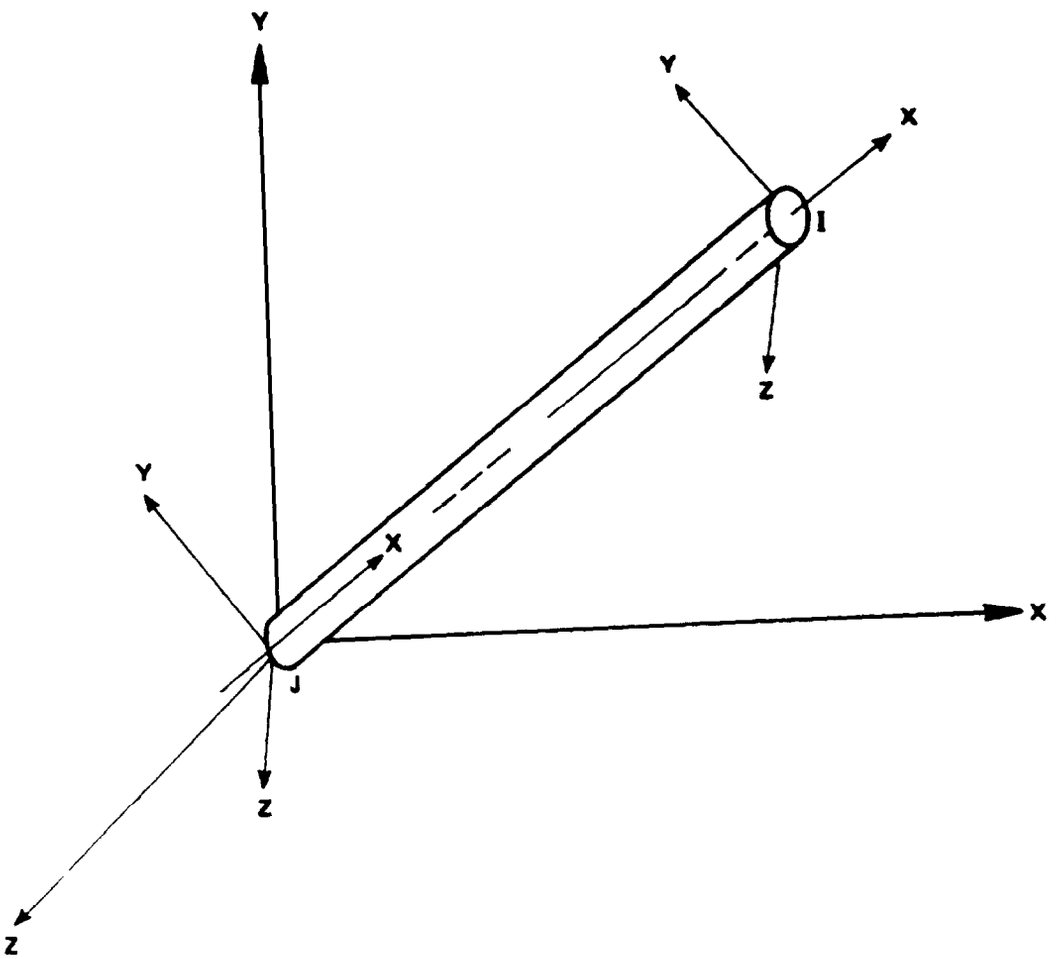
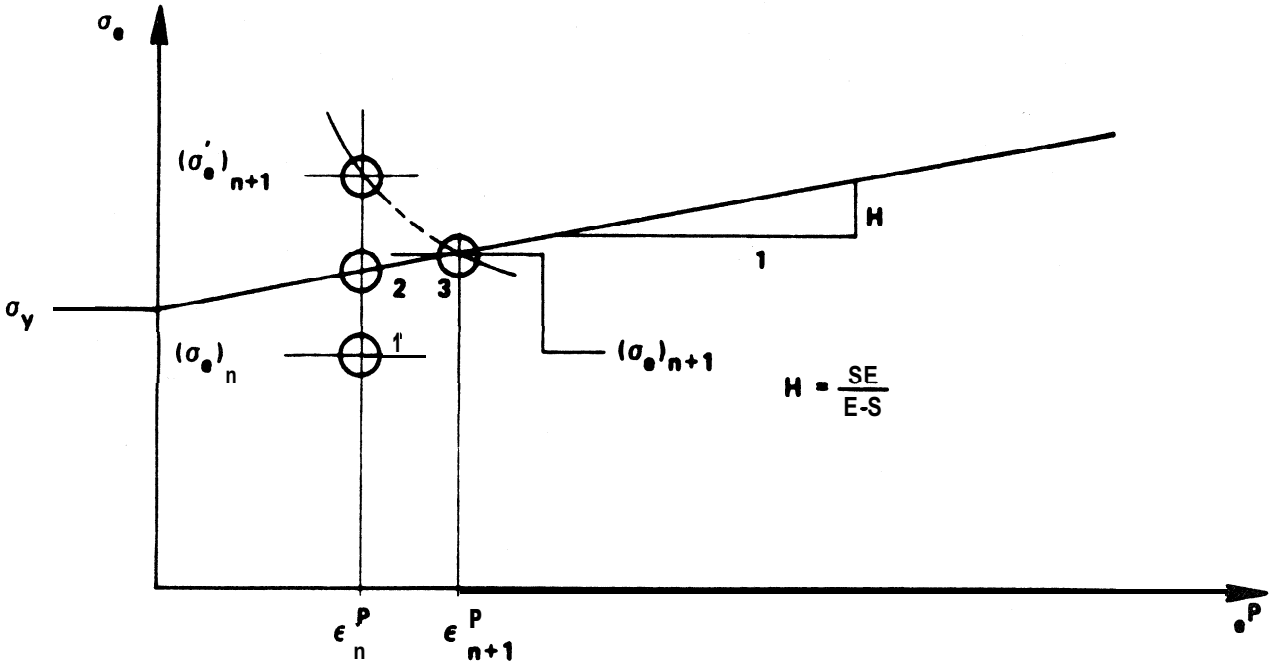


