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POWER SYSTEMS

June 30, 1981
LD-81-033

Mr. R. H. Vollmer, Director
Division of Engineering
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Subject: Design Basis Pipe Break Criteria

Dear Mr. Vollmer:

The purpose of this letter is to forward a copy of the slides used by Combustion Engineering (C-E) in a meeting with you and senior members of your staff on June 5, 1981 and to request a follow-up meeting on the same subject. At the June meeting, C-E presented an overview of our program to redefine the design basis pipe break for reactor coolant system main loop piping in a C-E designed NSSS. We believe that the comments we received at that time were valuable and we appreciate your taking the time to review our efforts to date.

C-E believes that the use of this alternate pipe break criteria will produce significant improvements in plant design, reduce personnel exposure and enhance plant safety. In particular, this program will justify the use of a new complete set of conservative subcritical pipe breaks to be used in mechanical and structural analyses. However, before embarking on an extensive development effort for any applicant, we believe it would be beneficial to meet with the members of your staff who would be directly involved in the review of this effort. This meeting will help ensure that NRC concerns, if any, regarding the development of a new design basis pipe break are properly addressed. It is requested that this meeting be scheduled at the earliest convenience of your staff.

Please contact me or Mr. J. M. Westhoven of my staff at (203)688-1911, Extension 4114 to establish the time and date of the meeting.

Very truly yours,

COMBUSTION ENGINEERING, INC.

A. E. Scherer
Director
Nuclear Licensing

AES:dac

Attachment

XG01
S/1

AGENDA

I.	INTRODUCTION	T. E. NATAN
II.	PIPE BREAK CRITERIA	D. A. PECK
	A. CURRENT PRACTICE	
	B. ALTERNATIVE CRITERIA	
III.	JUSTIFICATION OF CRITERIA	D. J. AYRES
	A. FLAW FATIGUE GROWTH	
	B. CRACK OPENING AND LEAKAGE	
	C. CRACK STABILITY DURING SSE	
IV.	SUMMATION	T. E. NATAN
	FUTURE ACTION	

I. PURPOSE

ESTABLISH A COMPLETE SET OF
SUBCRITICAL DESIGN BASIS PIPE BREAKS

II. SCOPE

1. RCS MAIN LOOP PIPES ONLY
2. MECHANISTIC EFFECTS ONLY

III. HISTORICAL DEVELOPMENT

1. CONTAINMENT DESIGN BASIS
2. ECCS DESIGN BASIS
3. MECHANISTIC EFFECTS

CURRENT PIPE BREAK PHILOSOPHY

1. A PLANT DESIGNED FOR A LIMITED NUMBER OF CONSERVATIVE PIPE BREAKS CAN WITHSTAND MORE REALISTIC PIPE BREAKS AT OTHER LOCATIONS FOR WHICH THE PLANT IS NOT SPECIFICALLY DESIGNED.

2. STRESS AND/OR USAGE FACTOR IN THE PIPE SYSTEM CAN BE USED TO DETERMINE THE LIMITED NUMBER OF PIPE BREAK LOCATIONS FOR WHICH THE PLANT SHOULD BE DESIGNED.

3. SYSTEM CHARACTERISTICS, SUCH AS PIPE STRENGTH AND STIFFNESS, AND PLANT FEATURES, SUCH AS PIPE WHIP RESTRAINTS, MAY BE USED TO MITIGATE THE CONSEQUENCES OF POSTULATED PIPE BREAKS.

PIPE BREAK CRITERIA

BASIS

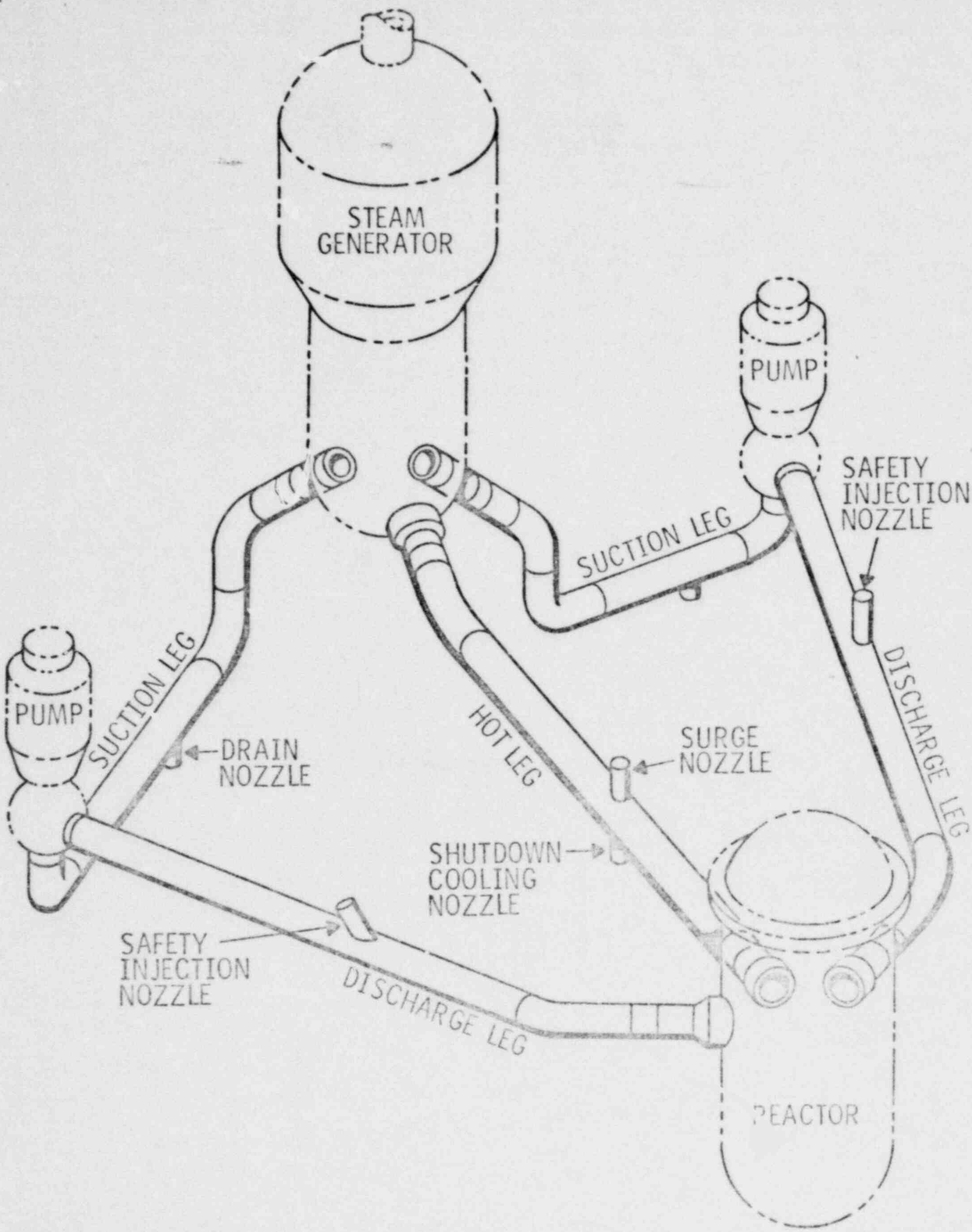
PIPES ARE MORE LIKELY TO EXPERIENCE A FAILURE AT LOCATIONS OF RELATIVELY HIGHER STRESS OR RESTRAINT

CURRENT PRACTICE

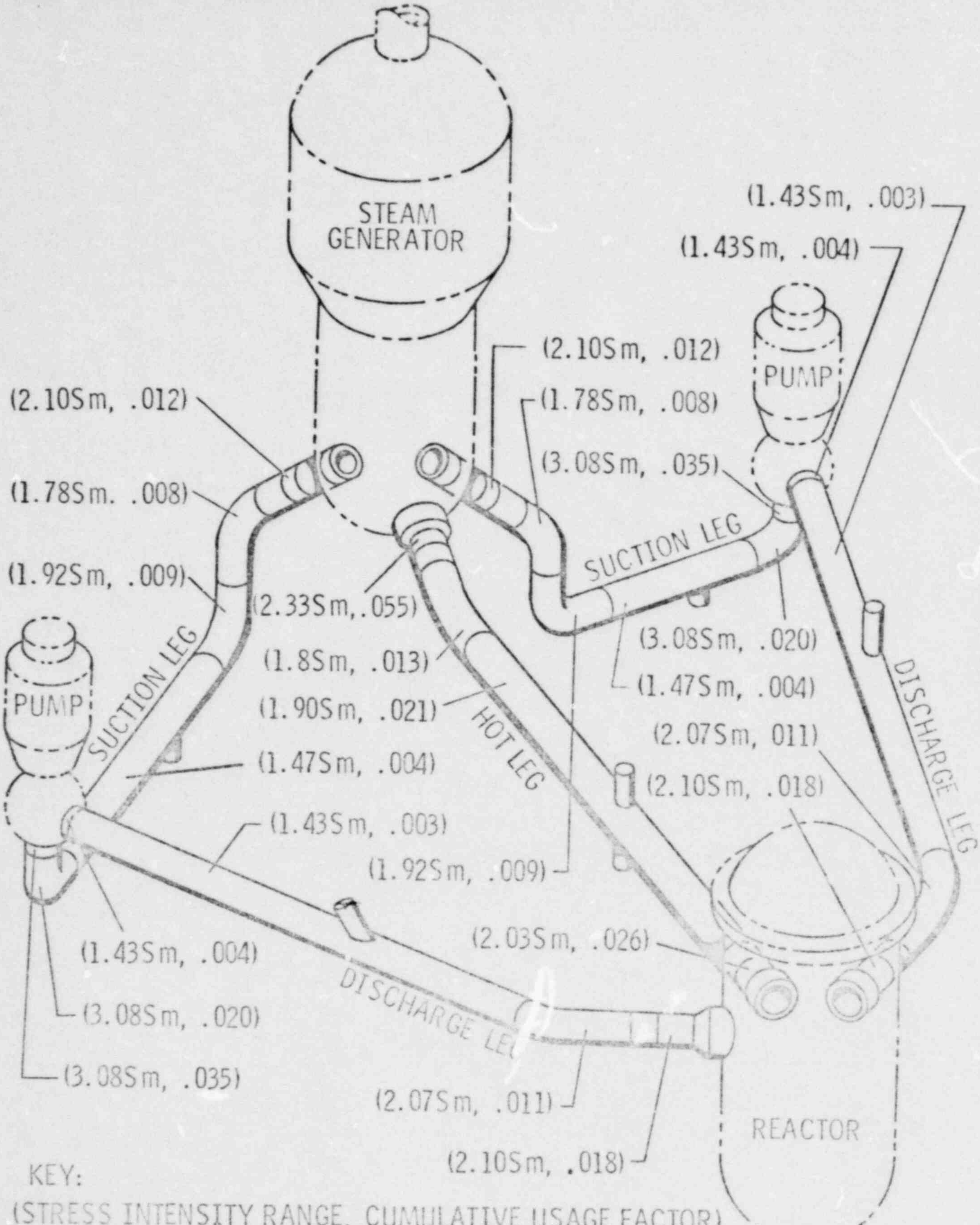
DESIGN FOR A LIMITED NUMBER OF CONSERVATIVELY LARGE BREAKS TO PROVIDE A LEVEL OF PLANT STRENGTH CAPABLE OF WITHSTANDING A SIGNIFICANT NUMBER OF ADDITIONAL BREAKS

