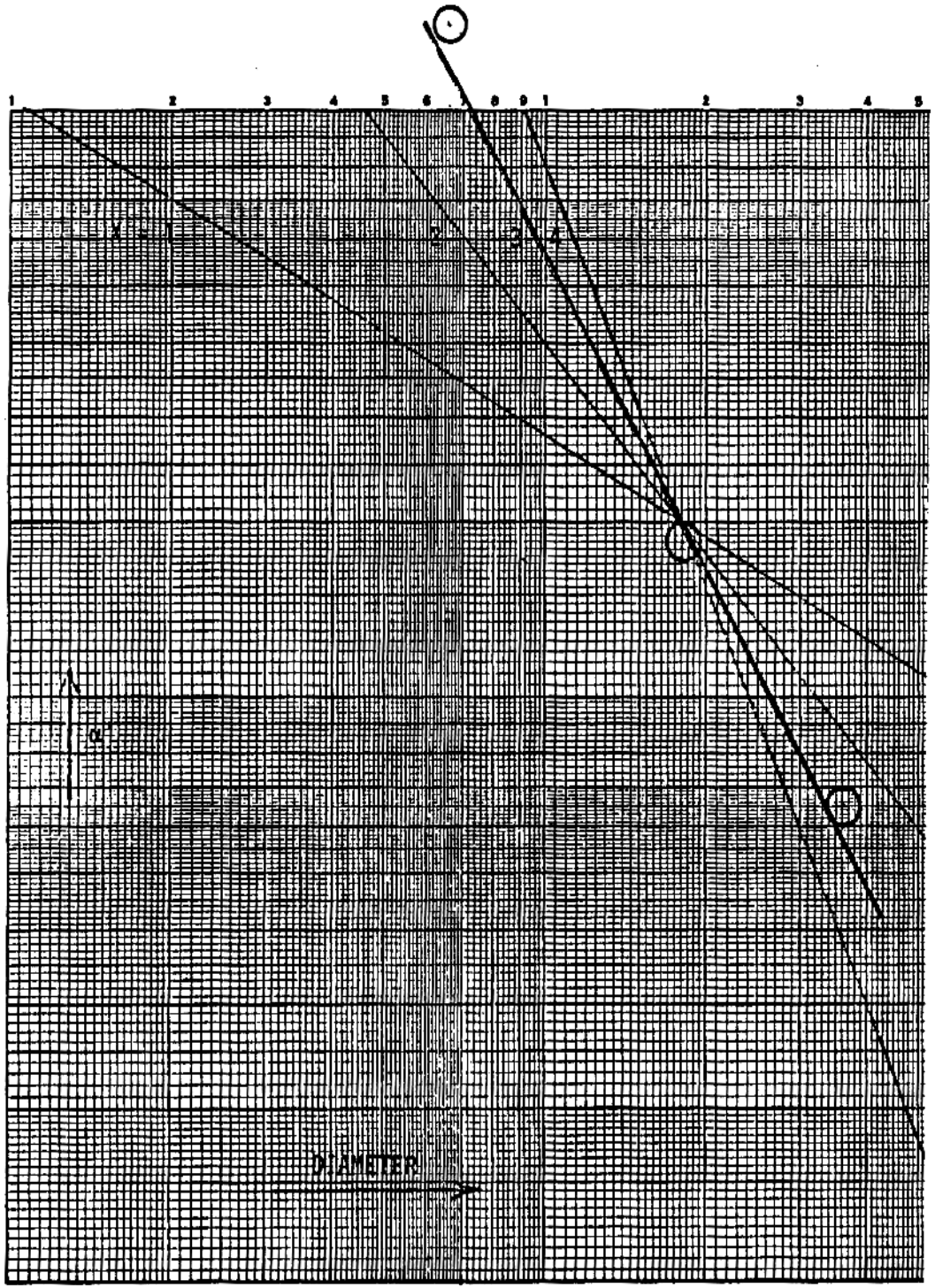
ONE WELD, TWICE AS LONG?	m PROPORTIONAL TO D
TWICE THE SURFACE?	D^2
TWICE THE VOLUME?	D^3

LET $m = CD^X$

$$\alpha' = \alpha(CD^X)^{-1/\beta} = \hat{C}\, D^{-X/\beta}$$

$$\log \alpha' = \log \hat{C} - \frac{X}{\beta} \log D; \text{ then} \longrightarrow$$





SUPPOSE

TESTED 6.6" SAMPLE,
PREDICTED OTHERS
USING m PROPORTIONAL TO D^3

	MEDIAN LIFE		
DIA.	TEST	PREDICTED	TEST
6.6"	1.1×10^6		
18"		1.9×10^5	1.5×10^5
36"		5.6×10^4	5.3×10^4

CONCLUSIONS

(1) "HOT SPOT STRAIN" MEASUREMENTS ARE A VERY USEFUL TECHNIQUE FOR WELD FATIGUE LIFE PREDICTION

(2) WATCH TECHNOLOGY COMING FROM WORK ON OFF-SHORE DRILLING PLATFORMS

(3) THE AWS "X*7" IS ESSENTIALLY EQUIVALENT TO A NEUBER ANALYSIS WITH:

- o CYCLIC PROPERTIES OF ASTM A-36
- o $K_f = 2.0$
- o MEAN STRESS IGNORED

BOTH HAVE CORRELATED WITH GE-ERIE DATA ON STRUCTURES USING 1/4" TO 1/2" NON-CONTOURED FILLET WELDS

(4) DIJKSTRA AND DEBACK EXPERIMENTS SHOW AN IMPORTANT SIZE EFFECT. MY ANALYSIS SUGGESTS THAT VOLUME OF HIGHLY STRESSED WELD IS THE "SERIES SYSTEM" PARAMETER FOR A WEIBULL MODEL

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[3] "Development and Application of Fatigue Data for Structural Steel Weldments", H.S. Reemsnyder, ASTM STP 648.

[4] "Fracture and Fatigue Control in Structures", Rolfe and Barsom, Prentice Hall, 1977.

[5] "The Initiation of Fatigue Cracks from Notches in Mild Steel Plates", A.R. Jack and A.T. Price, International Journal of Fracture Mechanics, Vol 6, N 4, December 1970.

[6] "Fatigue Properties of Welded Roller-Quenched and Tempered (RQ) Steels", H.S. Reemsnyder, SAE paper 790519.

[7] "Structural Welding Code - Steel", American Welding Society, AWS D 1.1-79, Part 10, New Tubular Structures, Jan. 1, 1979.

[8] "Basis for Tubular Joint Design", P.W. Marshall and A.A. Toprac, Welding Journal Magazine, Welding Research Supplement, 1974.

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[11] "Fatigue Strength of Tubular T- and X-Joints", O.D. Dijkstra and J. DeBack, Offshore Technology Conference, (6200 N Central Expressway, Dallas, TX 75026), May 1980.