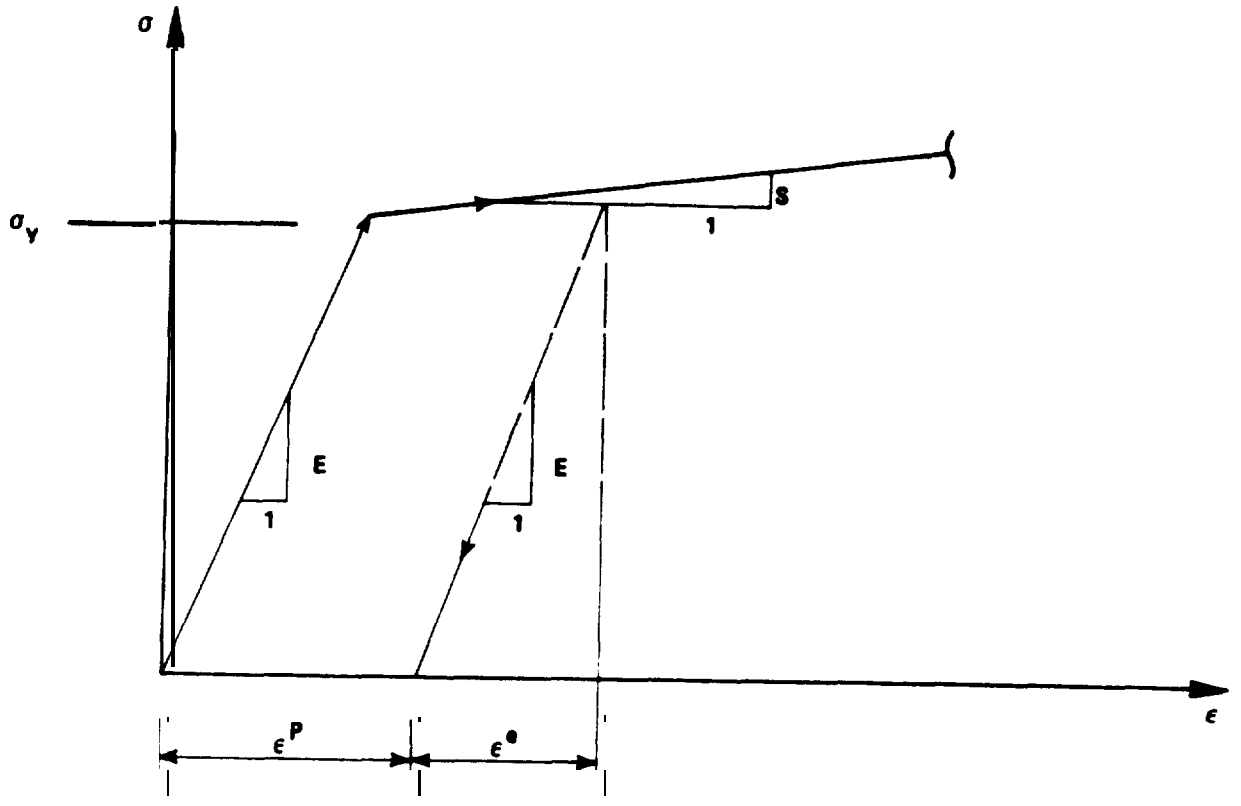
STRAIGHT PIPE ELEMENT

FIGURE: 2.1.1



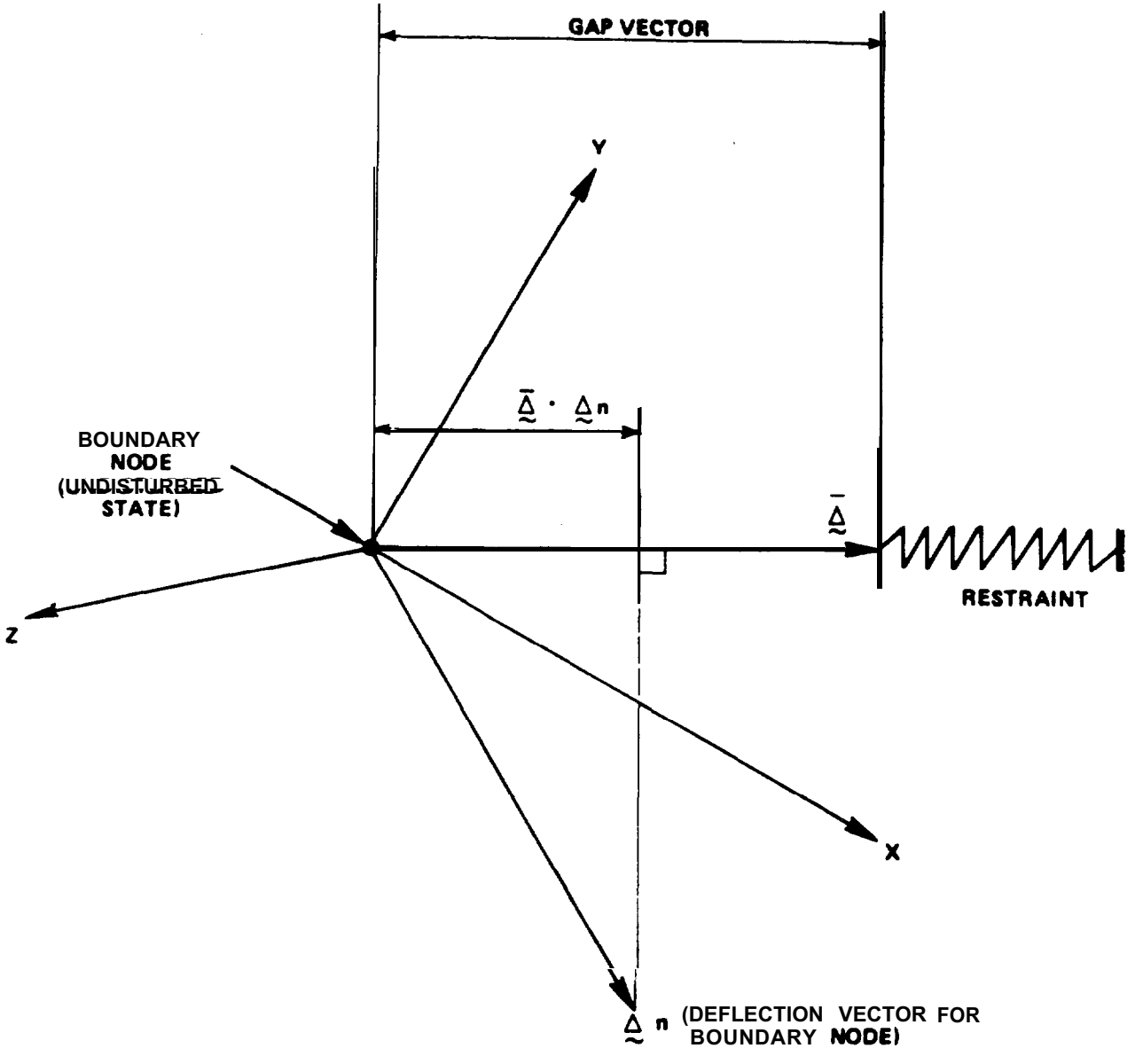
EFFECTIVE STRESS STRAIN CURVE

FIGURE: 2.1.2



STRESS - STRAIN CURVE FOR A BI-LINEAR STRAIN HARDENING MATERIAL

FIGURE: 2.1.3



GAP MODEL AT RESTRAINT

FIGURE: 2.1.4

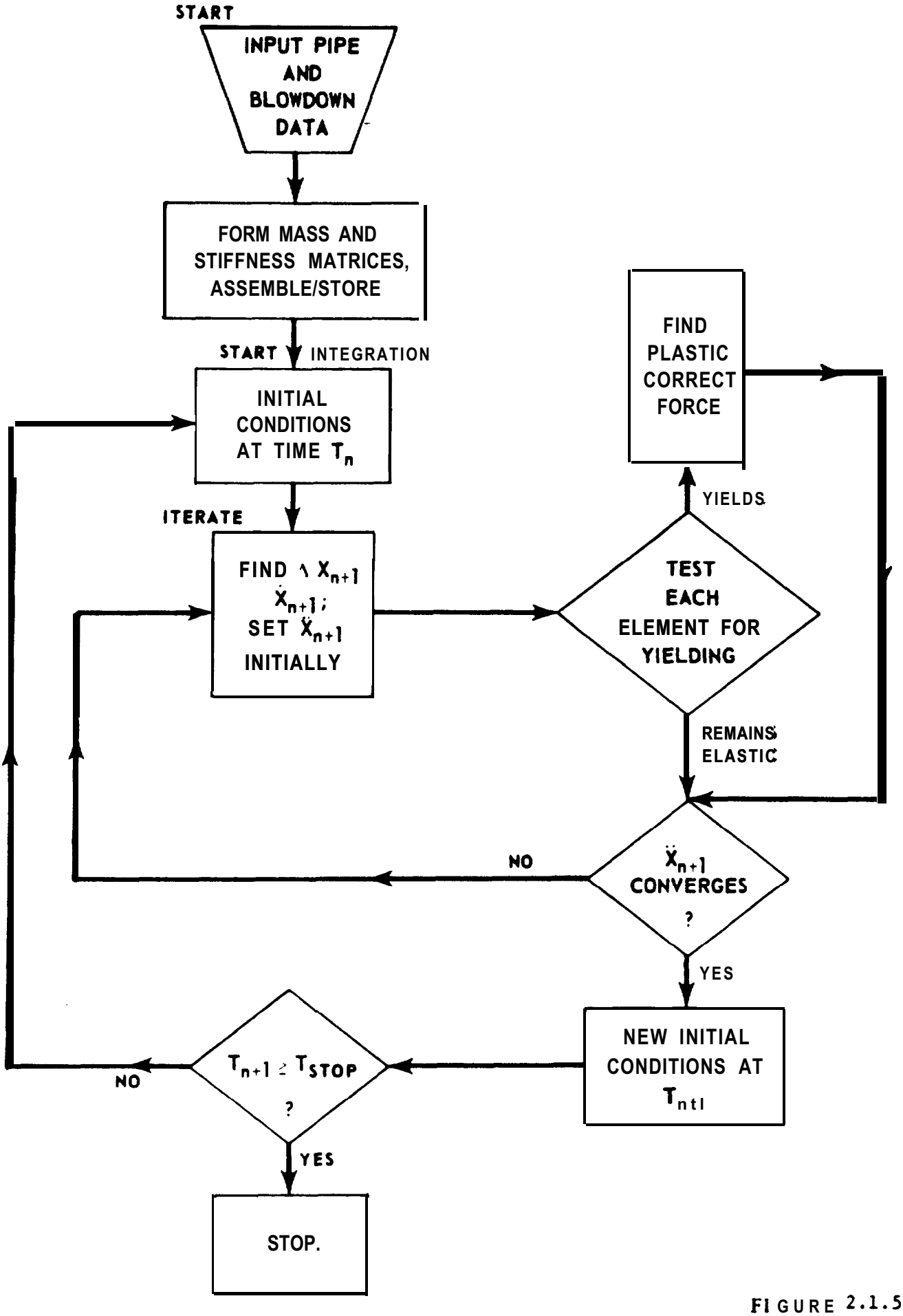
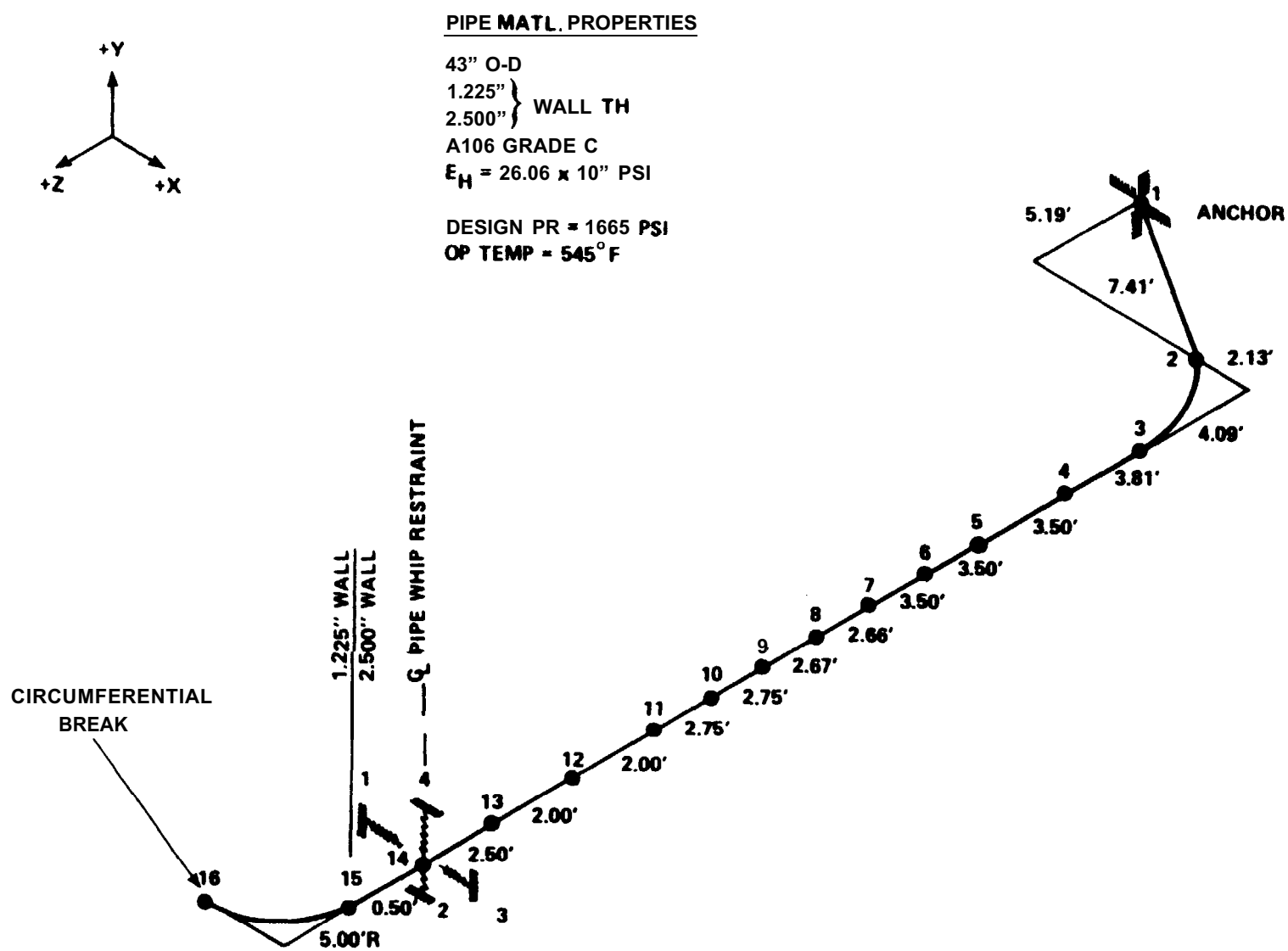
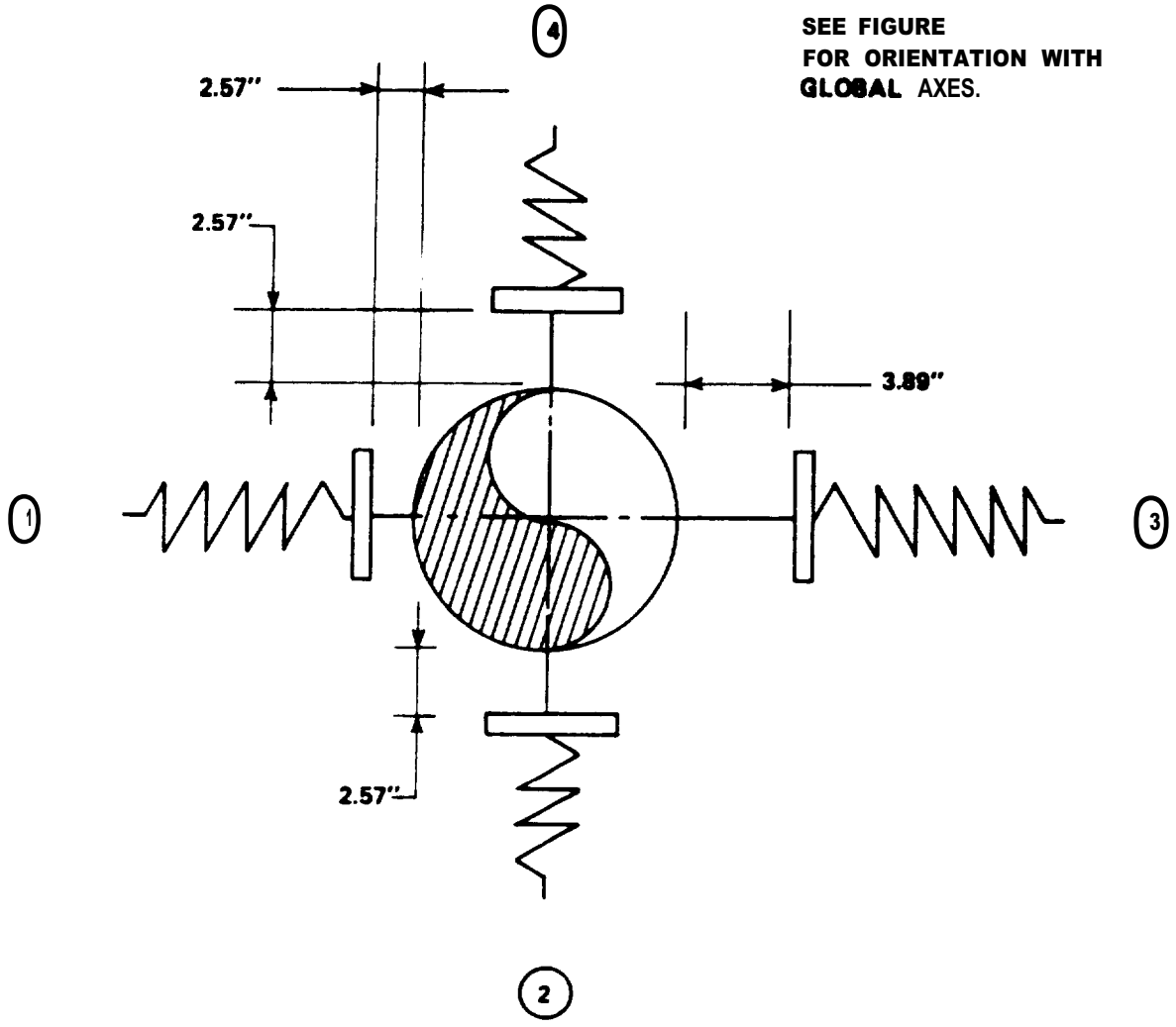

START
INPUT PIPE AND BLOWDOWN DATA
FORM MASS AND STIFFNESS MATRICES, ASSEMBLE/STORE
START INTEGRATION
INITIAL CONDITIONS AT TIME T_n
ITERATE
FIND X_{n+1}, $\dot{X}_{n+1}$; SET $\ddot{X}_{n+1}$ INITIALLY
TEST EACH ELEMENT FOR YIELDING
YIELDS
FIND PLASTIC CORRECT FORCE
REMAINS ELASTIC
$\ddot{X}_{n+1}$ CONVERGES ?
NO
YES
NEW INITIAL CONDITIONS AT T_{n+1}
$T_{n+1} \geq T_{STOP}$?
NO
YES
STOP.

FIGURE 2.1.5



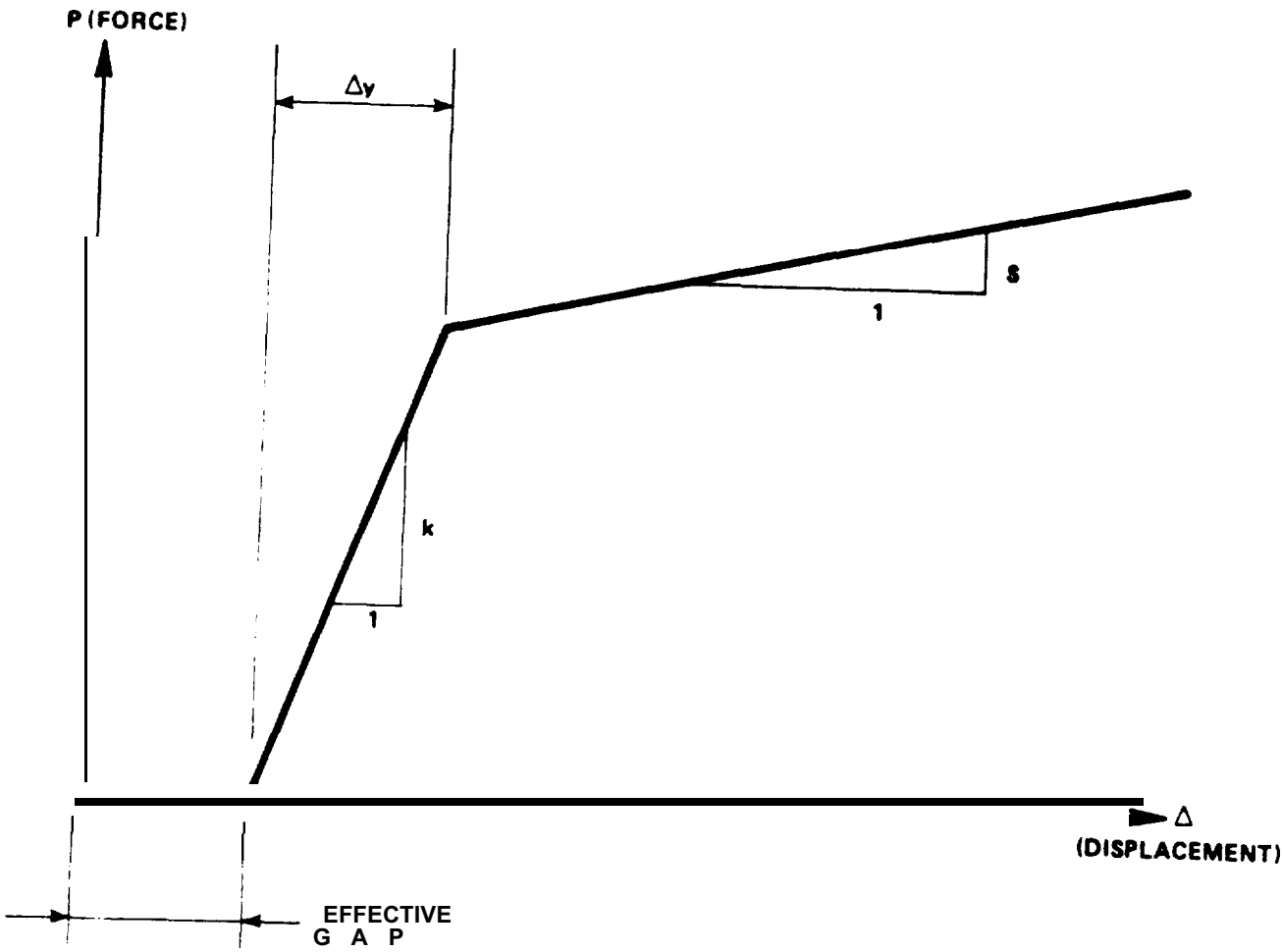
CIRCUMFERENTIAL BREAK IN MAIN STEAM LINE'

FIGURE: 2.3.1



EFFECTIVE GAPS AT RESTRAINT AT NODE 14

FIGURE: 2.3.2

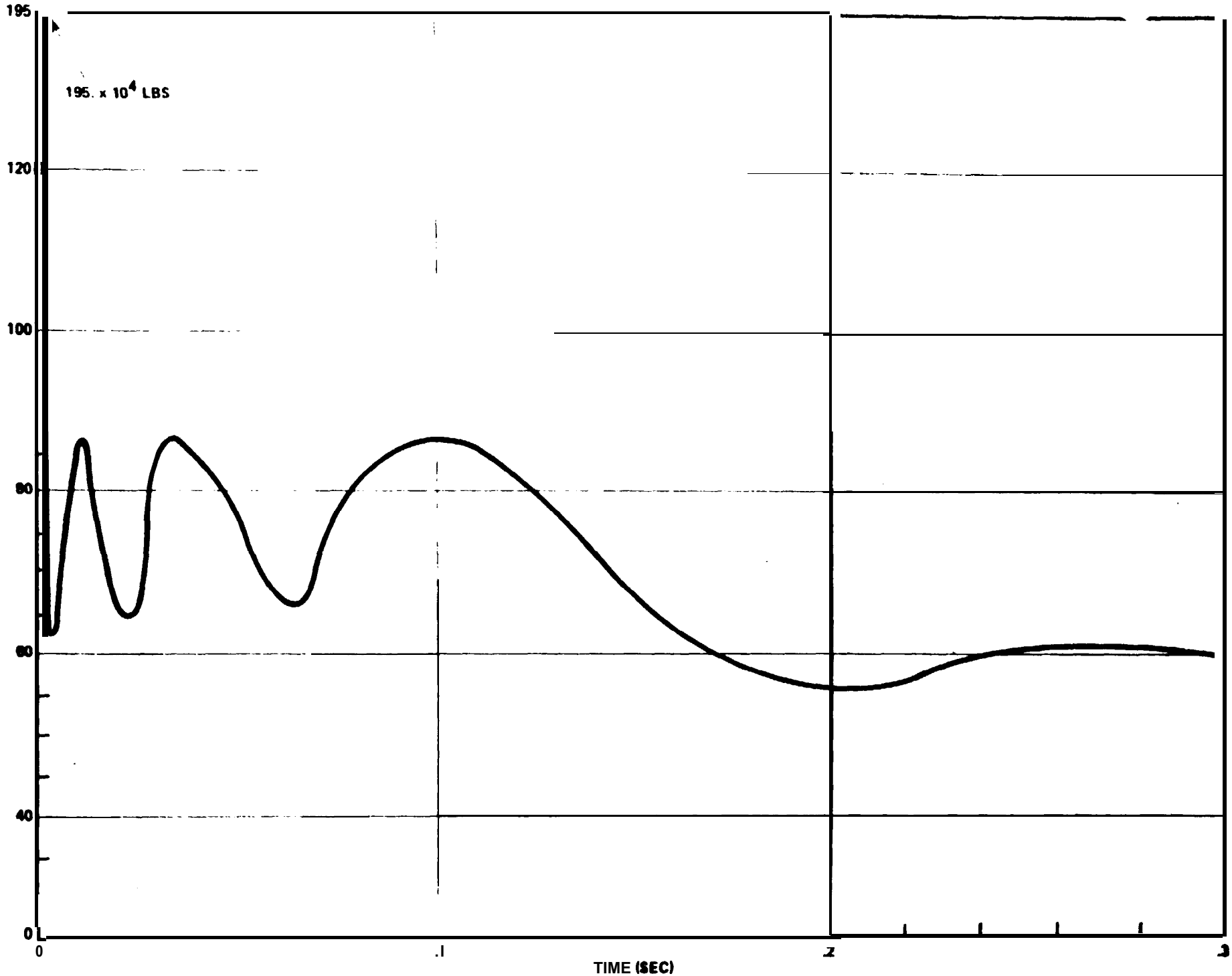


SPRING a	k (psi)	s (psi)	Δy (in)
1	6.66 x 10^6	2.99 x 10^4	0.16
2	"	"	"
3	5.95 x 106	"	"
4	6.66 x 10^6	"	0.20
			0.15