ALTERNATIVE PRACTICE

DESIGN FOR A SIGNIFICANTLY LARGE NUMBER OF REASONABLY CONSERVATIVE PIPE BREAKS TO PROVIDE A HIGH LEVEL OF PLANT STRENGTH

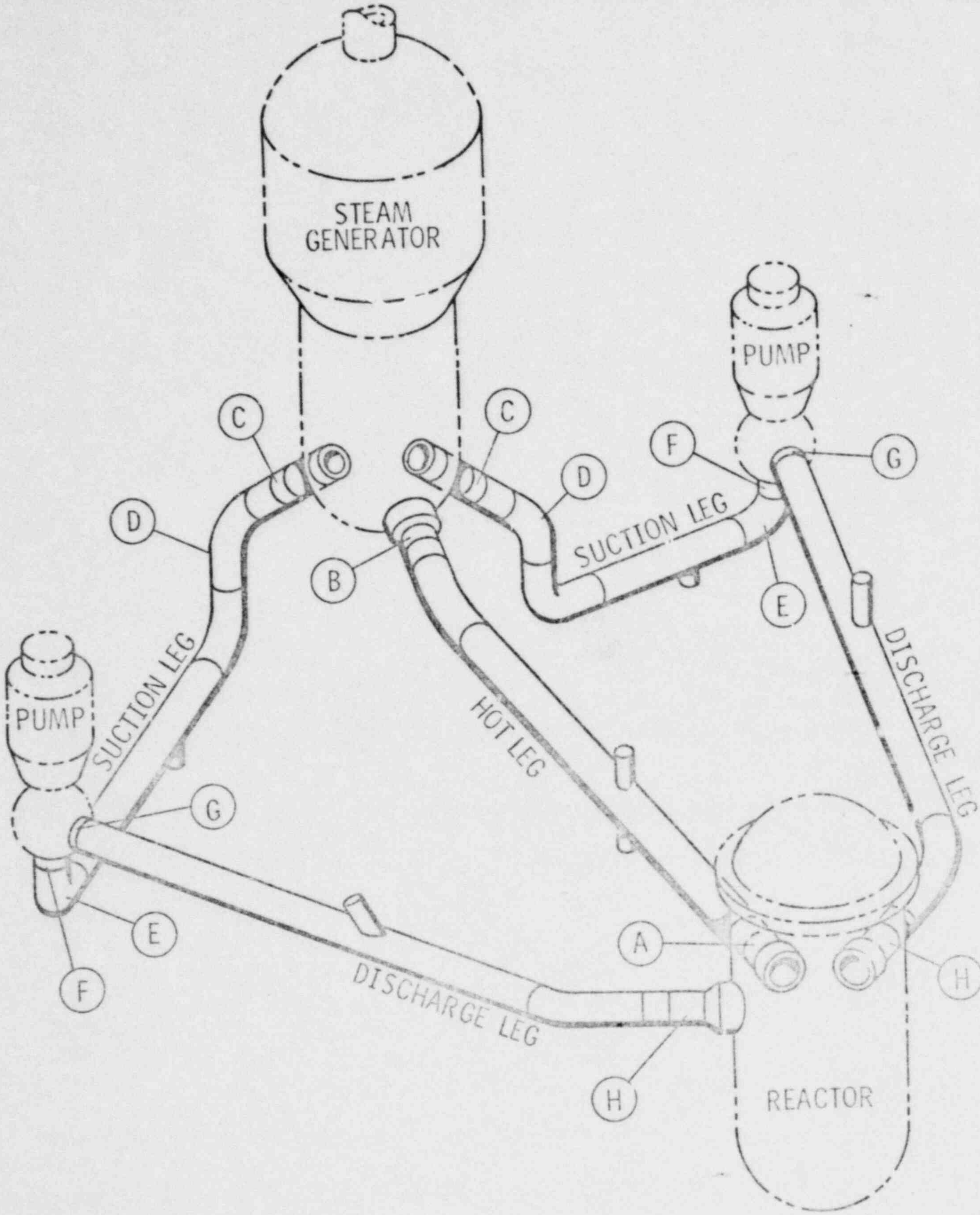


POWER SYSTEMS COMBUSTION ENGINEERING, INC.	MAIN LOOP PIPING ARRANGEMENT	Figure



KEY:
(STRESS INTENSITY RANGE, CUMULATIVE USAGE FACTOR)

POWER SYSTEMS COMBUSTION ENGINEERING, INC.	MAIN LOOP PIPING STRESS SURVEY	Figure



POWER SYSTEMS COMBUSTION ENGINEERING, INC	SUMMARY OF PIPE BREAK LOCATIONS FOR CURRENT CRITERIA	Figure 2-1

361/js

Table 2-1

Pipe Break Summary for Current Criteria

(Reference CENPD-168A)

Pipe	Location	Break Type Description	Flow Area (Sq. in.)
	(2) R.V. terminal end	circumferential break	100
hot leg	(2) S.G. terminal end	circumferential break	600
discharge leg	[illegible] terminal end	circumferential break	350
	[illegible] terminal end	circumferential break	480
	(4) Pump terminal end	circumferential break	430
suction leg	(4) pump elbow	slot ±90° from elbow crotch	532
	(4) S.G. elbow	slot ±90° from elbow crotch	532
	(4) S.G. terminal end	circumferential break	592
Total	28		

Note: Flow areas listed are total area available for flow from both sides of a given break location.

Numbers in parentheses indicate total number of locations in the complete piping system.

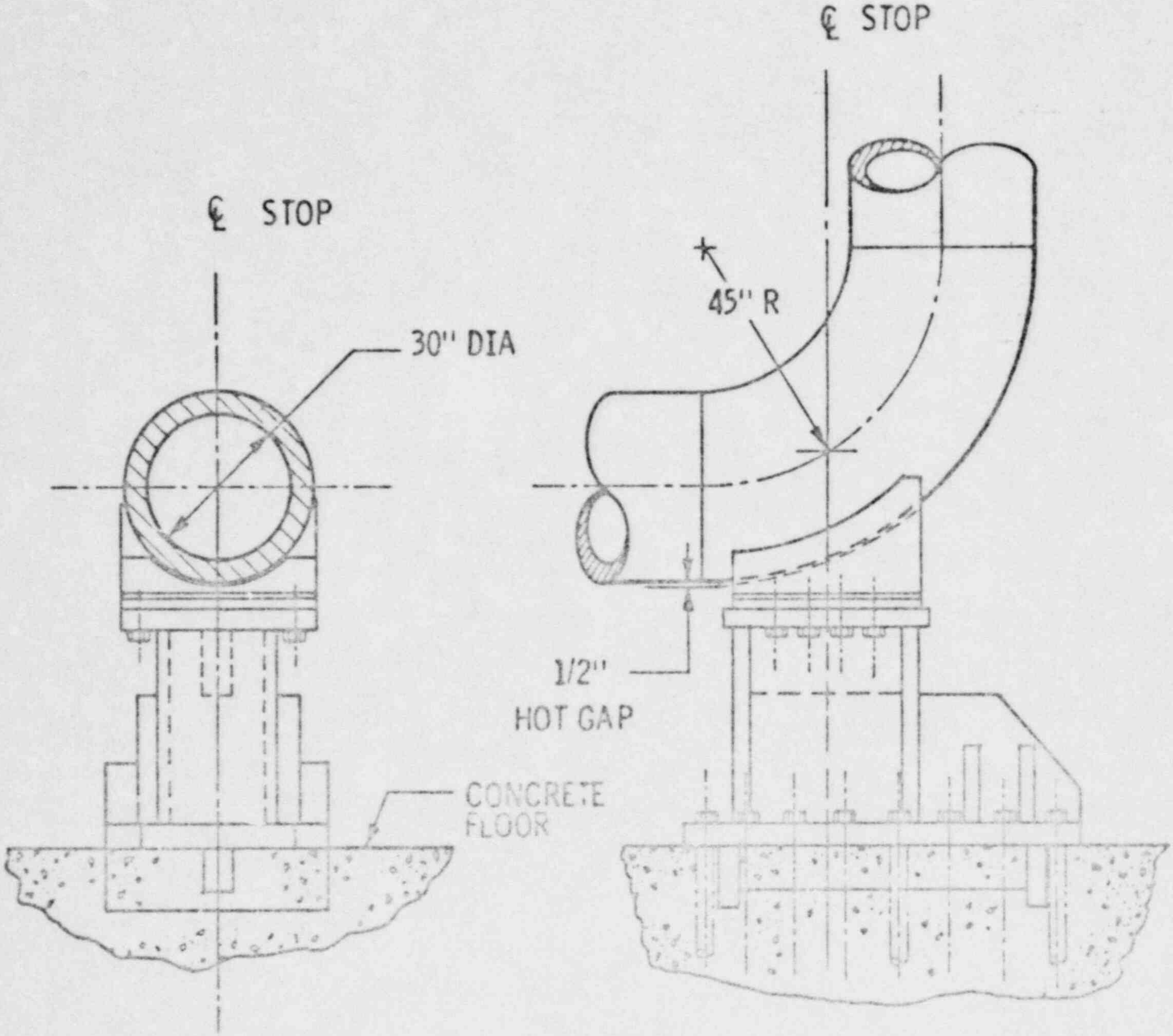
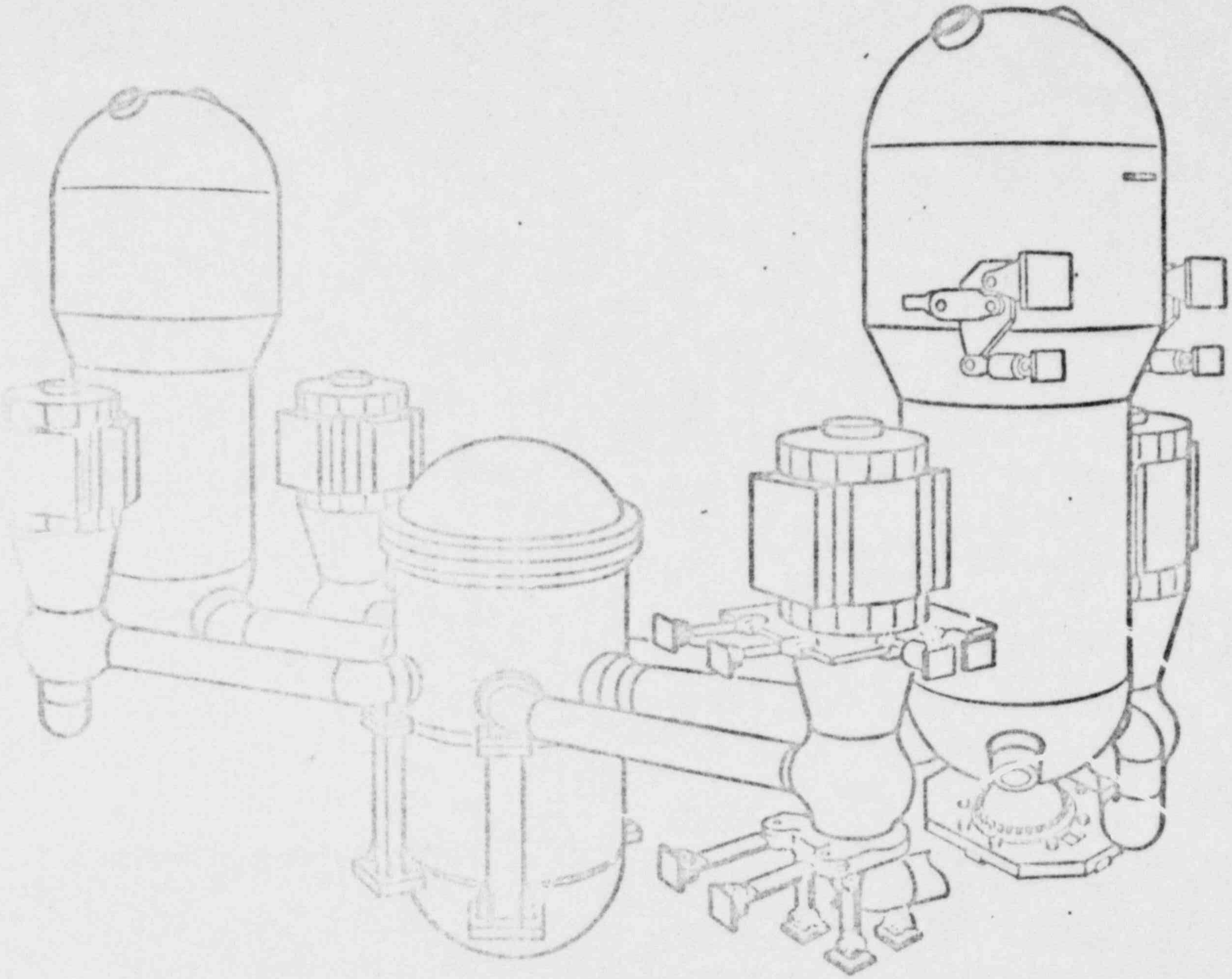