FORCE - DISPLACEMENT DIAGRAM FOR RESTRAINTS

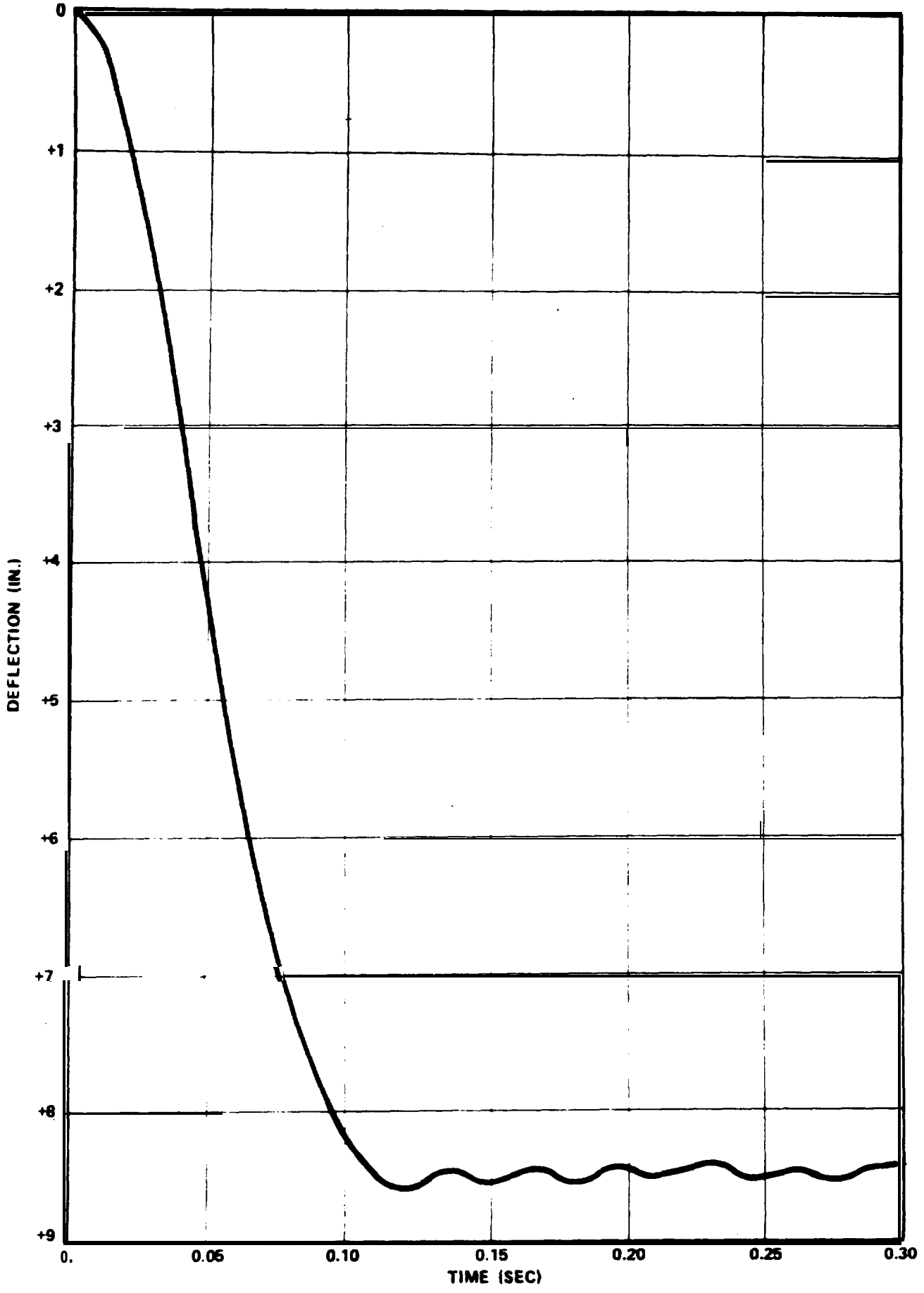
IN 43" MAIN STEAM LINE

FIGURE: 2.3.3



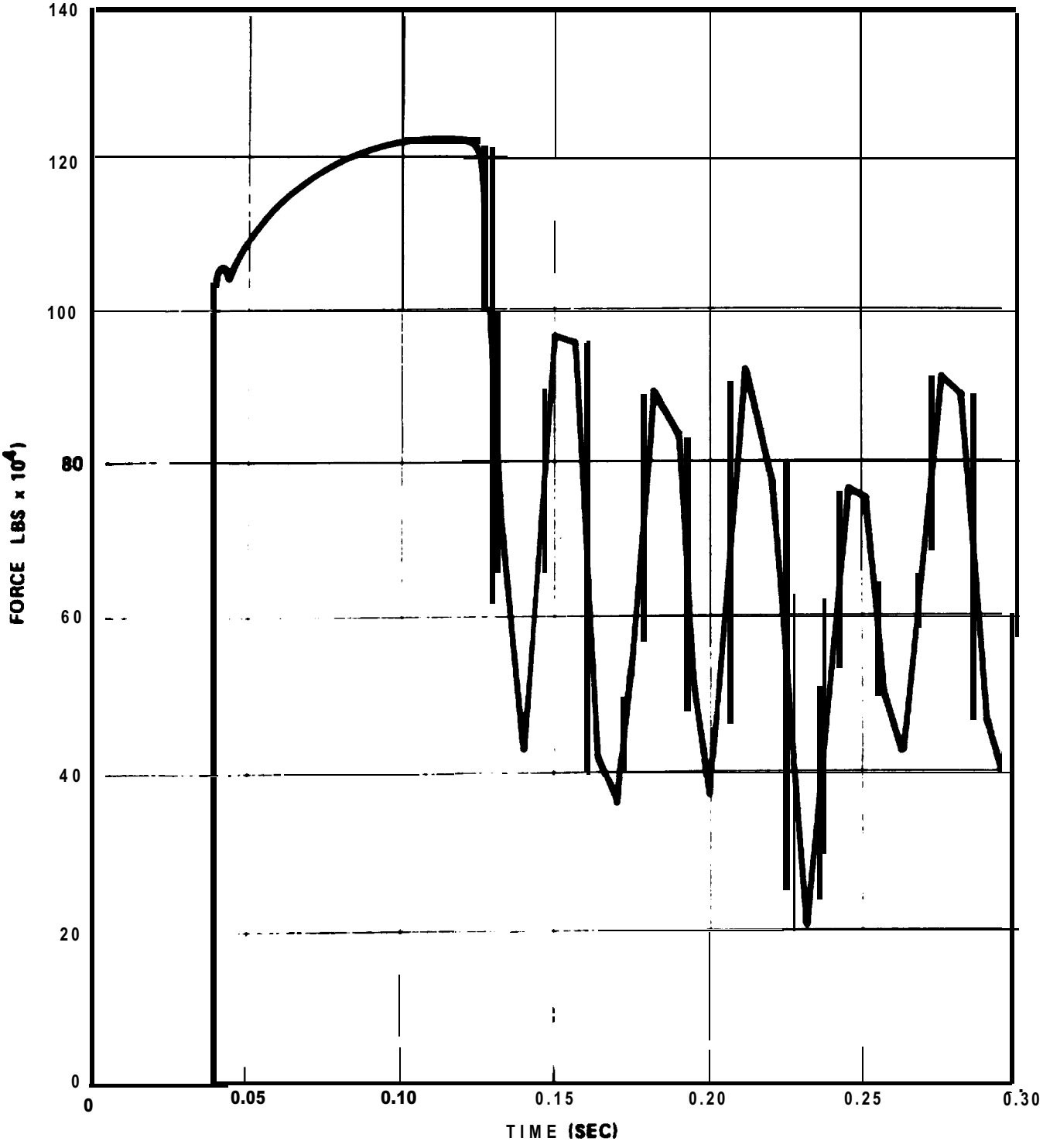
BLOWDOWN FORCE VS. TIME AT NODE 16 IN MAIN STEAM LINE

FIGURE: 2.3.4



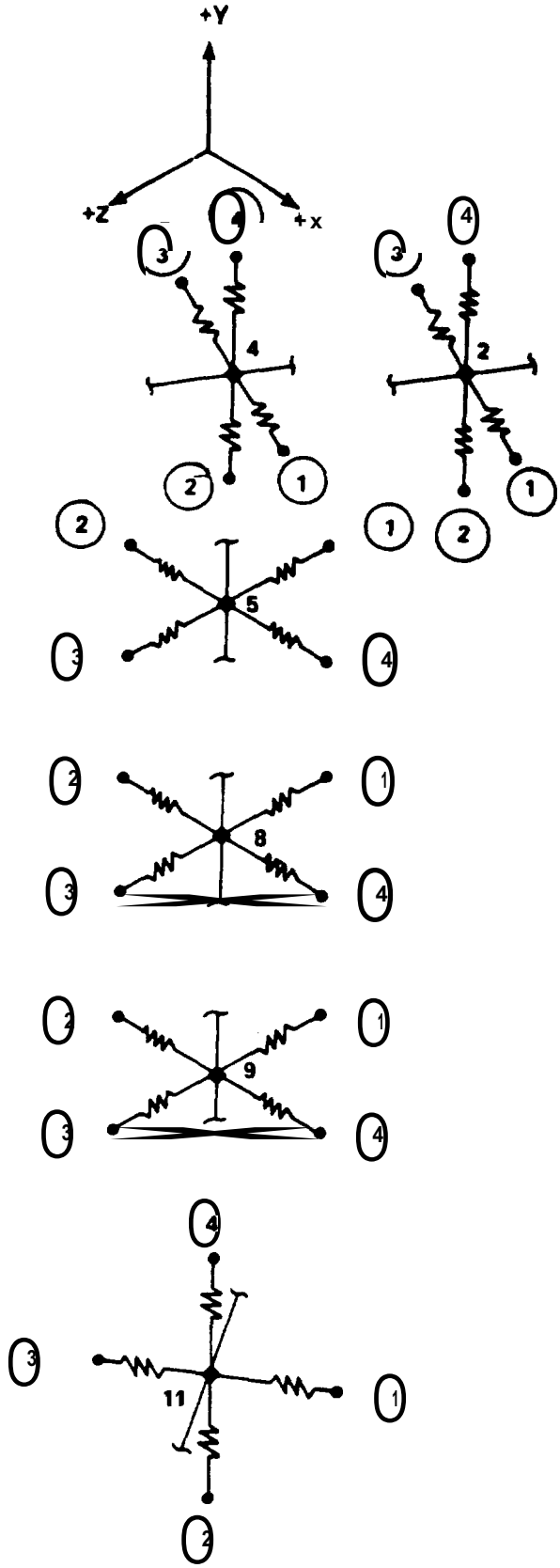
DEFLECTION OF RESTRAINT
(NODE # 14)
IN (+ x) DIRECTION

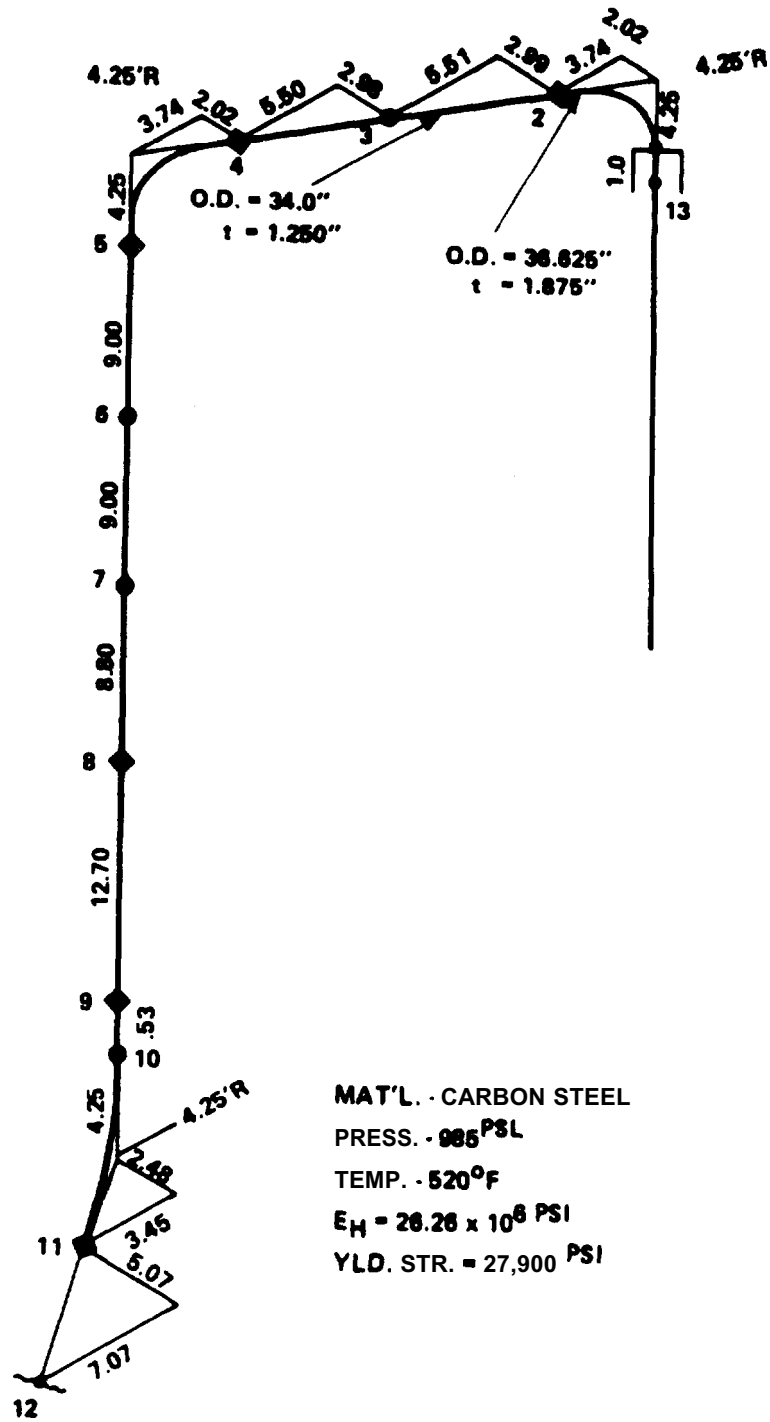
FIGURE: 2.3.5



FORCE ON RESTRAINT AT NODE #14

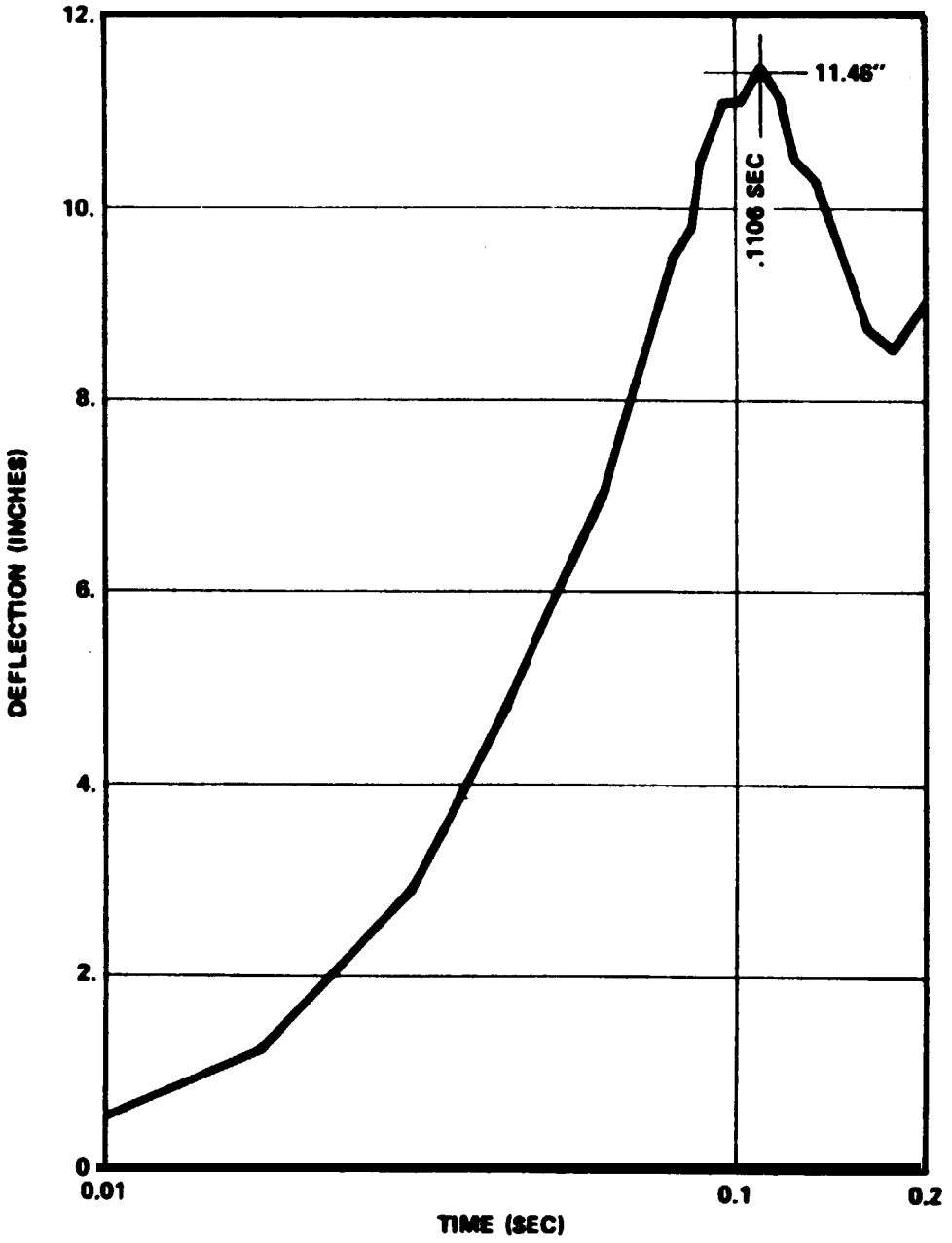
FIGURE: 2.3.6





NAIN STM. LINE TRANSVERSE BREAK AT NOOE #12

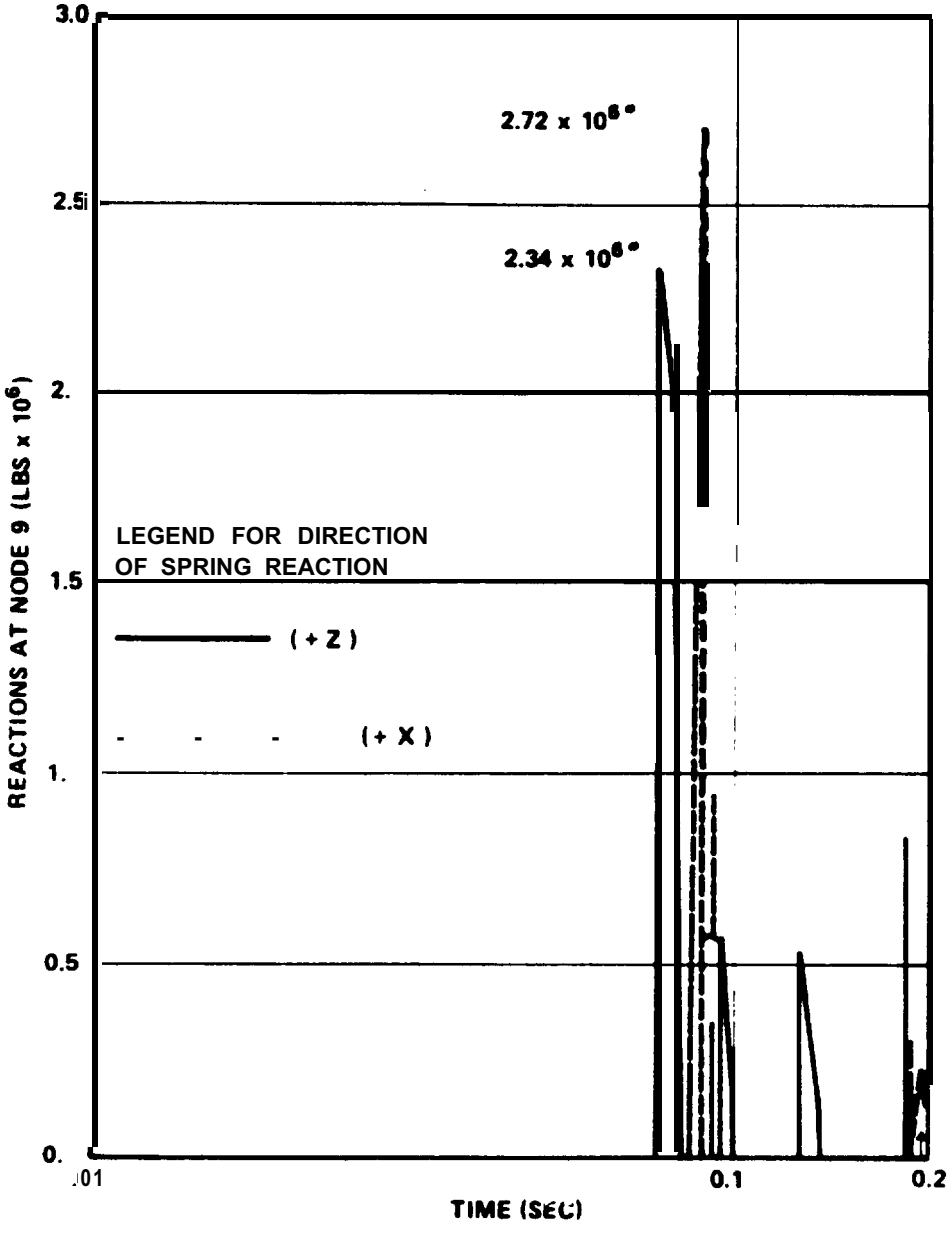
FIGURE: 2.3.7



MAXIMUM PLASTIC
STRAIN = 0.0762

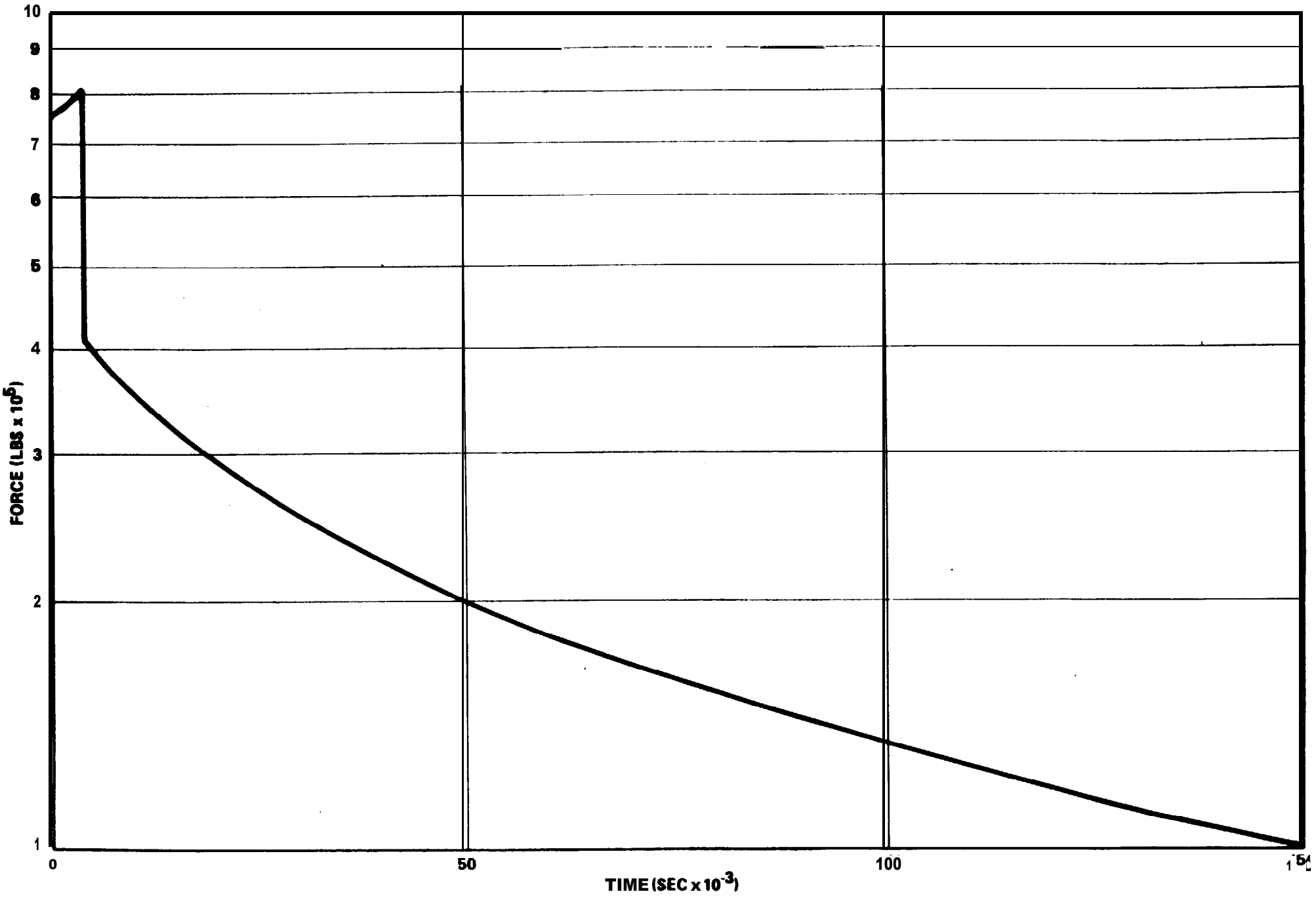
MAIN STEAM LINE (BREAK AT NODE 12) DEFLECTION OF NODE 12 VERSUS TIME

FIGURE: 2.3.8



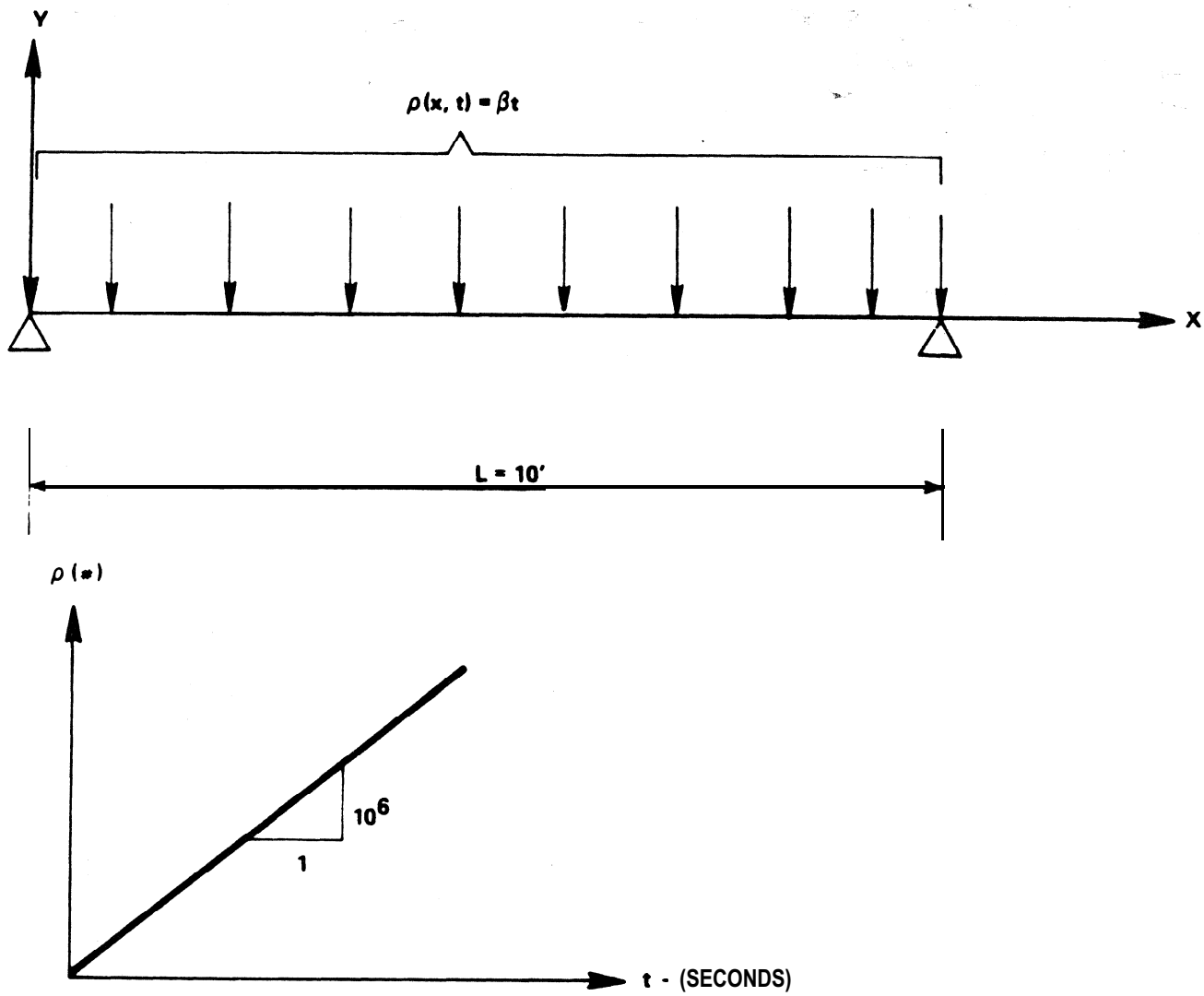
MAIN STEAM LINE BREAK AT NODE 12 REACTION AT PIPE WHIP RESTRAINT AT NODE.9 IN + X & + Z DIRECTIONS VERSUS TIME

FIGURE: 2.3.9



MAIN STEAM BLOWDOWN FORCE

FIGURE: 2.3.10



$E = 30 \times 10^6$ psi

$I = 28.1$ in'

$\beta = 10^6$ # / SEC.

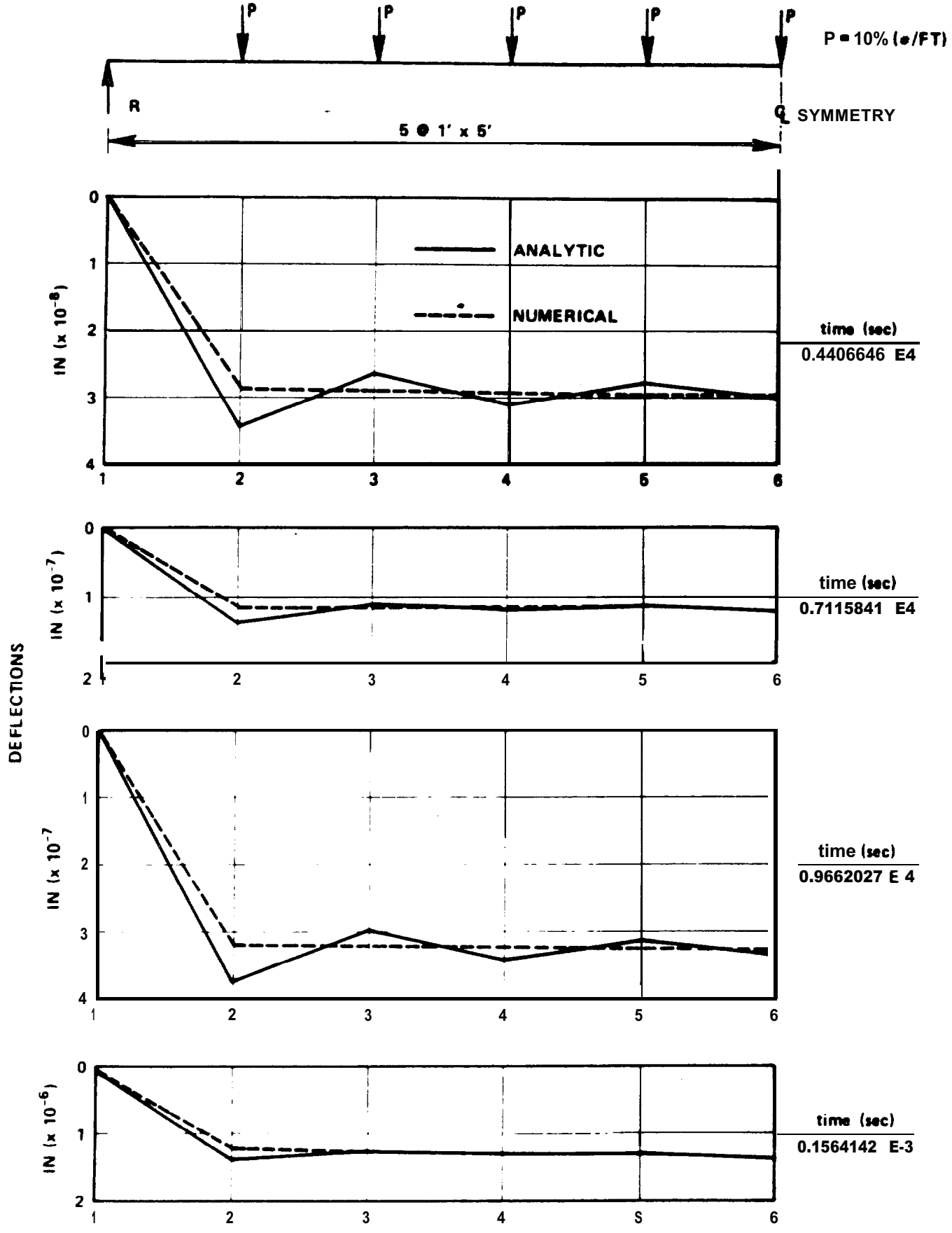
$\gamma = 0.25$

$w = 18.9$ #/FT.

$Mo = \frac{wL}{g}$

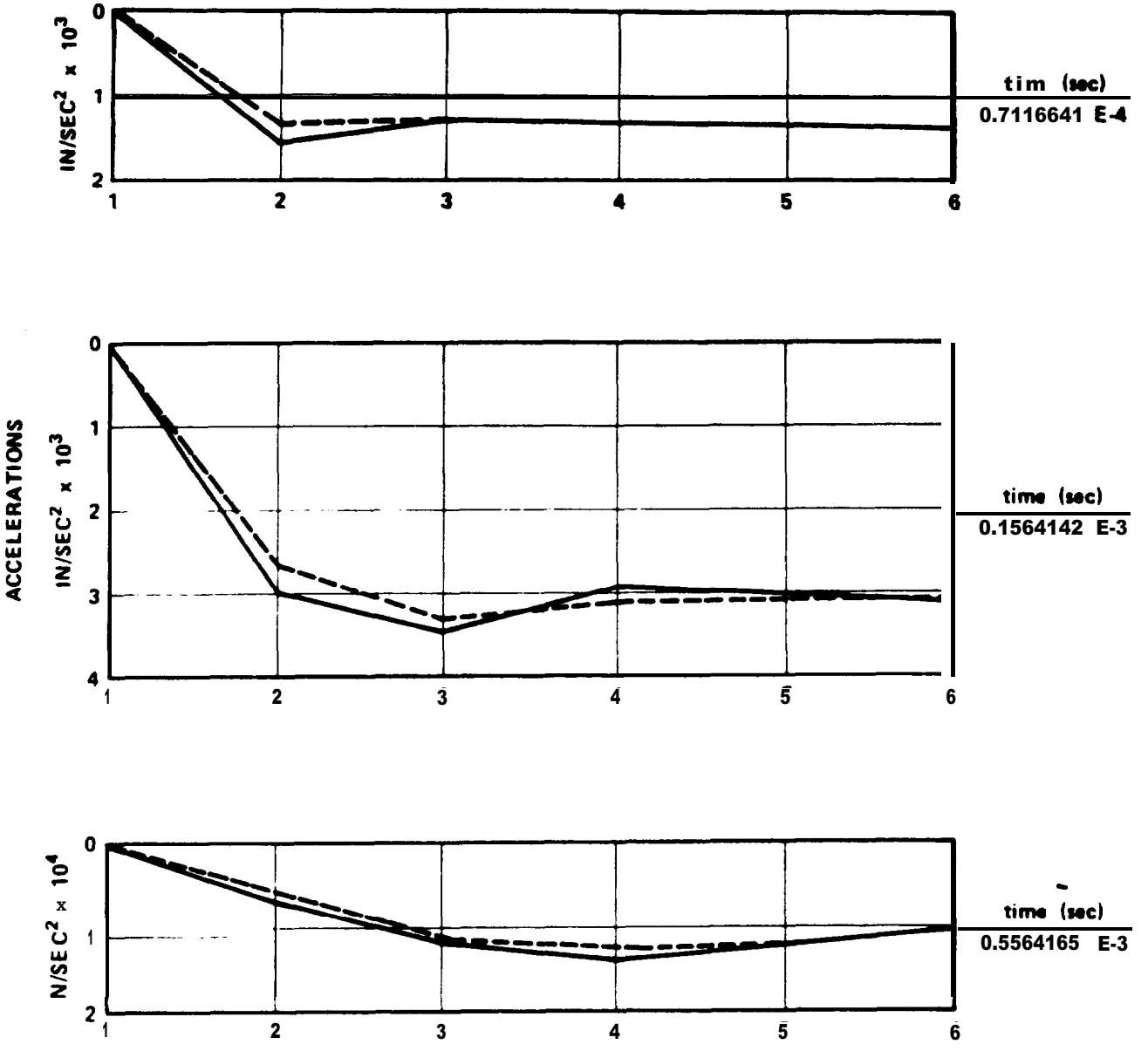
ELASTIC BEAM UNDER UNIFORM DYNAMIC LOAD

FIGURE: 3.1.1



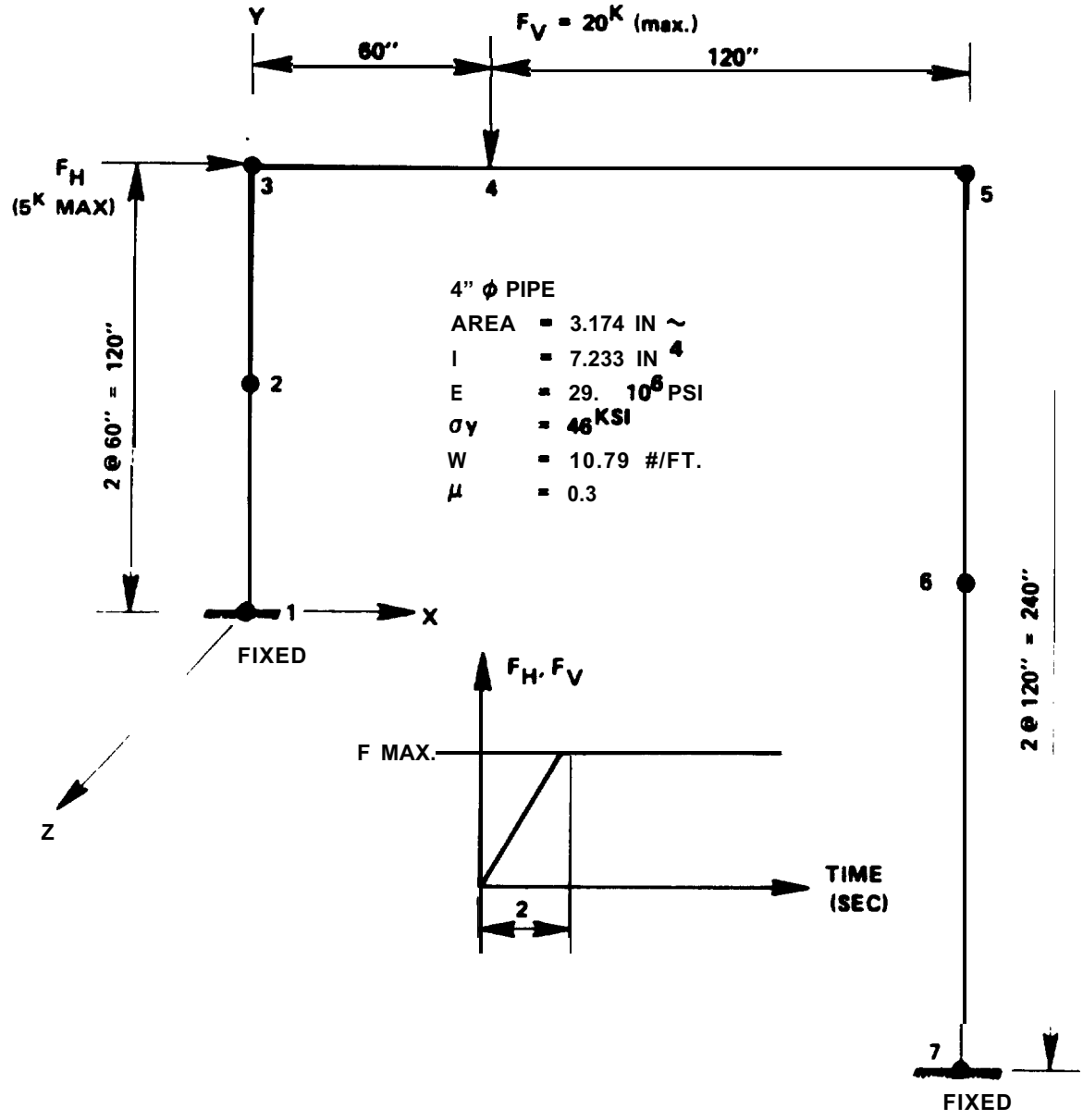
DEFLECTION HISTORY -
UNIFORM SIMPLE BEAM