Figure 2-2
TYPICAL PIPE RESTRAINT

SYSTEM 80™ NUCLEAR STEAM SUPPLY SYSTEM



C-E RCS MAIN LOOP PIPING CHARACTERISTICS

UNRESTRAINED THERMAL EXPANSION OF LOOP

SLOW PUMP STARTS/STOPS

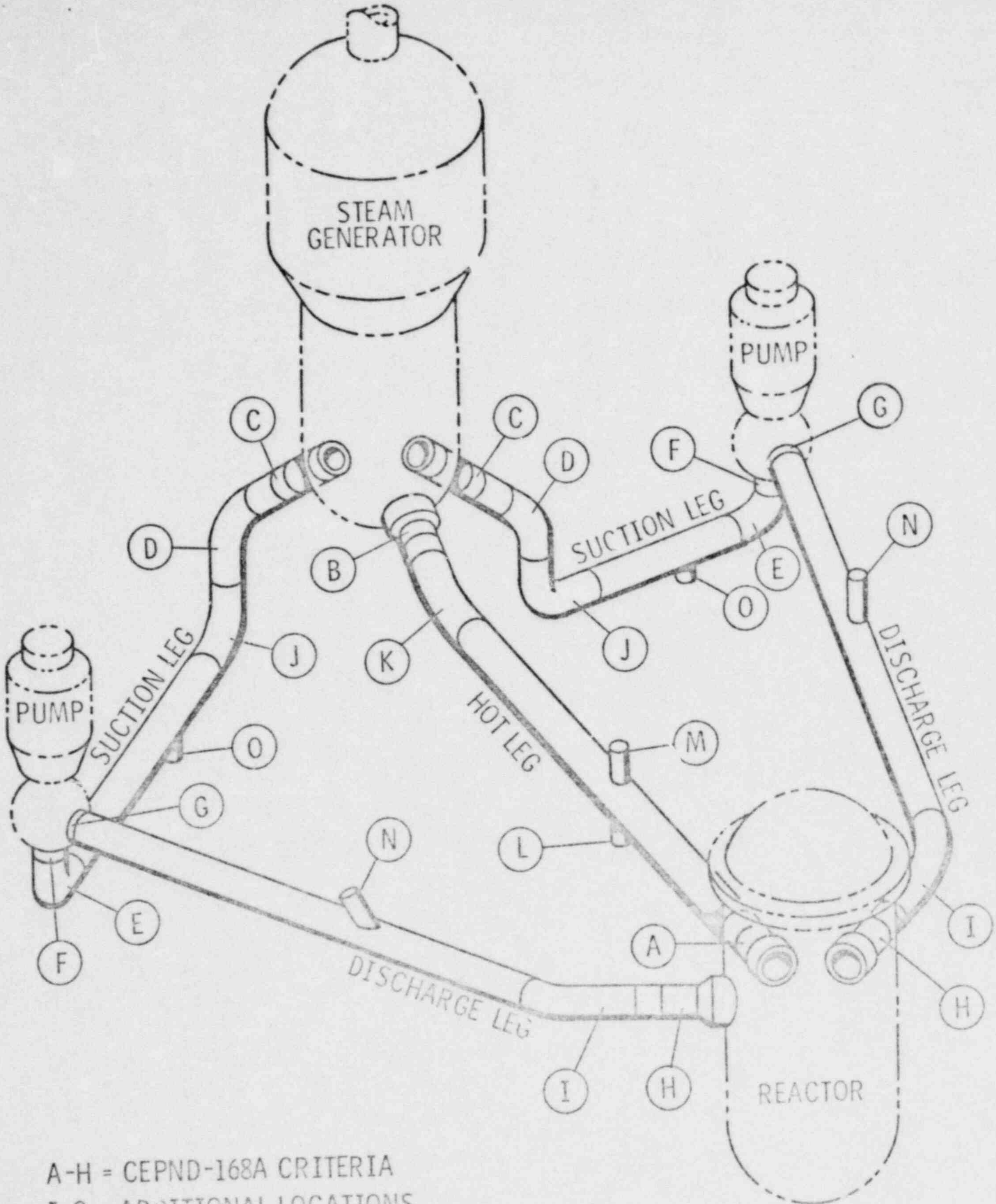
PUMP VIBRATION LIMITS

NO MAIN LOOP VALVE CLOSURE TRANSIENTS

MILD THERMAL TRANSIENTS

LOW SEISMIC RESPONSES

LOW WATER TEMPERATURE STRATIFICATION



A-H = CEPND-168A CRITERIA
I-O = ADDITIONAL LOCATIONS

POWER SYSTEMS COMBUSTION ENGINEERING, INC.	SUMMARY OF PIPE BREAK LOCATIONS FOR ALTERNATE CRITERIA	Figure 9-1

Table 9-1

Pipe Break Summary for Alternate Criteria

Pipe	Location	Break Type Description	Flow Area (Sq. in.)
hot leg	(2) R.V. terminal end	circumferential slot	138.5
	(1) Intermediate	branch line guillotine	80.5
	(2) Intermediate	branch line guillotine	129.
	(2) Elbow	slot ±90° from elbow crotch	138.5
	(2) S.G. terminal end	circumferential slot	138.5
discharge leg	(4) R.V. terminal end	circumferential slot	70.7
	(4) Elbow	slot ±90° from elbow crotch	70.7
	(4) Intermediate	branch line guillotine	98.5
	(1) Intermediate	branch line guillotine	2.25
	(2) Intermediate	branch line guillotine	5.5
	(4) Pump terminal end	circumferential slot	70.7
suction leg	(4) Pump terminal end	circumferential slot	70.7
	(4) Pump elbow	slot ±90° from elbow crotch	70.7
	(4) Intermediate	branch line guillotine	2.25
	(4) Elbow	slot ±90° from elbow crotch	70.7
	(4) S.G. elbow	slot ±90° from elbow crotch	70.7
	(4) S.G. terminal end	circumferential slot	70.7
Total	52		

Note: Only one of each type of main loop pipe is shown. Results apply at all typical locations throughout the piping system.

Numbers in parentheses indicate total number of locations in the whole piping system.

EFFECTS ON PLANT OF NEW PIPE BREAKS

ELIMINATION OF RCS PIPE WHIP RESTRAINTS

ELIMINATION OF COMPONENT STOPS

REDUCTION OF BOLT STRENGTHS AND PRELOADS

REDUCTION OF FOUNDATION LOADS

REDUCTION OF ASYMMETRIC LOADS EFFECTS

NO CHANGE IN SUPPORTS STIFFNESS FOR SEISMIC

INCREASED NUMBER OF SMALLER JETS

REDUCED ISI TIME

INCREASED BRANCH LINE ROUTING ACCESS

OBJECTIVE

DEMONSTRATION OF
LEAK BEFORE BREAK

MAJOR GOALS

I. INITIAL FLAWS WOULD TEND TO PROPOGATE THROUGH THE WALL (RATHER THAN EXTEND) DUE TO LOADING CONDITIONS IN MAIN LOOP.

II. THROUGH WALL CRACKS WOULD OPEN SUFFICIENTLY TO ALLOW DETECTION BY NORMAL LEAKAGE MONITORING UNDER NORMAL LOADING CONDITIONS.