FIGURE: 3.1.2A



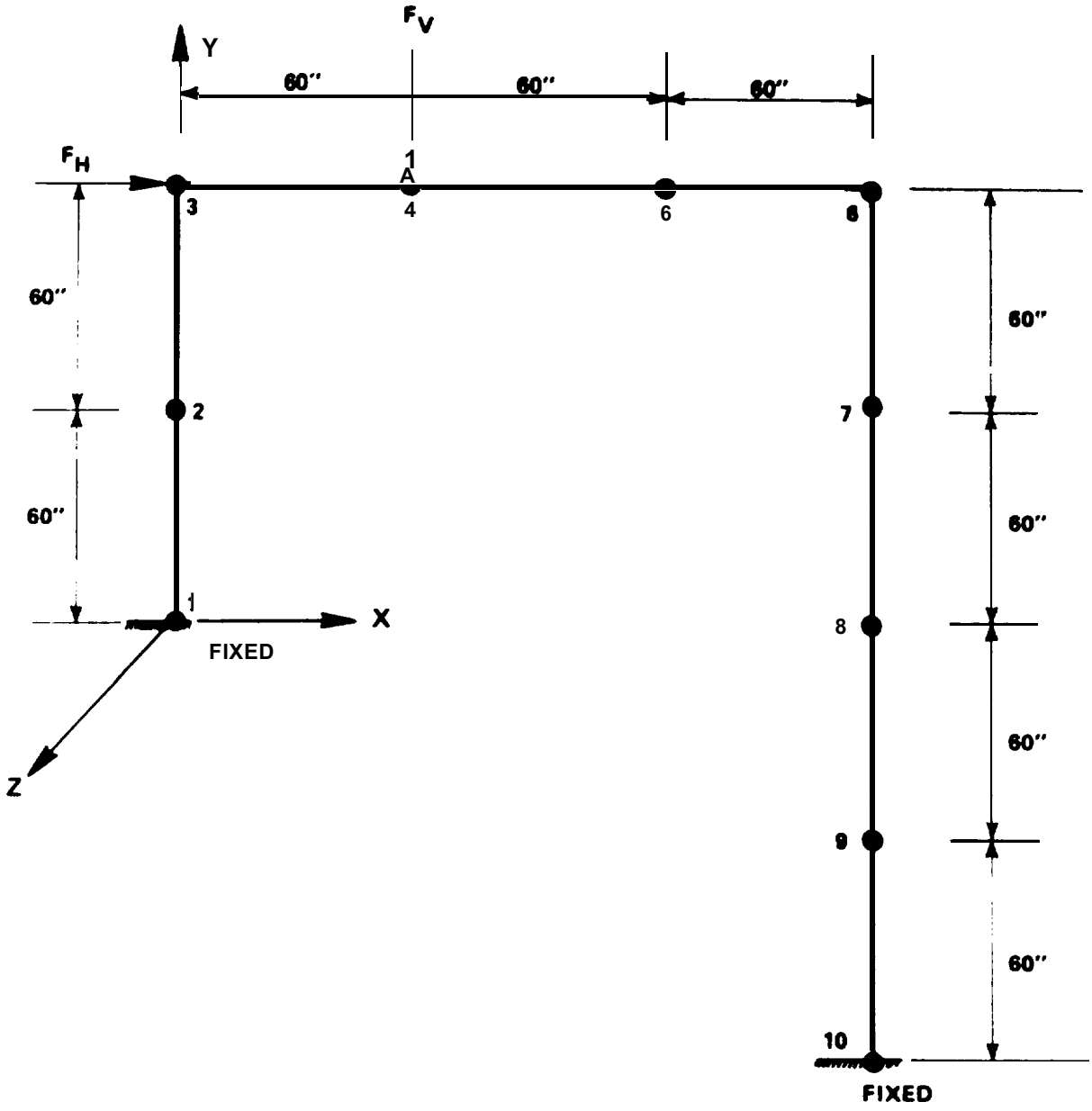
ACCELERATION HISTORY
UNIFORM SIMPLE BEAM

FIGURE: 3.1.2B



7 MASS PLANE FRAME

FIGURE: 3.1.3A



10 MASS PLANE FRAME

FIGURE: 3.1.3B

ELASTIC FRAME

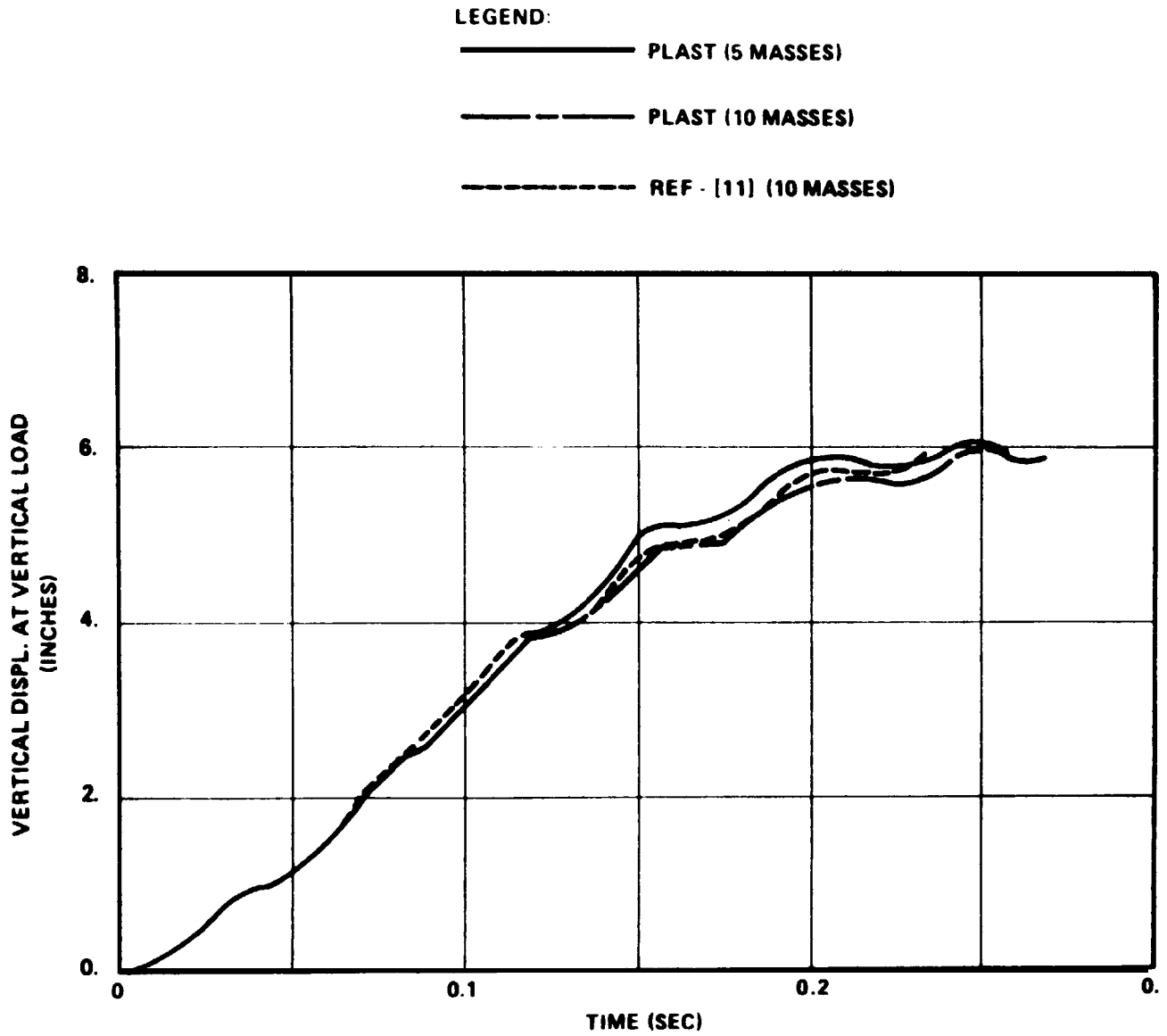


FIGURE: 3.1.4A

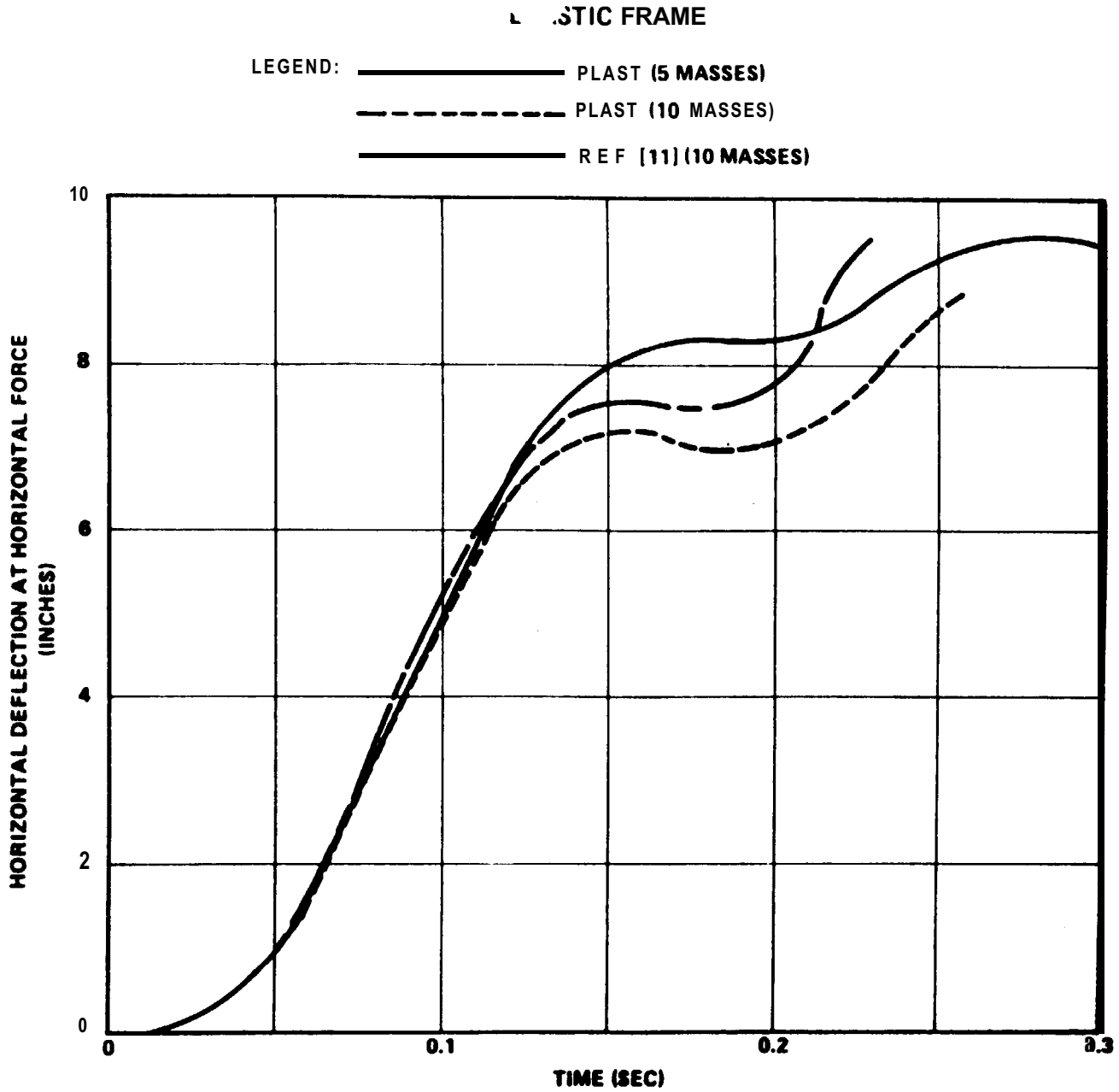

.STIC FRAME
LEGEND:
PLAST (5 MASSES)
PLAST (10 MASSES)
REF [11] (10 MASSES)
HORIZONTAL DEFLECTION AT HORIZONTAL FORCE (INCHES)
10
8
6
4
2
0
0
0.1
0.2
0.3
TIME (SEC)

FIGURE: 3.1.4B

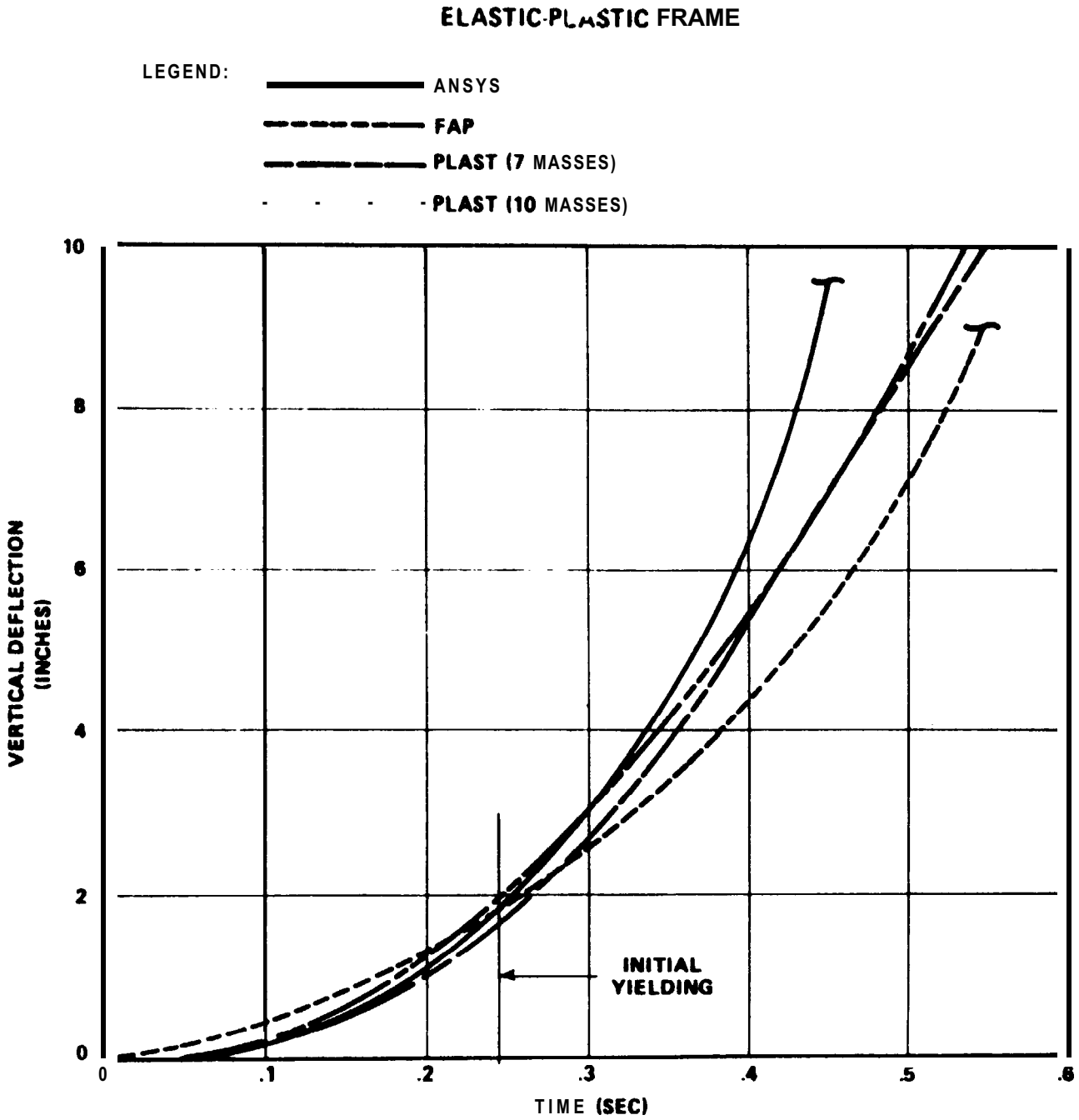

ELASTIC-PLASTIC FRAME
LEGEND:
ANSYS
FAP
PLAST (7 MASSES)
PLAST (10 MASSES)
VERTICAL DEFLECTION (INCHES)
10
8
6
4
2
0
0
.1
.2
.3
.4
.5
.6
TIME (SEC)
INITIAL YIELDING

FIGURE: 3.1.5A

E ASTIC-PLASTIC ⊏⊼AME

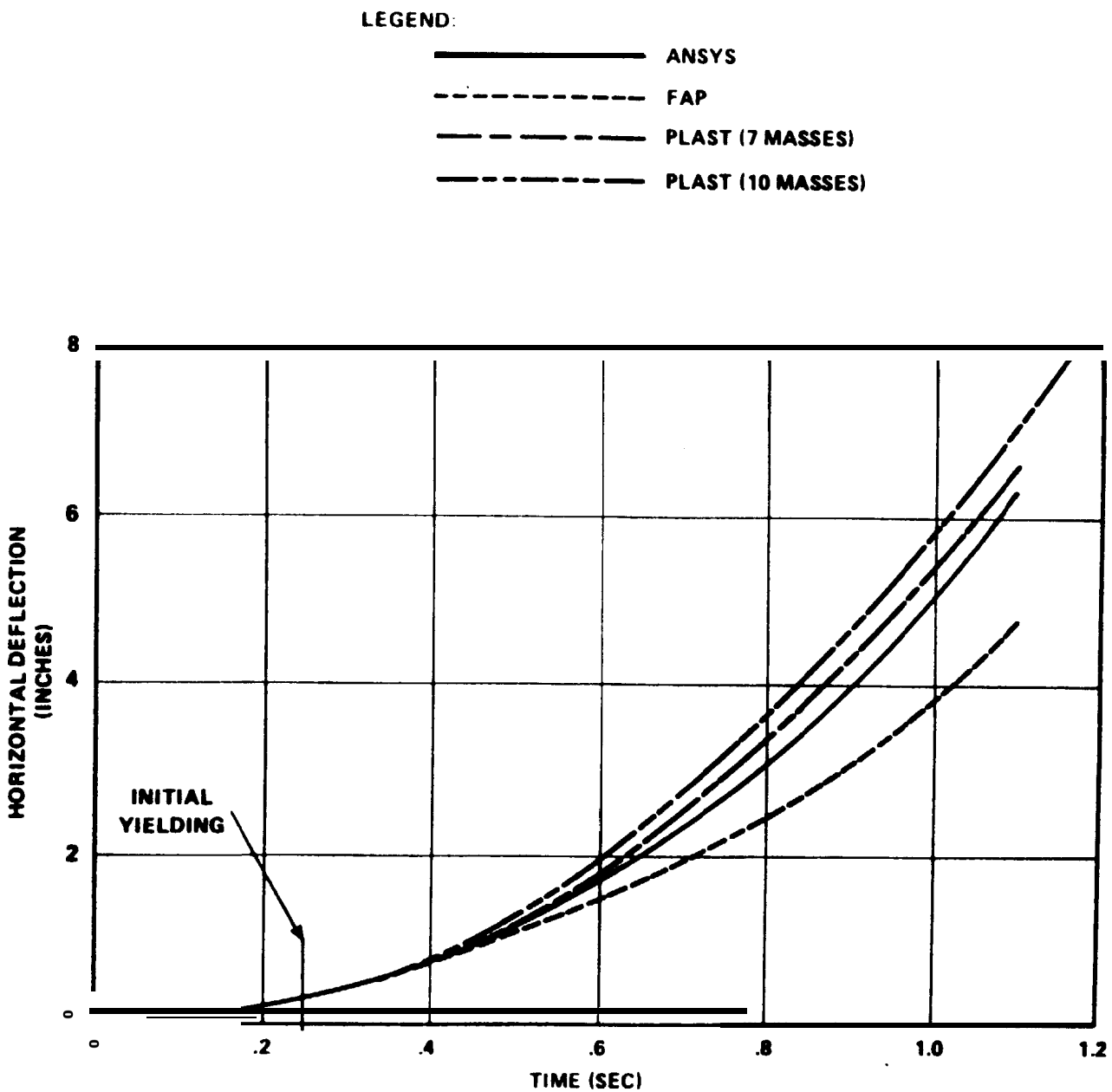
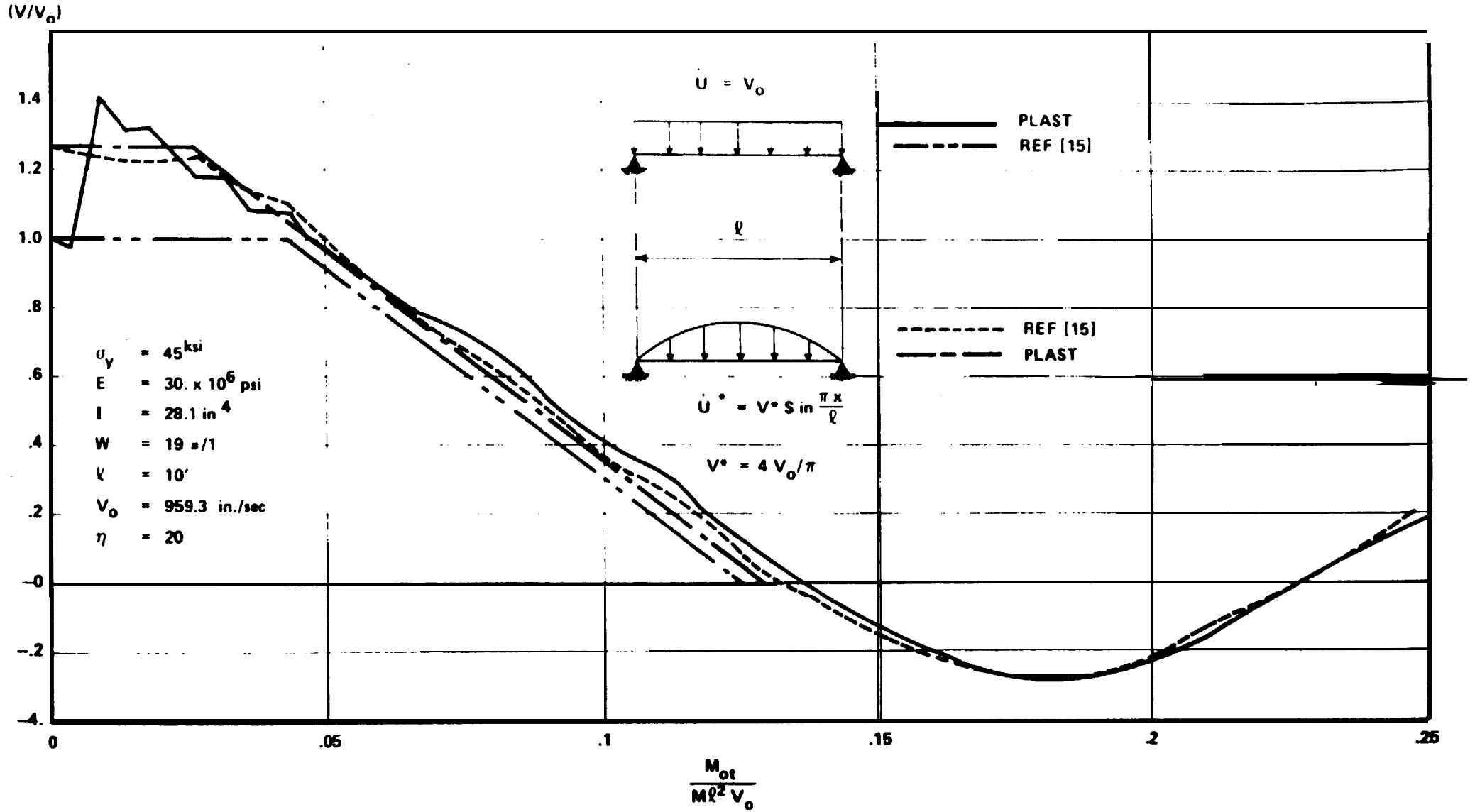


FIGURE: 3.1.5B

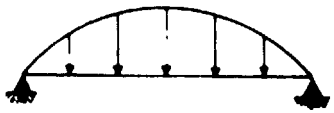


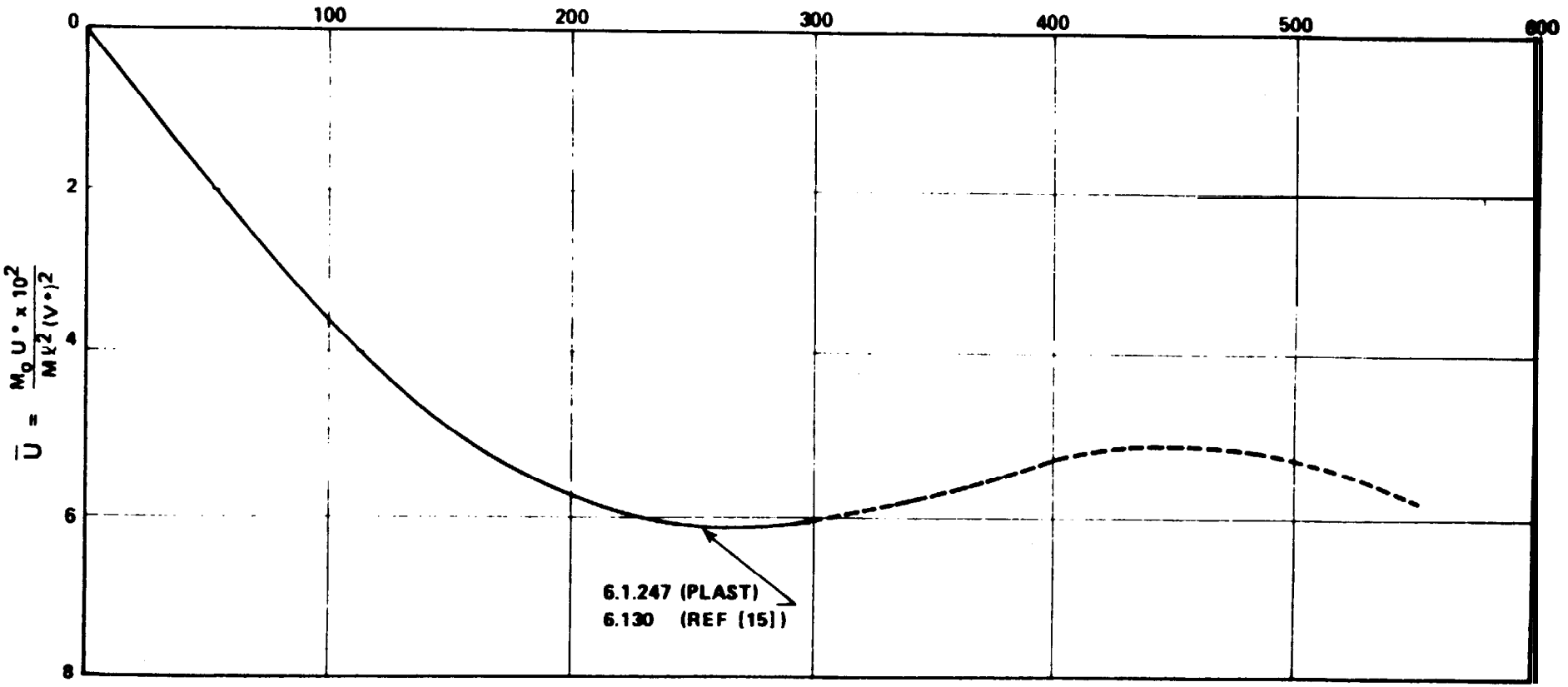
CENTRAL VELOCITY VS. TIME

FIGURE:3.1.6A

$$V^* = \frac{4V_0}{\pi}$$

$$U^* = V^* \sin \frac{\pi x}{\ell}$$





$$\tau = \frac{10^2 \, M_0 \, t}{MV^* \ell^2}$$

$$H = \frac{1}{1.8\pi\sqrt{\eta^*}}$$

$$\eta^* = 20$$

CENTRAL DEFLECTION VERSUS TIME

FIGURE: 3.1.6B

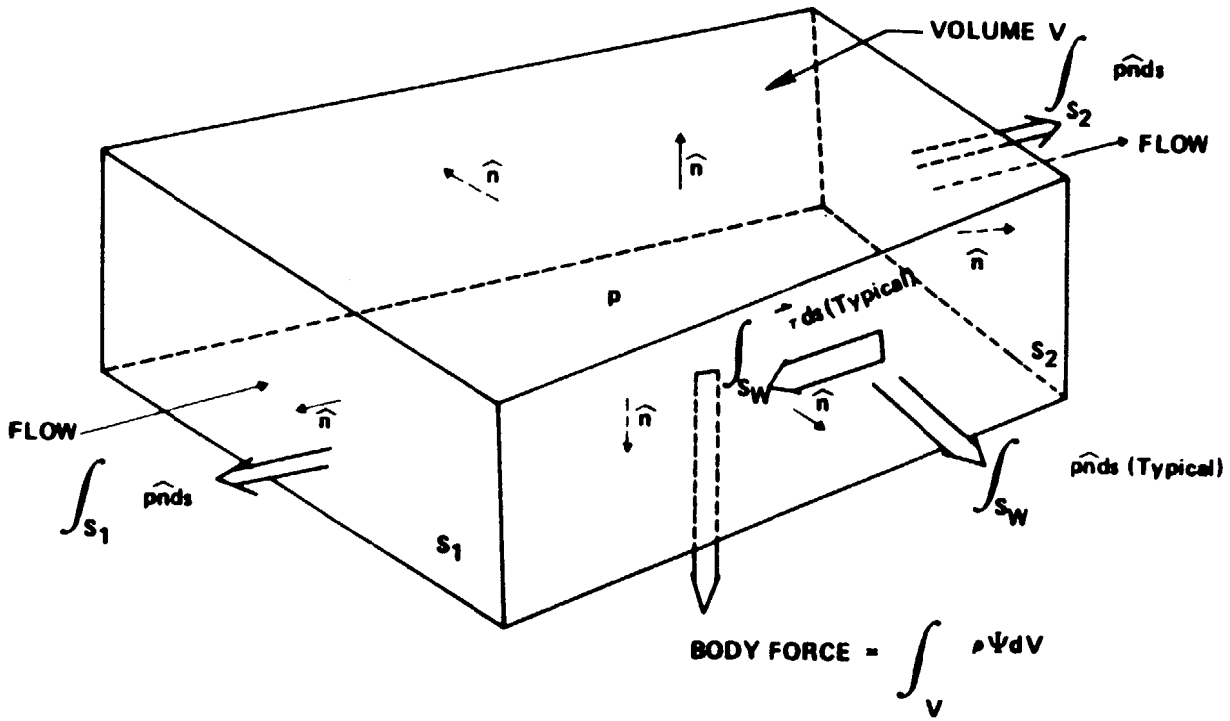


FIGURE 4.1
FLUID CONTROL VOLUME

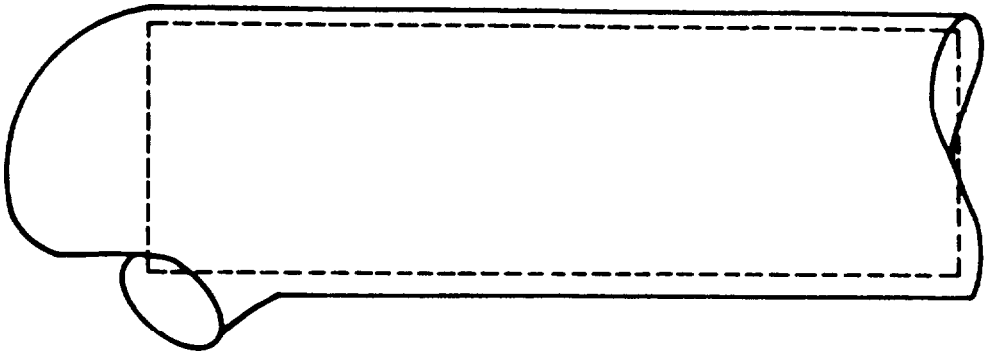


FIGURE 4.2
CIRCUMFERENTIAL BREAK CONTROL VOLUME

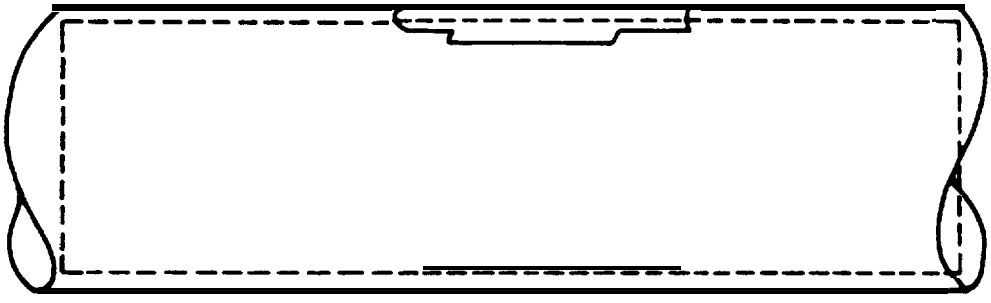


FIGURE 4.3
LONGITUDINAL BREAK CONTROL VOLUME

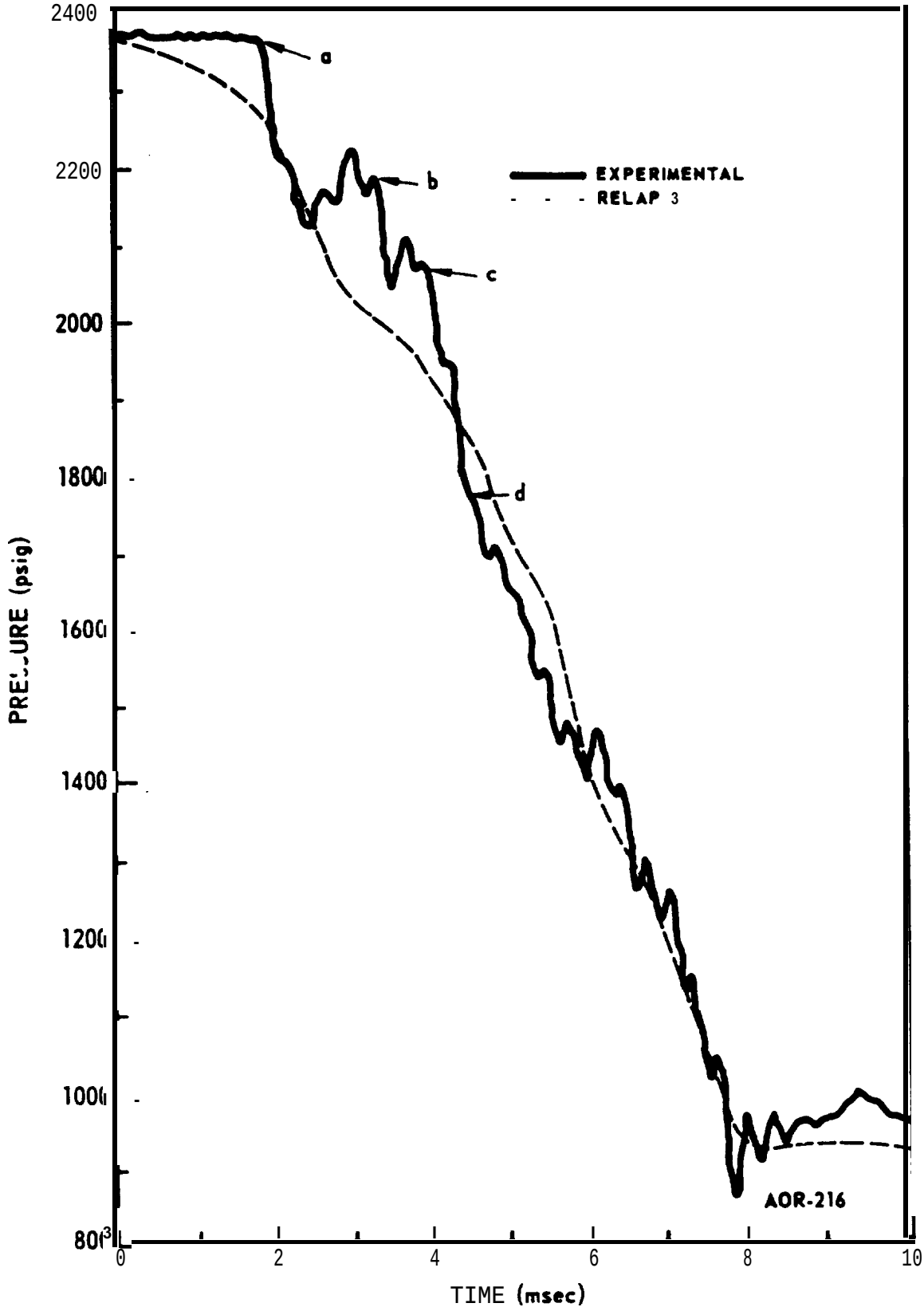

2400
2200
2000
1800
1600
1400
1200
1000
800
PRESSURE (psig)
a
b
c
d
EXPERIMENTAL
RELAP 3
AOR-216
0
2
4
6
8
10
TIME (msec)