III. DETECTABLE LENGTH CRACKS WOULD REMAIN STABLE UNDER SSE LOADING.

CRACK GROWTH

INITIAL CONSIDERATIONS

I. TRANSIENTS WELL UNDERSTOOD

II. SECTION III FABRICATION AND INSPECTION

III. ASSUMED FLAW SIZE 1" BY 10"

IV. CRACK GROWTH LAW:

$$\frac{DA}{DN} = C' \Delta K^{N}$$

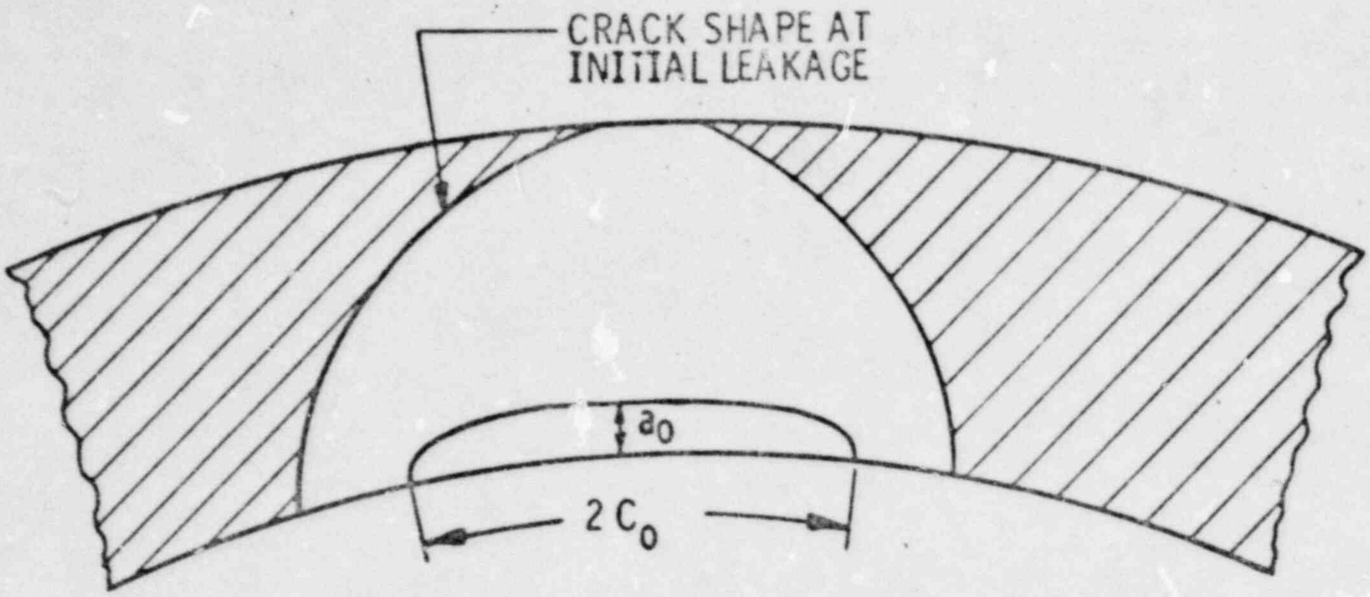


Figure 4-2a

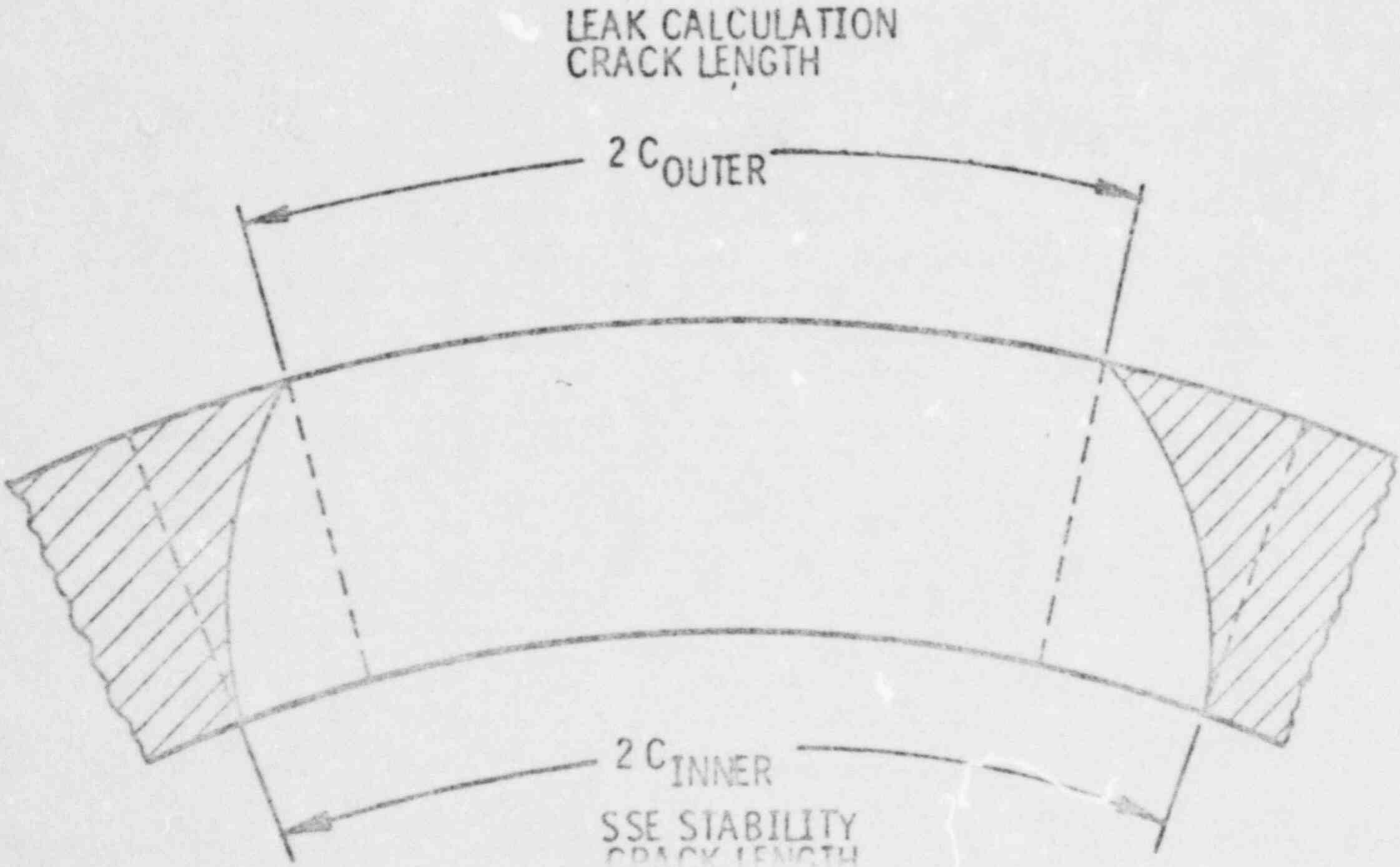
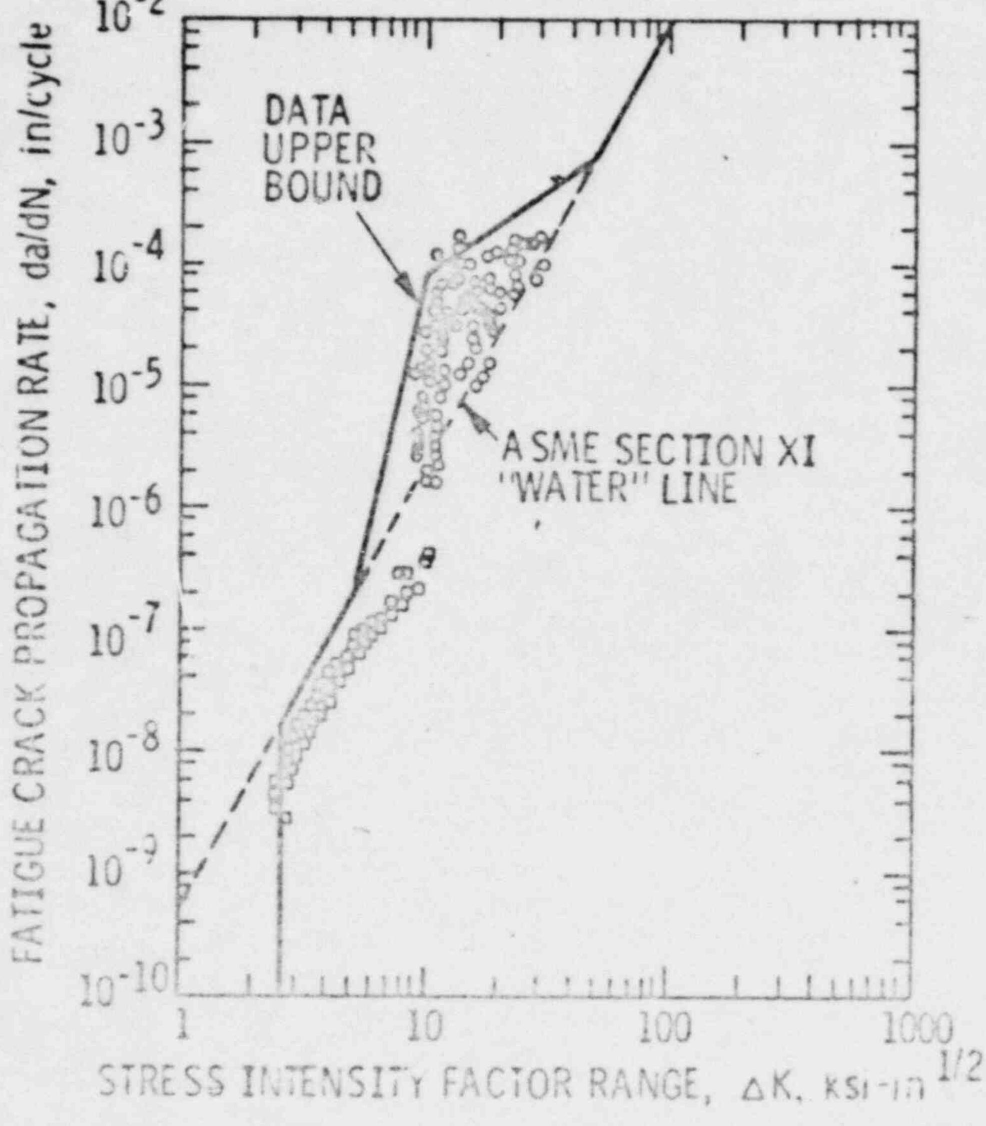