FIGURE 4.4

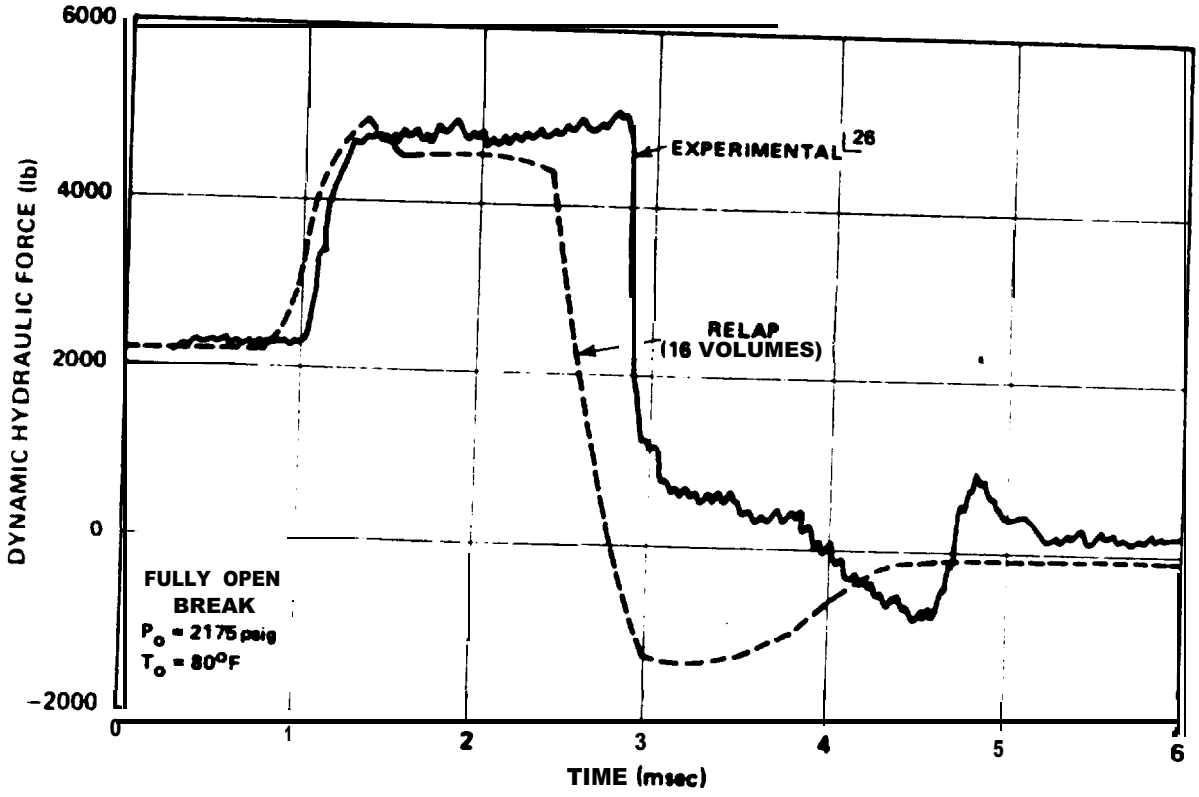
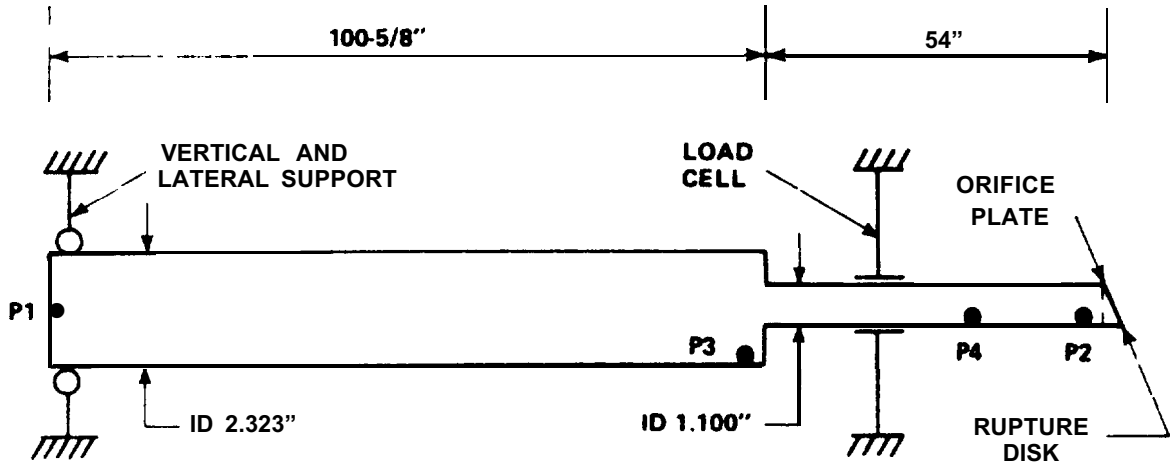

6000
4000
2000
0
-2000
DYNAMIC HYDRAULIC FORCE (lb)
EXPERIMENTAL [26]
RELAP
(16 VOLUMES)
FULLY OPEN
BREAK
P_o = 2175 psig
T_o = 80°F
0
1
2
3
4
5
6
TIME (msec)

FIGURE 4.5



X = LENGTH OF SMALL PIPE, INCHES

WITH NO EXTENSION 21 INCHES
WITH EXTENSION A 28-1/2 INCHES
WITH EXTENSION B 54 INCHES

P = PRESSURE TRANSDUCER

P2 IS 1-3/4 INCHES FROM RUPTURE DISC
P4 IS 19-1/4 INCHES FROM AREA CHANGE

WHEN NO PIPE EXTENSION WAS PRESENT, THERE WAS NO PRESSURE TRANSDUCER P4.

ORIFICE DIAMETERS OF 39/64 AND 11/32 INCH ARE USED; AREAS ARE 30 AND 10% OF SMALL PIPE, THICKNESS OF ORIFICE PLATE IS 3/16 INCH.

ORIFICE PLATE IS REMOVED FOR STUDIES WITH FULL-OPEN BREAK.

FIGURE 4.6
IDAHO NUCLEAR CORPORATION PIPE EXPERIMENT

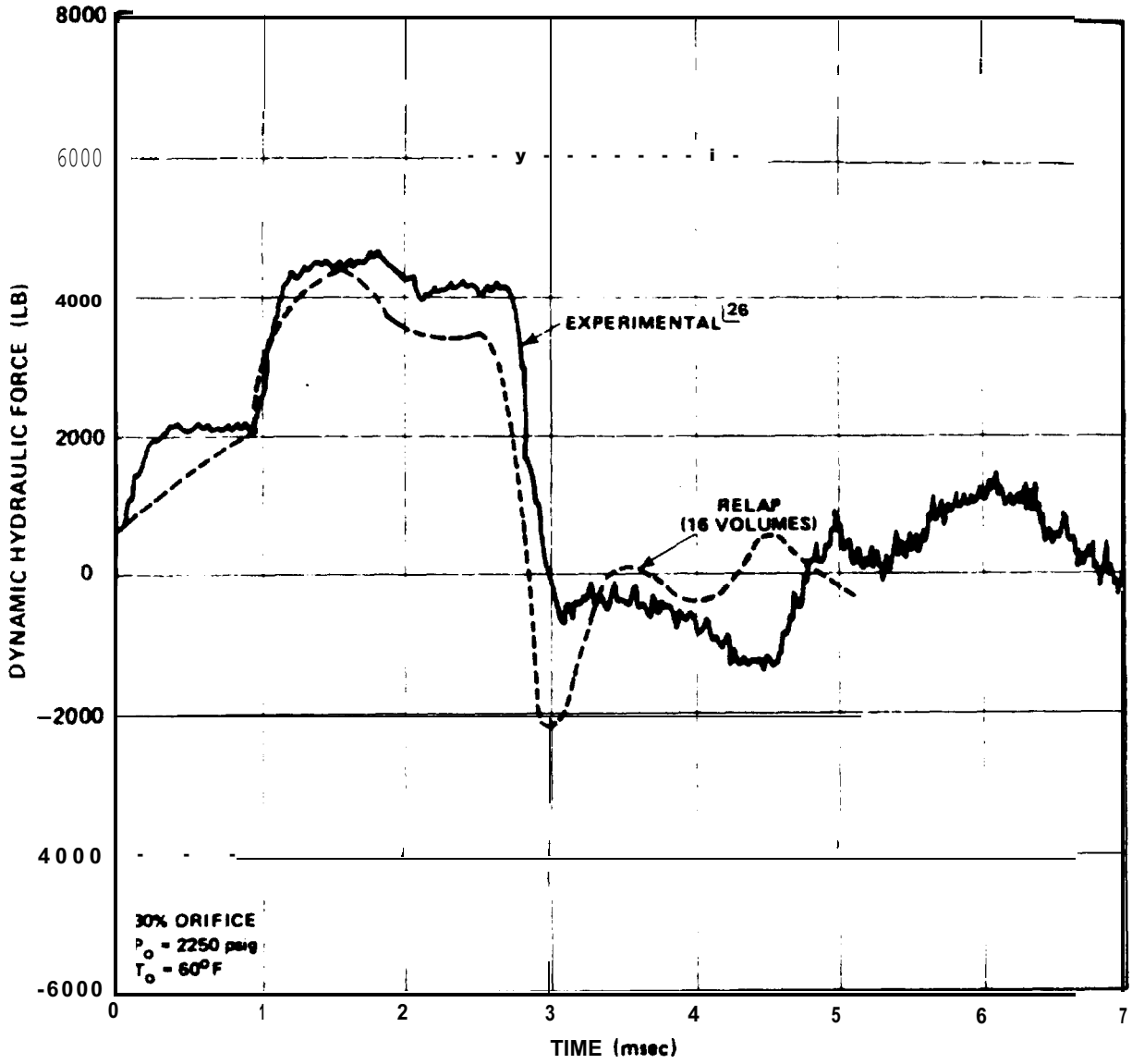

8000
6000
4000
2000
0
-2000
4000
-6000
DYNAMIC HYDRAULIC FORCE (LB)
EXPERIMENTAL [26]
RELAP
(16 VOLUMES)
30% ORIFICE
P_o = 2250 psig
T_o = 60°F
0
1
2
3
4
5
6
7
TIME (msec)

FIGURE 4.7

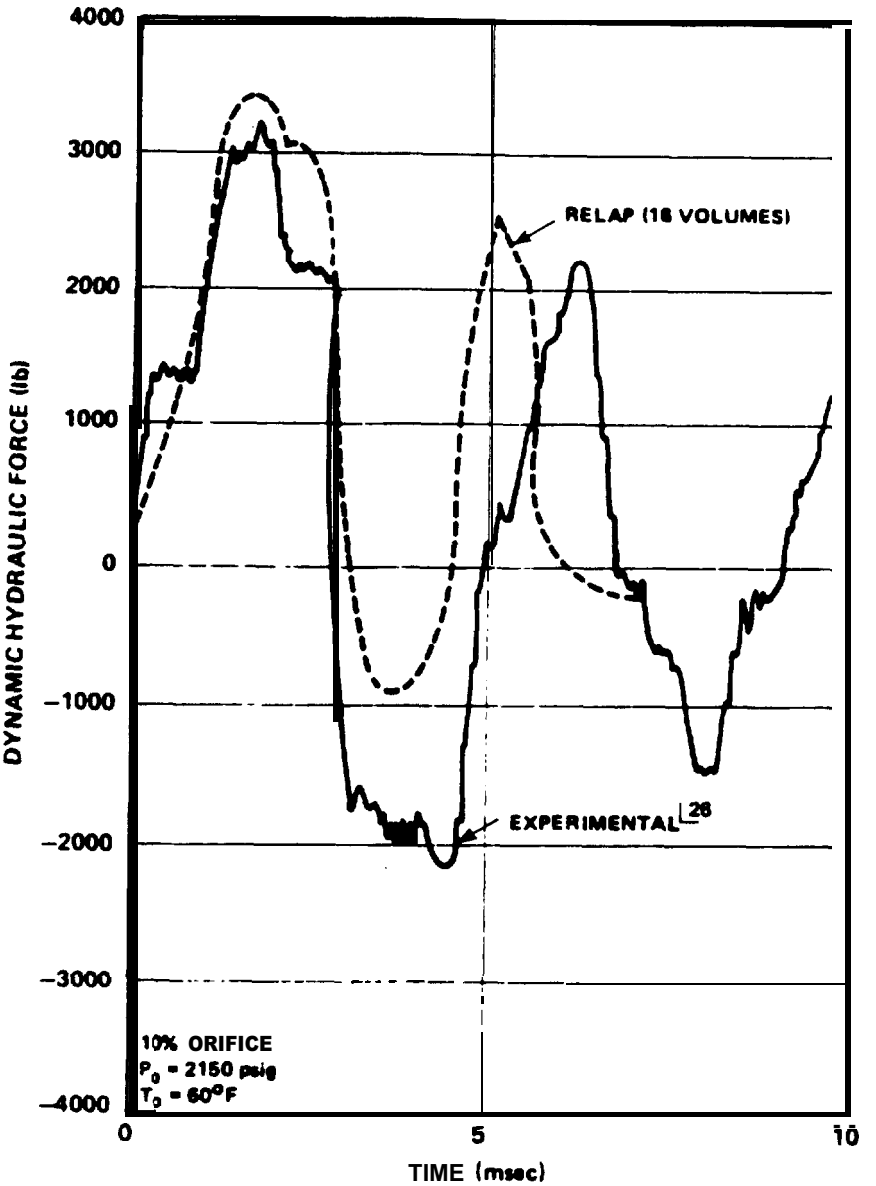

4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
DYNAMIC HYDRAULIC FORCE (lb)
RELAP (16 VOLUMES)
EXPERIMENTAL[28]
10% ORIFICE
P_0 = 2150 psig
T_0 = 60°F
0
5
10
TIME (msec)

FIGURE 4.8

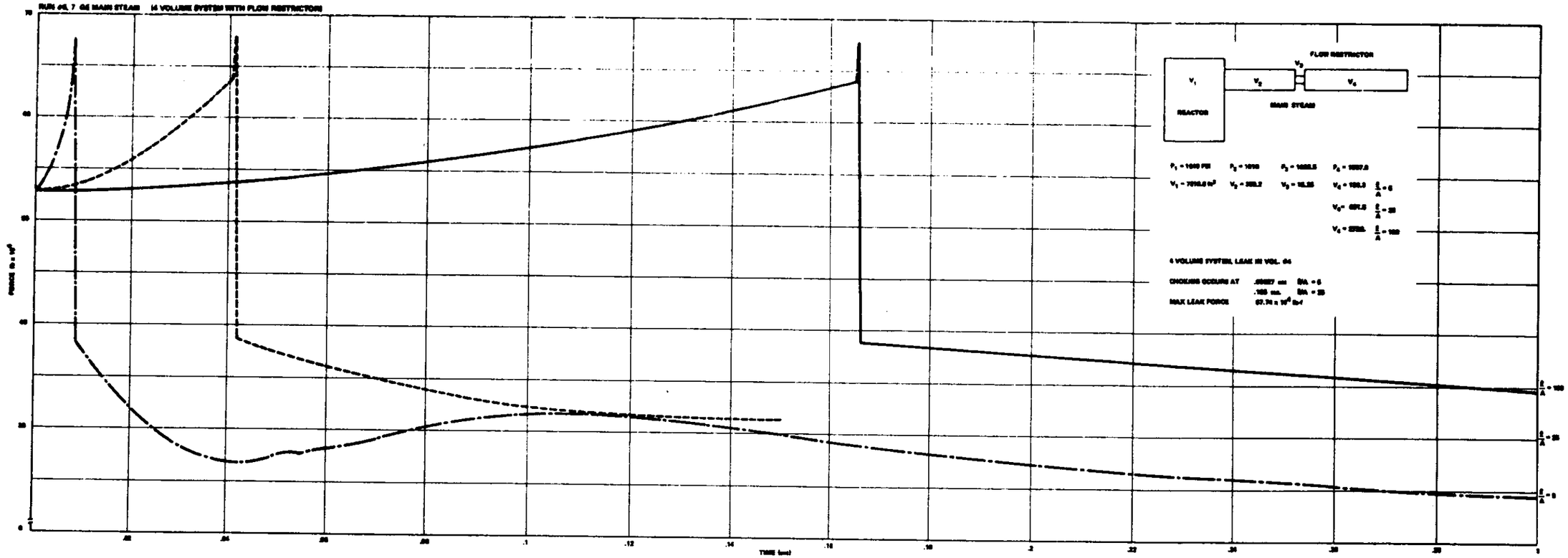

RUN #5_7 -04 MAIN STEAM 4 VOLUME SYSTEM WITH FLOW RESTRICTORS
FORCE lb x 10³
TIME (ms)
FLOW RESTRICTOR
REACTOR
MAIN STEAM
4 VOLUME SYSTEM, LEAK IN VOL. #4
CHOKING OCCURS AT
MAX LEAK FORCE