Figure 4-2b

Figure 4-1
REFERENCE FATIGUE CRACK GROWTH CURVE



DETECTABLE LEAKING CRACKS

I. LOCATION OF CRACKS

II. SUBSTRUCTURE MODELING TECHNIQUES

III. IN-SYSTEM STEADY STATE NORMAL OPERATION LOADS

- PRESSURE
- THERMAL DISPLACEMENTS

IV. AREA VS LENGTH

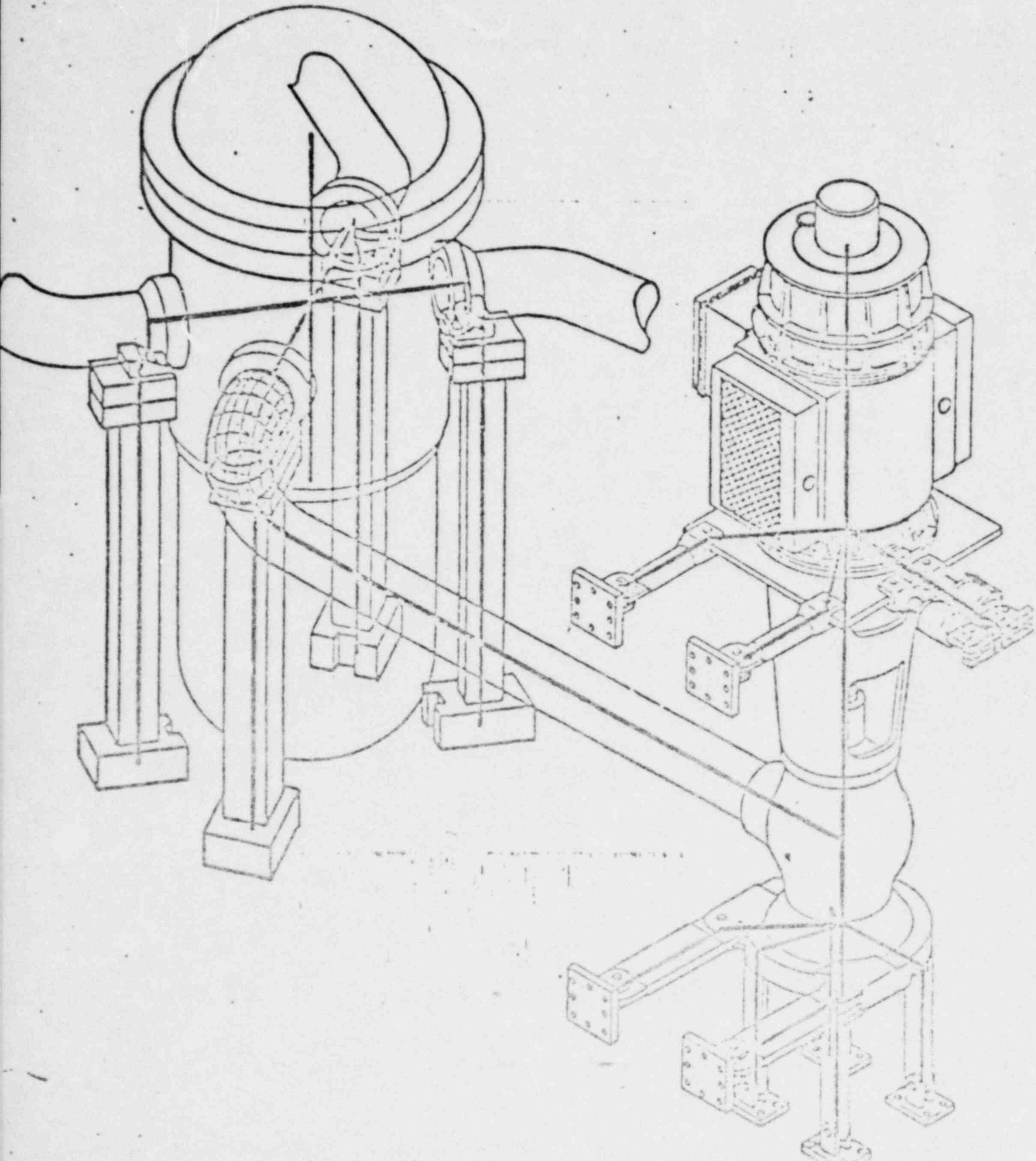


Figure 6

SYSTEM 80™ NUCLEAR STEAM SUPPLY SYSTEM

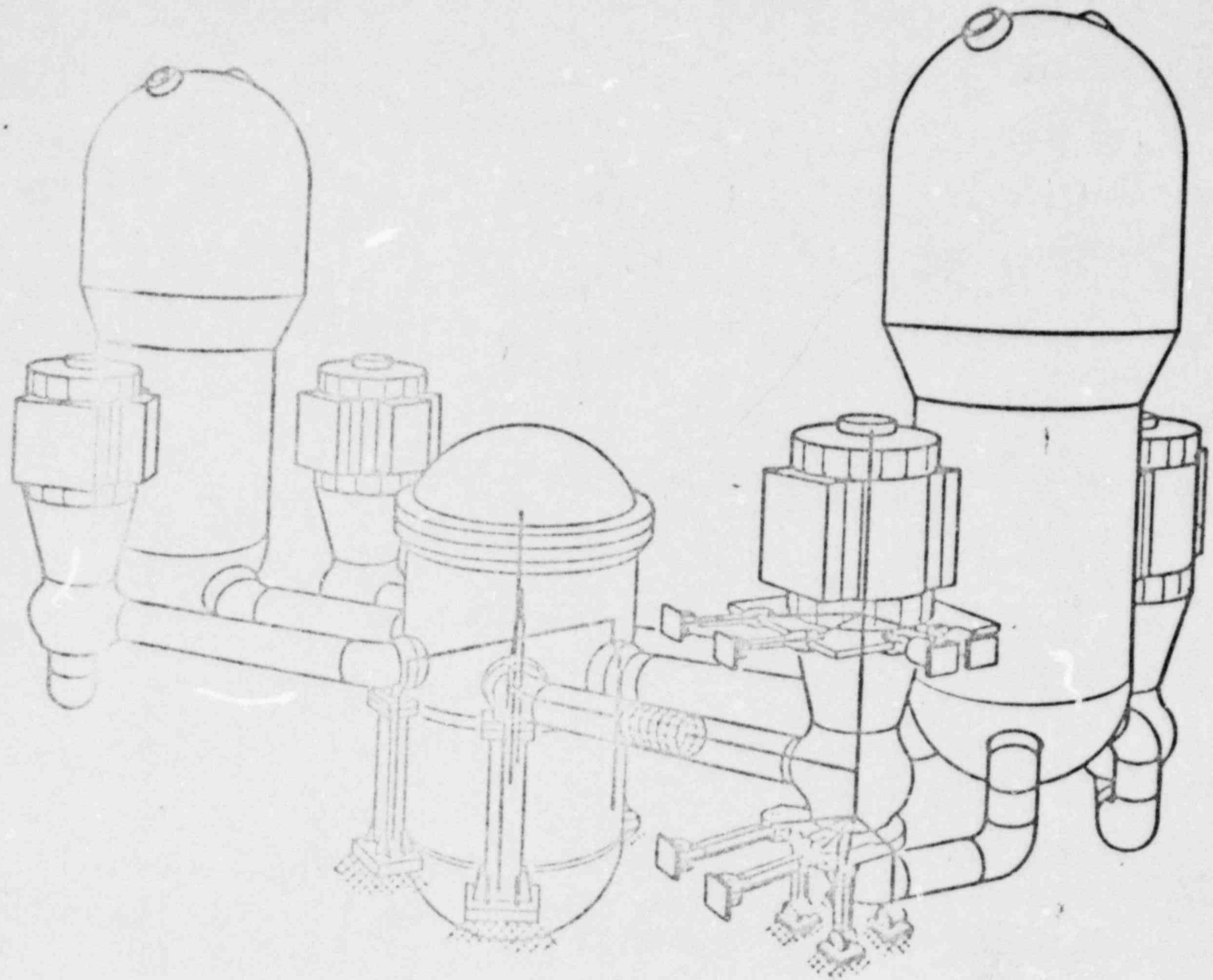
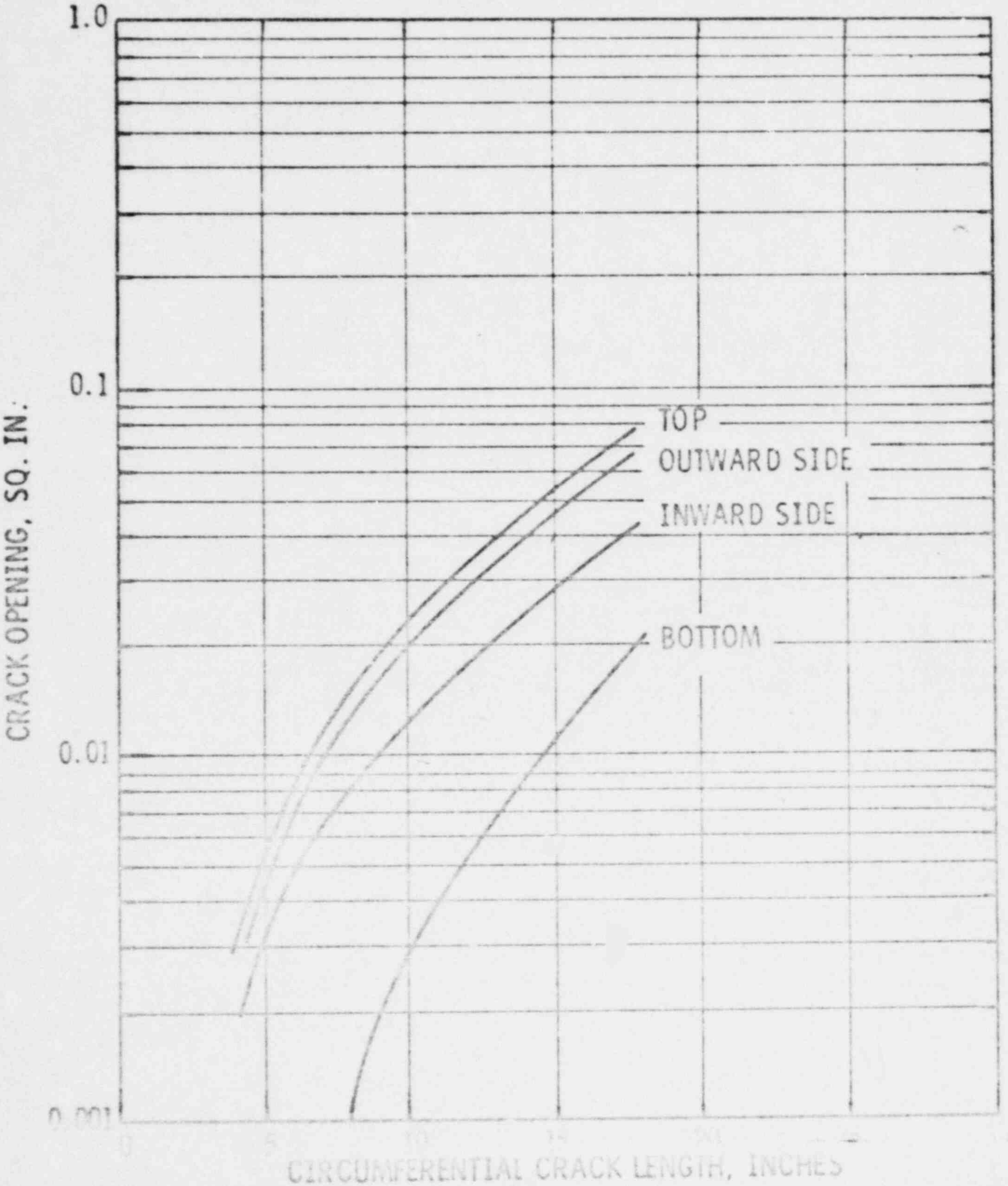


Figure 4

CRACK OPENING AREA vs. CRACK LENGTH FOR 30" DISCHARGE LEG TERMINAL END AT REACTOR VESSEL INLET NOZZLE WITH NORMAL OPERATING SYSTEM LOADS



CRACK OPENING AREA vs. CRACK LENGTH FOR 42" HOT LEG TERMINAL END AT REACTOR VESSEL OUTLET NOZZLE WITH NORMAL OPERATING SYSTEM LOADS

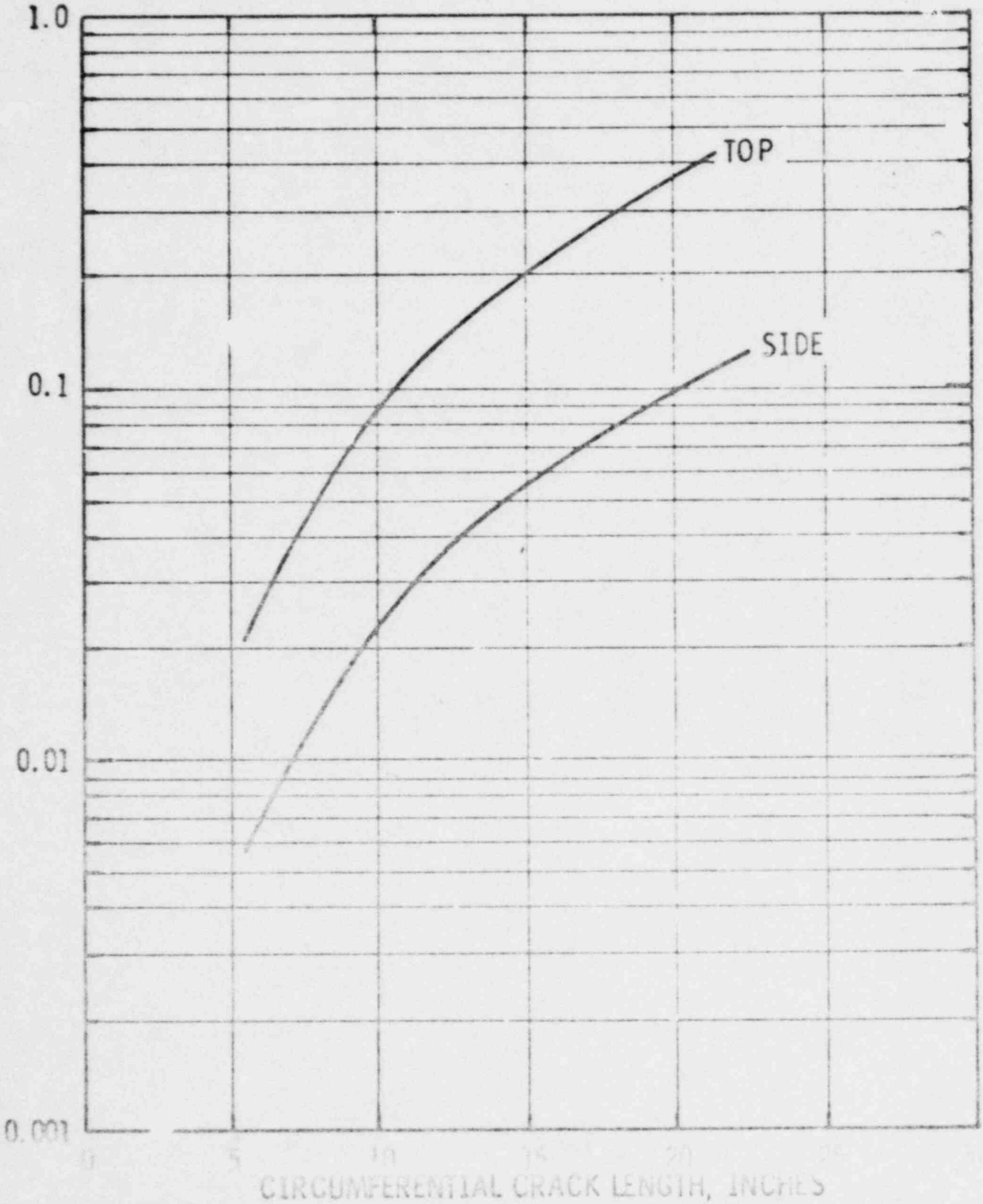
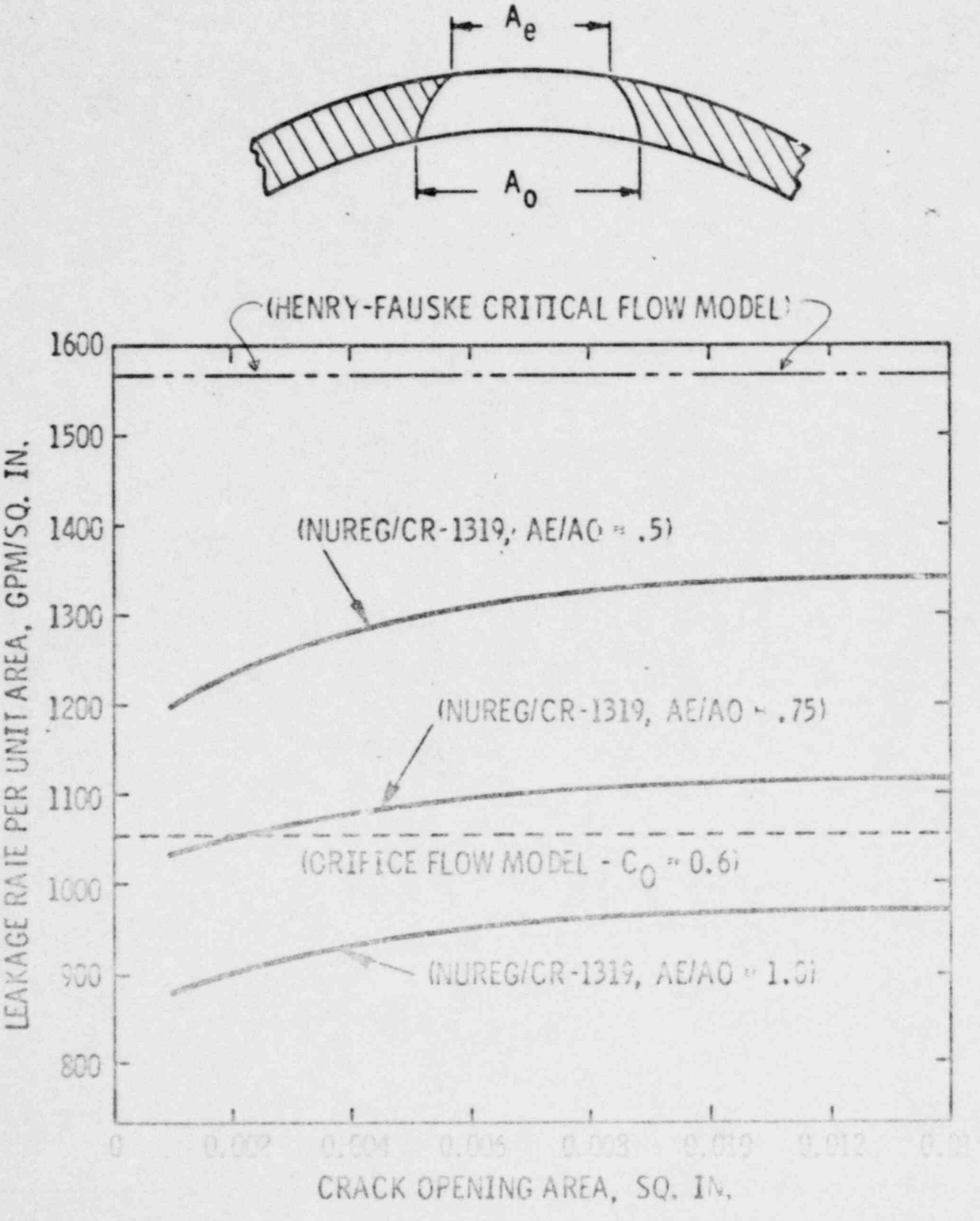
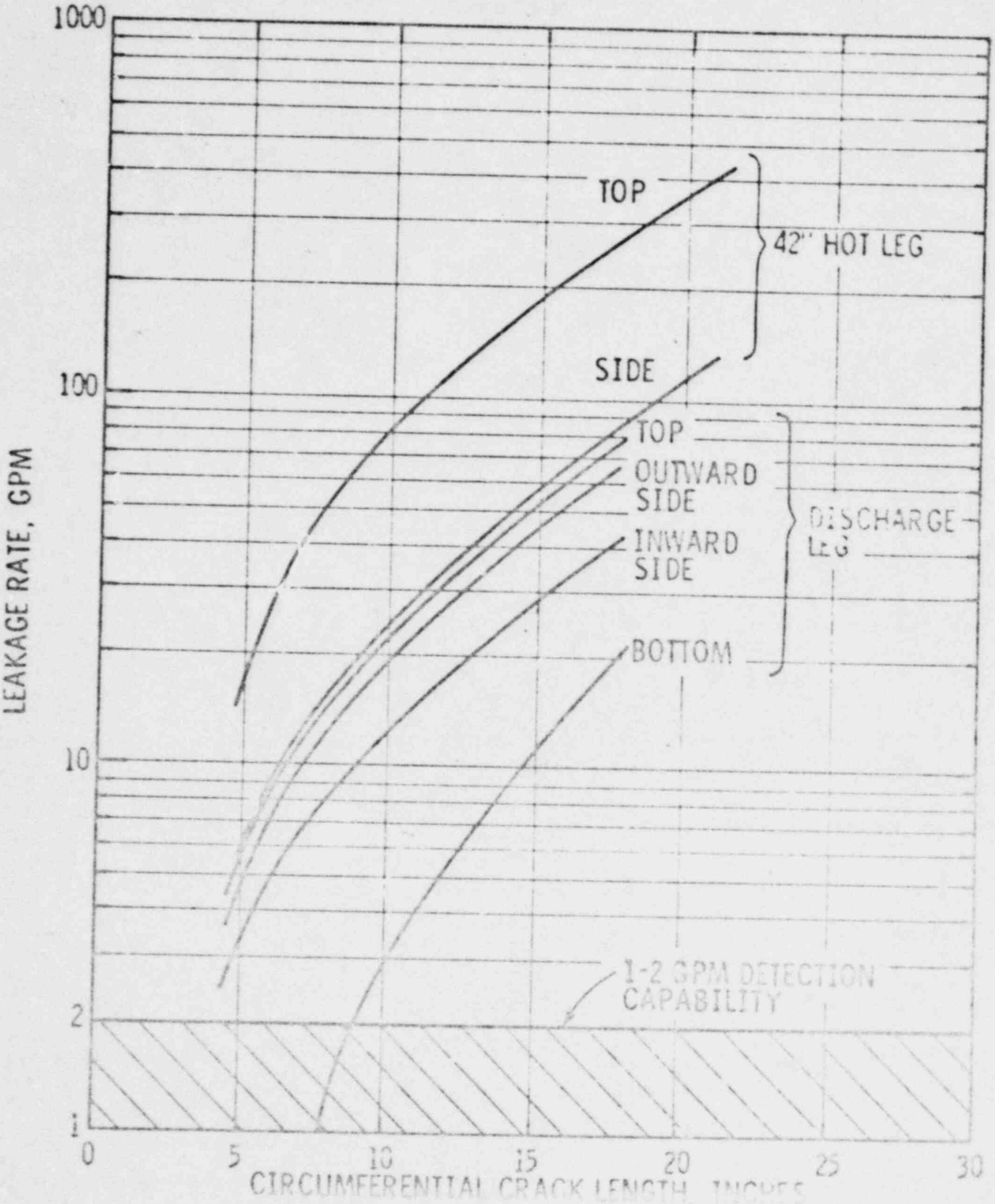


Figure 5.2-1

LEAKAGE RATE PER UNIT AREA FOR 30" DIA C. S. COLD LEG PIPE
AT 2250 PSI, 550^{0}F



LEAKAGE RATE vs. CRACK LENGTH FOR 30" AND 42" PIPE TERMINAL ENDS AT REACTOR VESSEL NOZZLES WITH NORMAL OPERATING SYSTEM LOADS



TEARING MODULUS CONCEPT

I. J-INTEGRAL AS ELASTIC PLASTIC CRACK TIP PARAMETER, A FUNCTION OF:

- CRACK SIZE
- LOADING
- GEOMETRY

II. TEARING MODULUS IS RATE OF CHANGE OF J_{APPL} WITH CRACK EXTENSION

$$T_{APPL} = \frac{E}{\sigma_0^2} \frac{D J_{APPL}}{DA}$$

III. INSTABILITY OCCURS WHEN

$$J_{APPL} > J_{IC}$$

AND

$$T_{APPL} > T_{MAT}$$

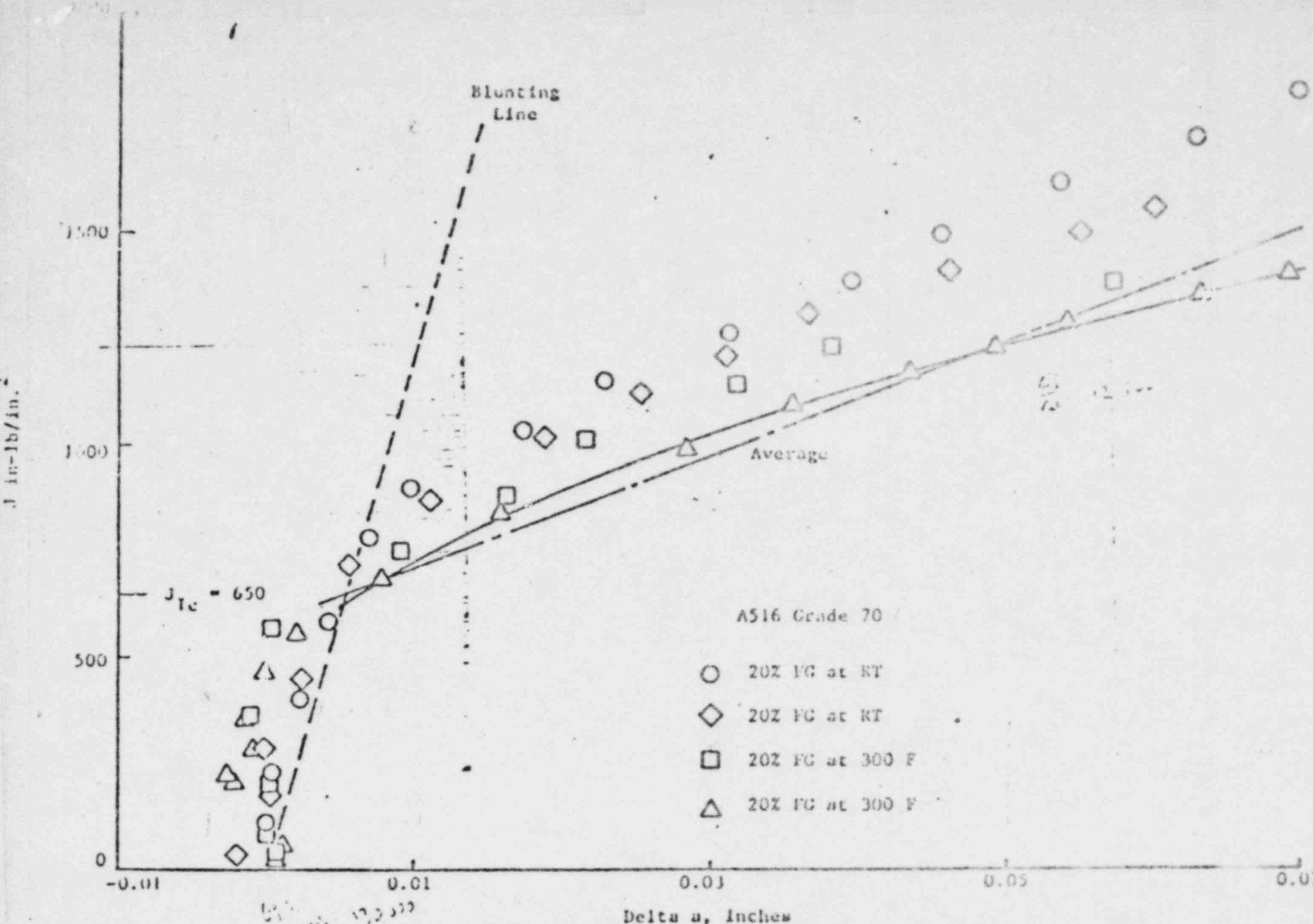
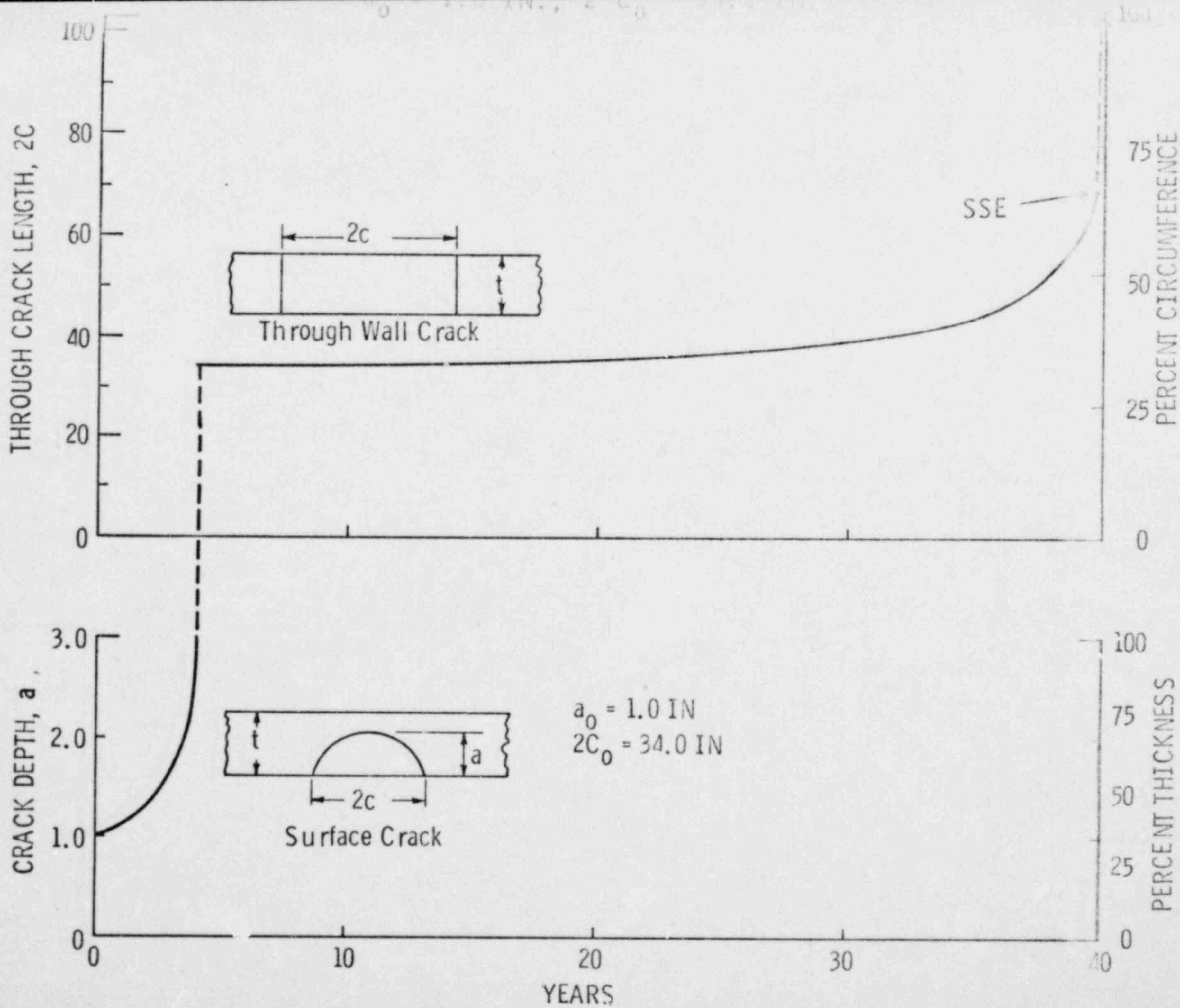
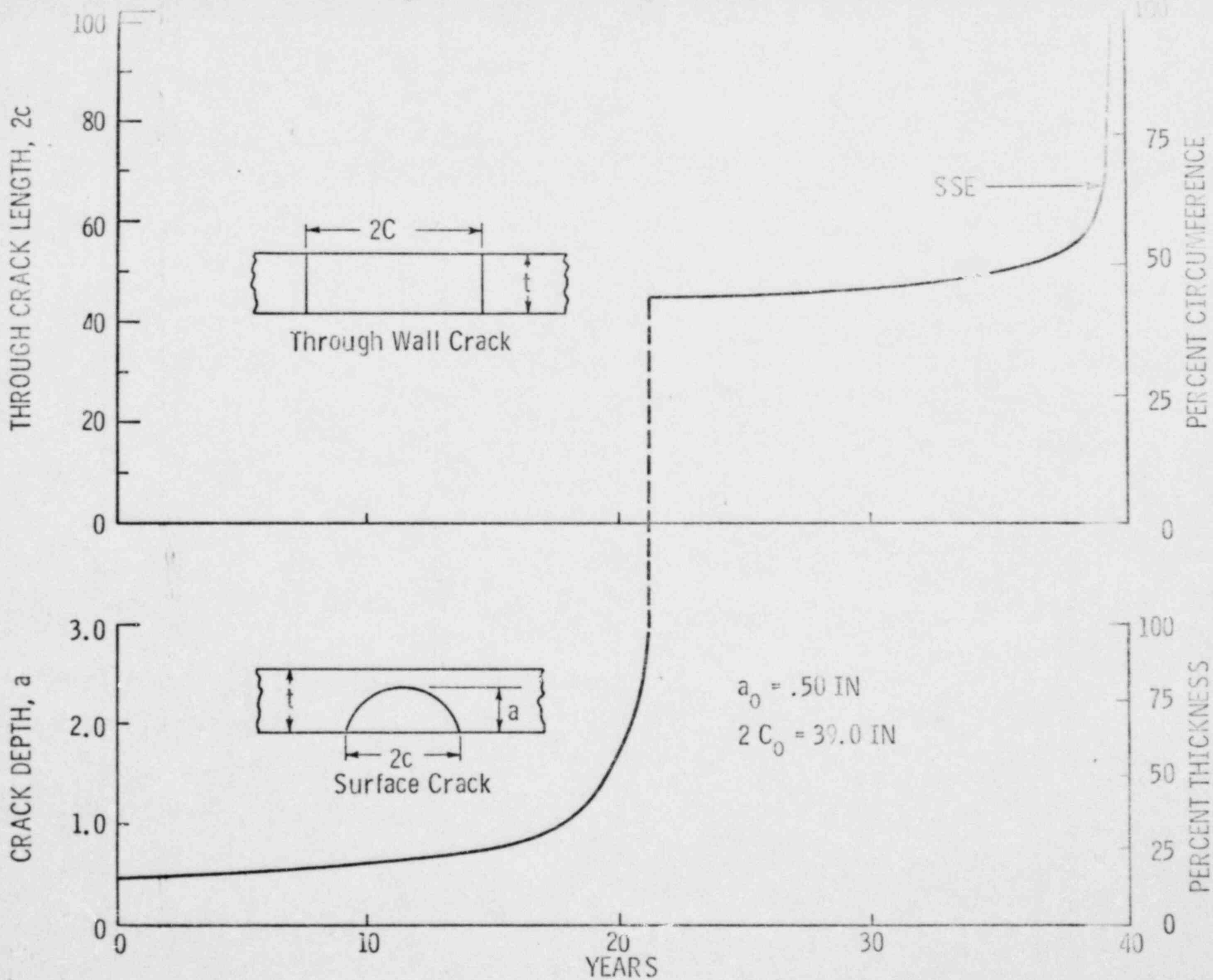

Blunting Line
J_{Ic} = 650
Average
A516 Grade 70
20% FG at RT
20% FG at RT
20% FG at 300 F
20% FG at 300 F
J in-lb/in.^{2}
1000
500
0
-0.01
0.01
0.03
0.05
0.07
Delta a, Inches

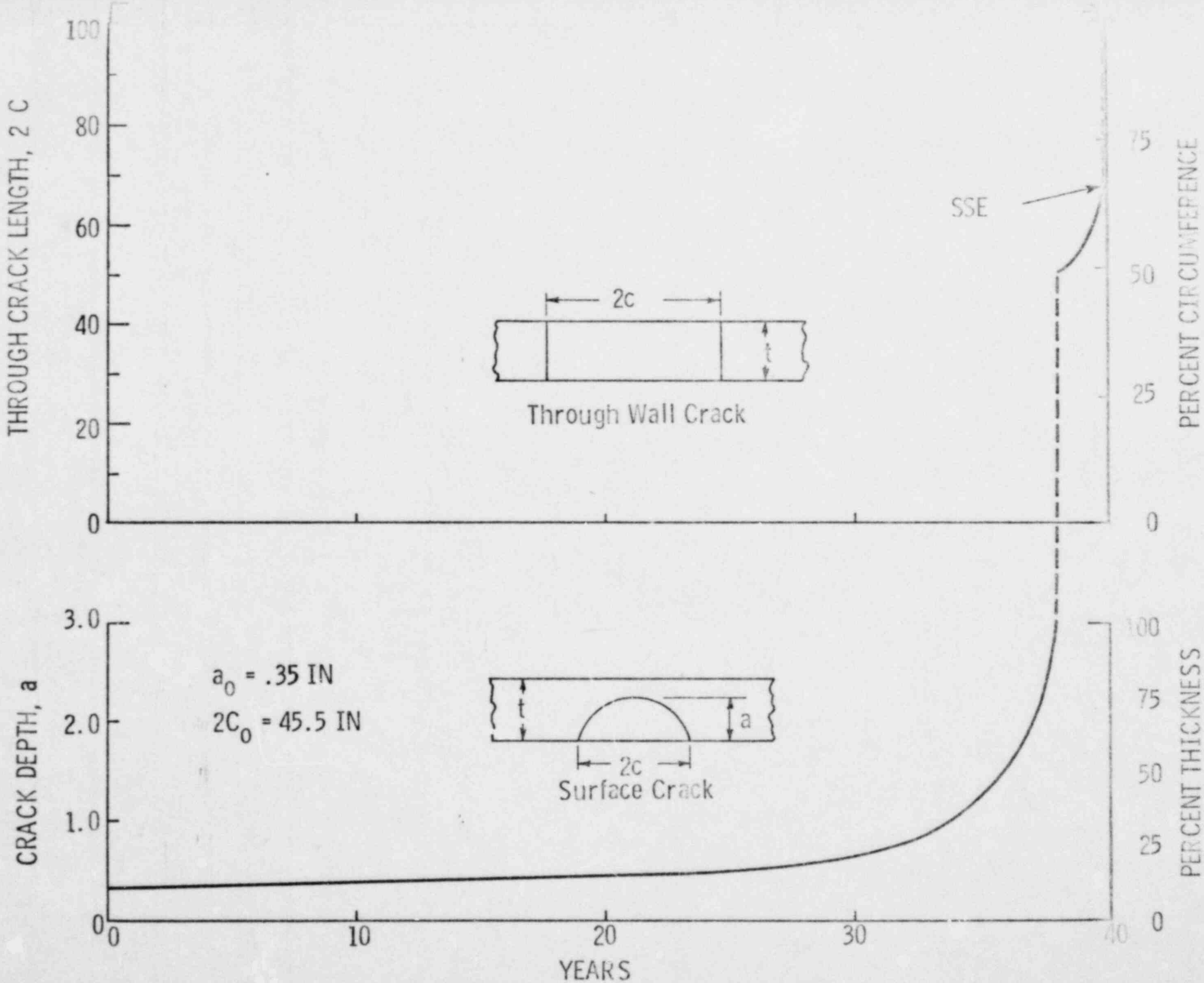
FIGURE A-10.



THROUGH CRACK LENGTH, 2C
PERCENT CIRCUMFERENCE
SSE
2c
t
Through Wall Crack
CRACK DEPTH, a
PERCENT THICKNESS
t
a
2c
Surface Crack
a_0 = 1.0 IN
$2C_0$ = 34.0 IN
YEARS
0
10
20
30
40
0
20
40
60
80
100
0
1.0
2.0
3.0
0
25
50
75
100



THROUGH CRACK LENGTH, 2c
100
80
60
40
20
0
PERCENT CIRCUMFERENCE
100
75
50
25
0
SSE
2C
t
Through Wall Crack
CRACK DEPTH, a
3.0
2.0
1.0
0
PERCENT THICKNESS
100
75
50
25
0
t
a
2c
Surface Crack
a_0 = .50 IN
2 C_0 = 39.0 IN
0
10
20
30
40
YEARS



THROUGH CRACK LENGTH, 2 C
100
80
60
40
20
0
PERCENT CIRCUMFERENCE
75
50
25
0
SSE
2c
t
Through Wall Crack
CRACK DEPTH, a
3.0
2.0
1.0
0
PERCENT THICKNESS
100
75
50
25
0
a_0 = .35 IN
$2C_0$ = 45.5 IN
t
a
2c
Surface Crack
0
10
20
30
40
YEARS

RANGE OF INITIAL FLAW SIZES

$2C_0$ VS. a_0

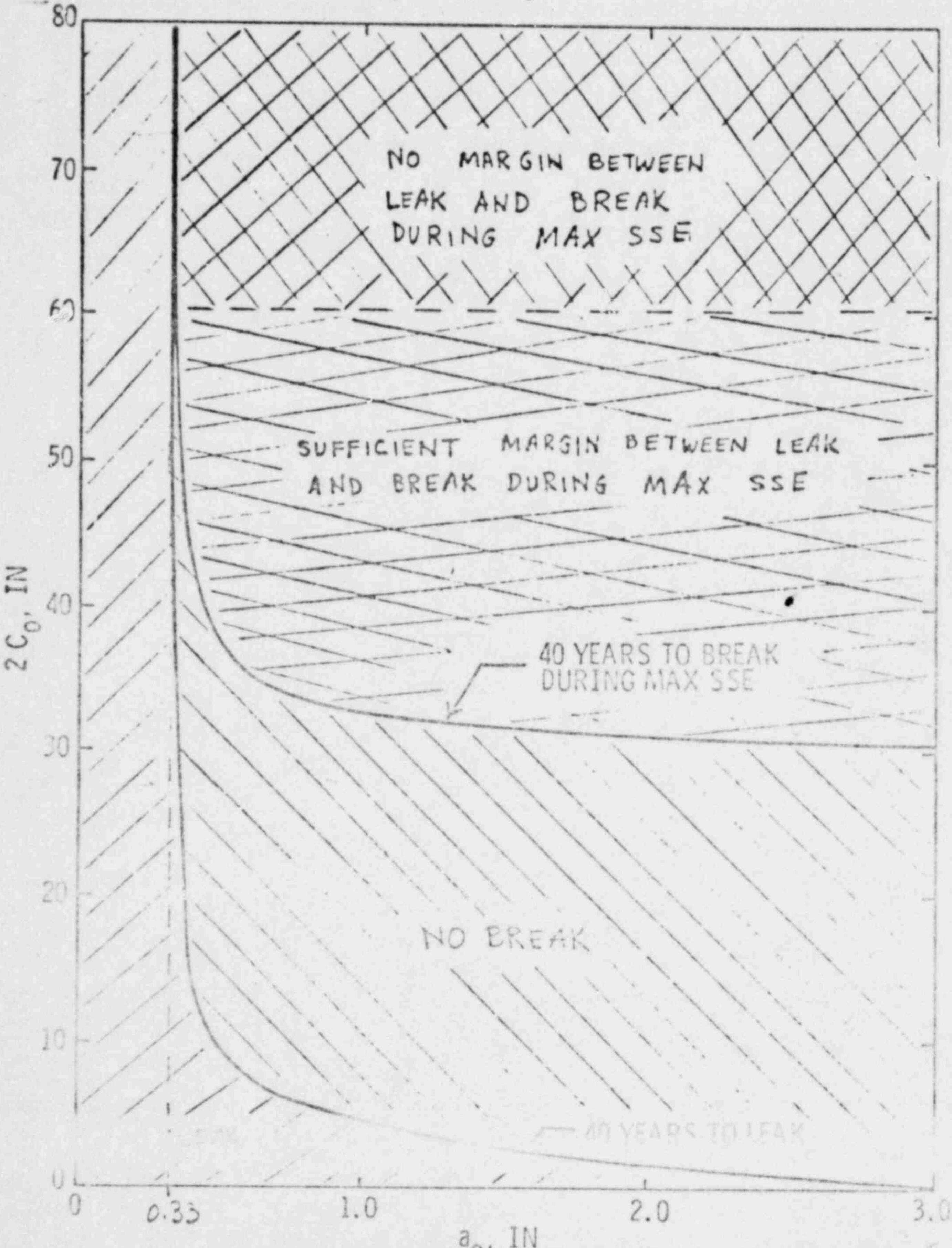
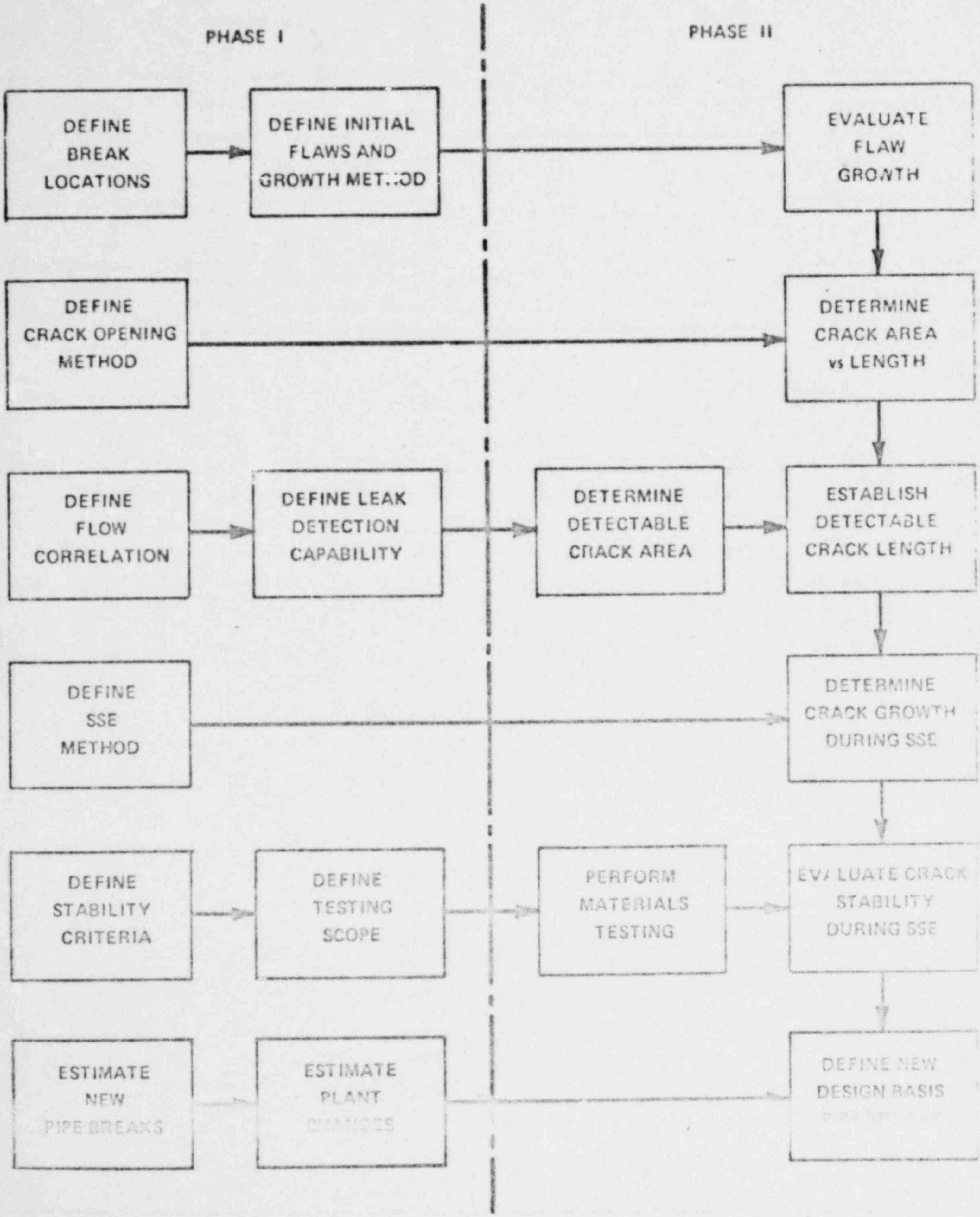


Figure 16

Figure II-1


PHASE I
PHASE II
DEFINE BREAK LOCATIONS
DEFINE INITIAL FLAWS AND GROWTH METHOD
EVALUATE FLAW GROWTH
DEFINE CRACK OPENING METHOD
DETERMINE CRACK AREA vs LENGTH
DEFINE FLOW CORRELATION
DEFINE LEAK DETECTION CAPABILITY
DETERMINE DETECTABLE CRACK AREA
ESTABLISH DETECTABLE CRACK LENGTH
DEFINE SSE METHOD
DETERMINE CRACK GROWTH DURING SSE
DEFINE STABILITY CRITERIA
DEFINE TESTING SCOPE
PERFORM MATERIALS TESTING
EVALUATE CRACK STABILITY DURING SSE
ESTIMATE NEW PIPE BREAKS
ESTIMATE PLANT CHANGES
DEFINE NEW DESIGN BASIS