FIGURE 4.9

RUN #8 GE MAIN STEAM ℓ/A = 5

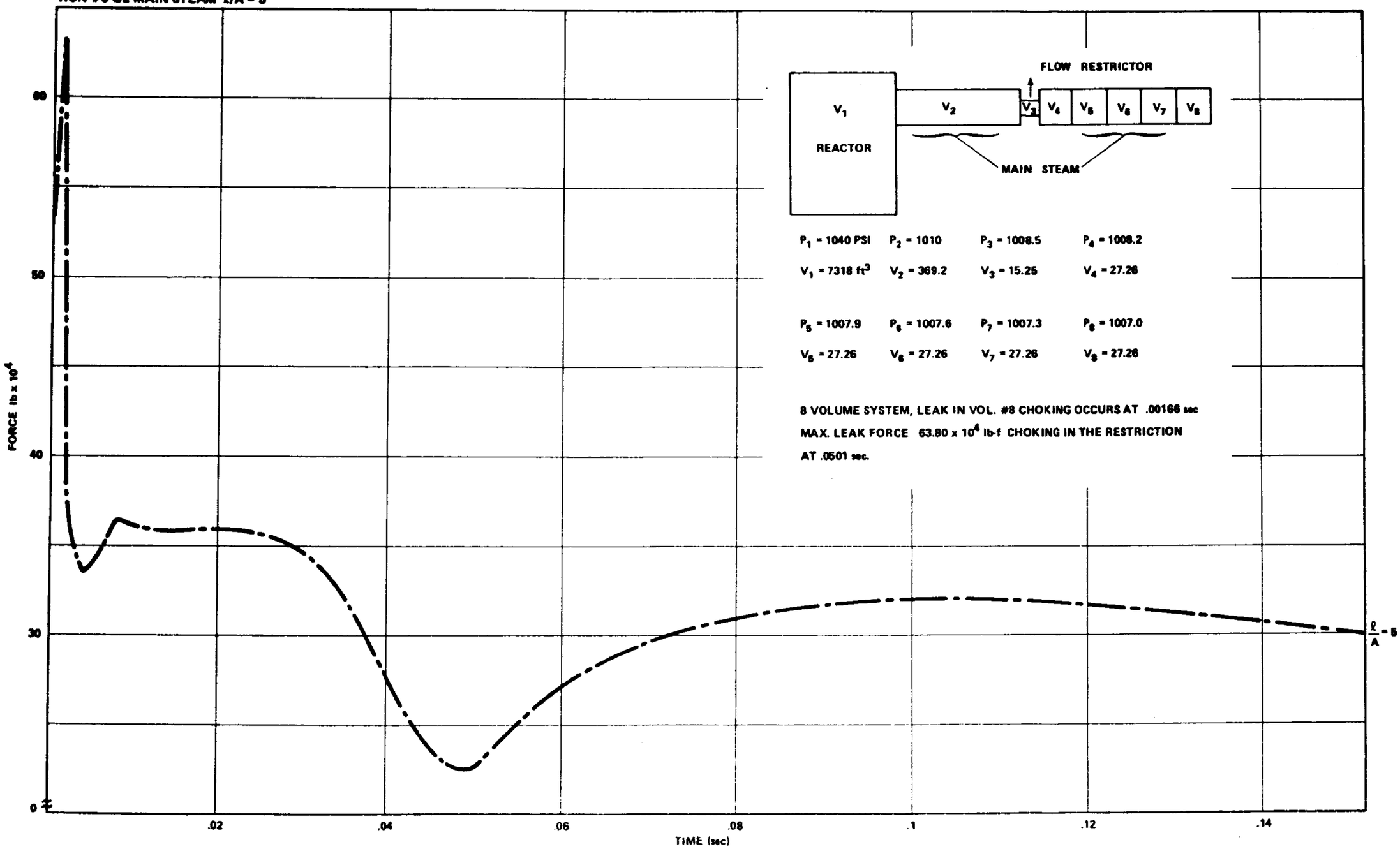


FIGURE 4.10

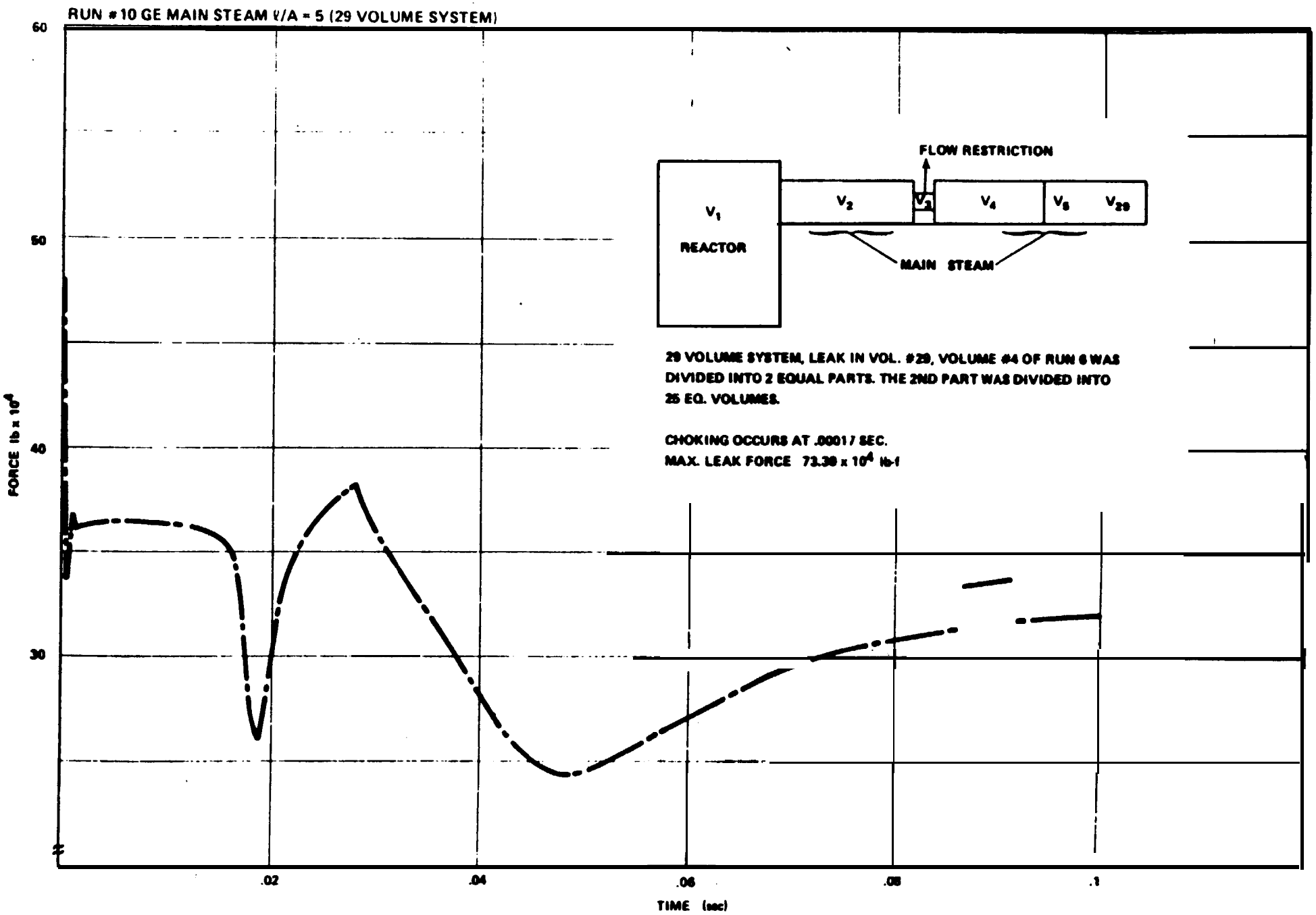

RUN #10 GE MAIN STEAM V/A = 5 (29 VOLUME SYSTEM)
60
50
40
30
FORCE lb x 10⁴
.02
.04
.06
.08
.1
TIME (sec)
FLOW RESTRICTION
V1
REACTOR
V2
V3
V4
V5
V29
MAIN STEAM
29 VOLUME SYSTEM, LEAK IN VOL. #29, VOLUME #4 OF RUN 6 WAS DIVIDED INTO 2 EQUAL PARTS. THE 2ND PART WAS DIVIDED INTO 25 EQ. VOLUMES.
CHOKING OCCURS AT .00017 SEC.
MAX. LEAK FORCE 73.39 x 10⁴ lb-f

FIGURE 4.11

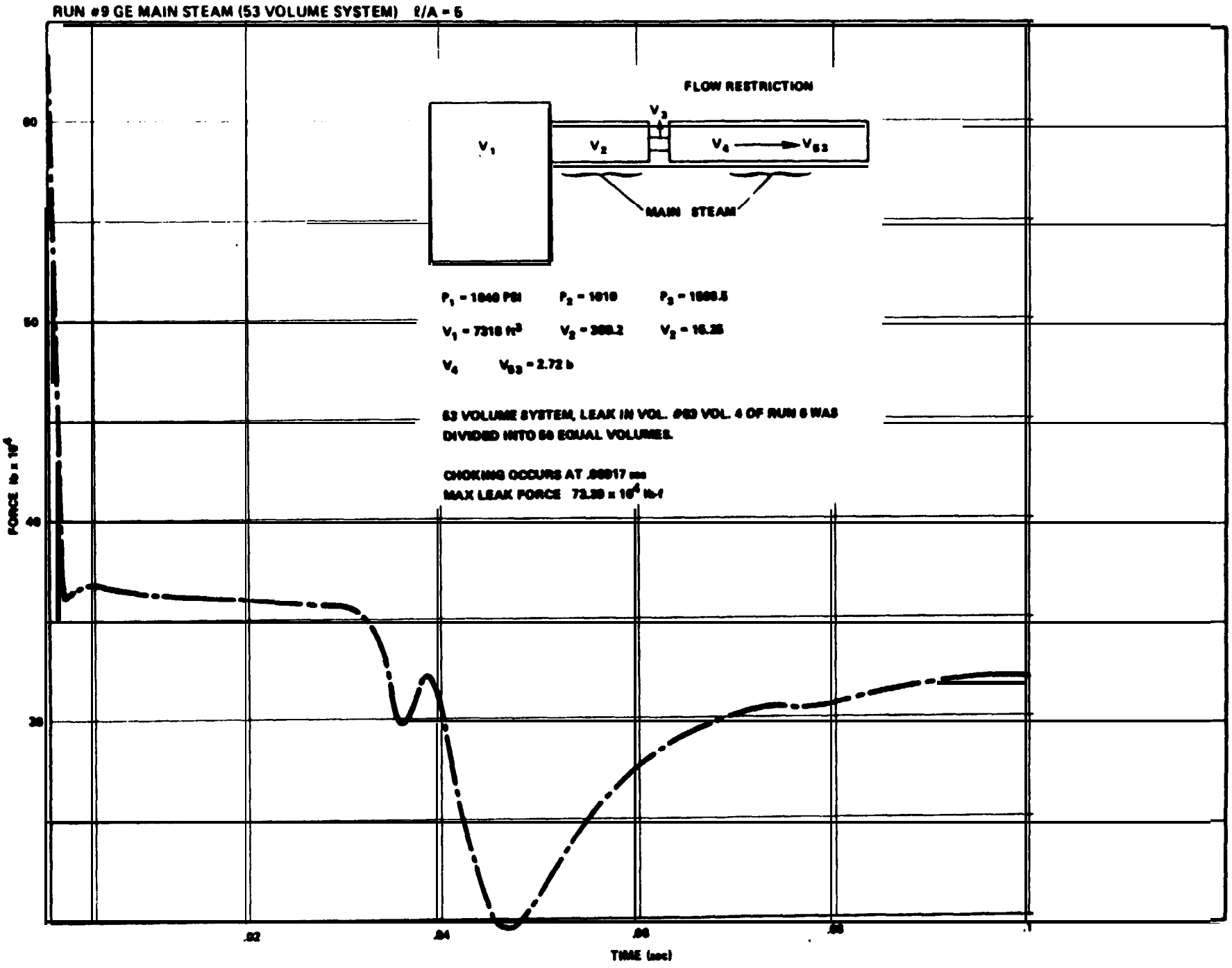

RUN #9 GE MAIN STEAM (53 VOLUME SYSTEM) ℓ/A = 5
FLOW RESTRICTION
V_1
V_2
V_3
V_4
V_{53}
MAIN STEAM
P_1 = 1040 PSI
P_2 = 1010
P_3 = 1000.5
V_1 = 7318 ft³
V_2 = 368.2
V_3 = 16.25
V_4
V_{53} = 2.72 b
53 VOLUME SYSTEM, LEAK IN VOL. #53 VOL. 4 OF RUN 6 WAS DIVIDED INTO 50 EQUAL VOLUMES.
CHOKING OCCURS AT .00917 sec
MAX LEAK FORCE 73.29 x 10⁴ lb-f
FORCE lb x 10⁴
60
50
40
30
.02
.04
.06
.08
TIME (sec)

FIGURE 4.12

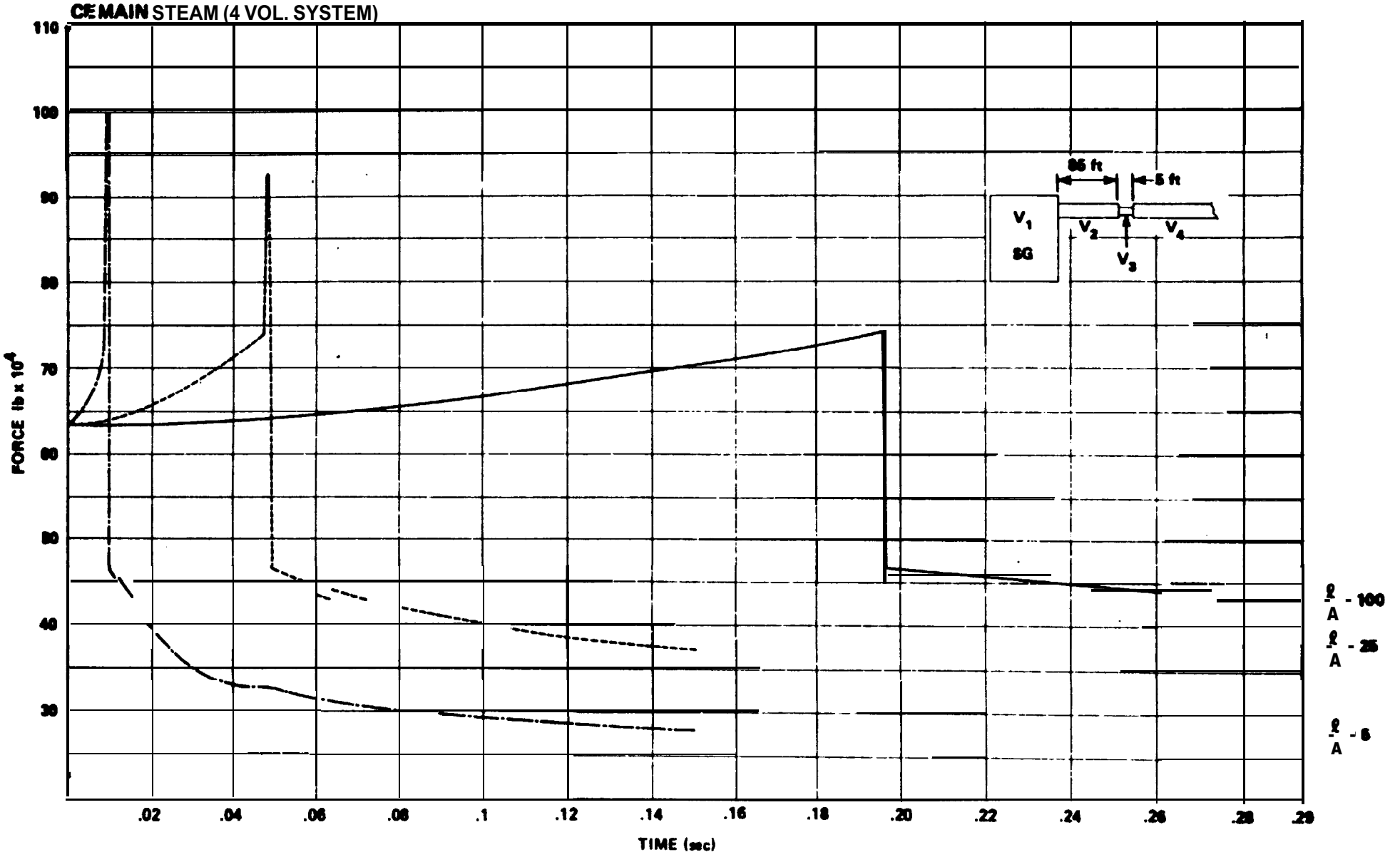

CE MAIN STEAM (4 VOL. SYSTEM)
FORCE lb x 10^4
110
100
90
80
70
60
50
40
30
.02
.04
.06
.08
.1
.12
.14
.16
.18
.20
.22
.24
.26
.28
.29
TIME (sec)
85 ft
5 ft
V1
SG
V2
V3
V4
ℓ/A - 100
ℓ/A - 25
ℓ/A - 6

FIGURE 4.13

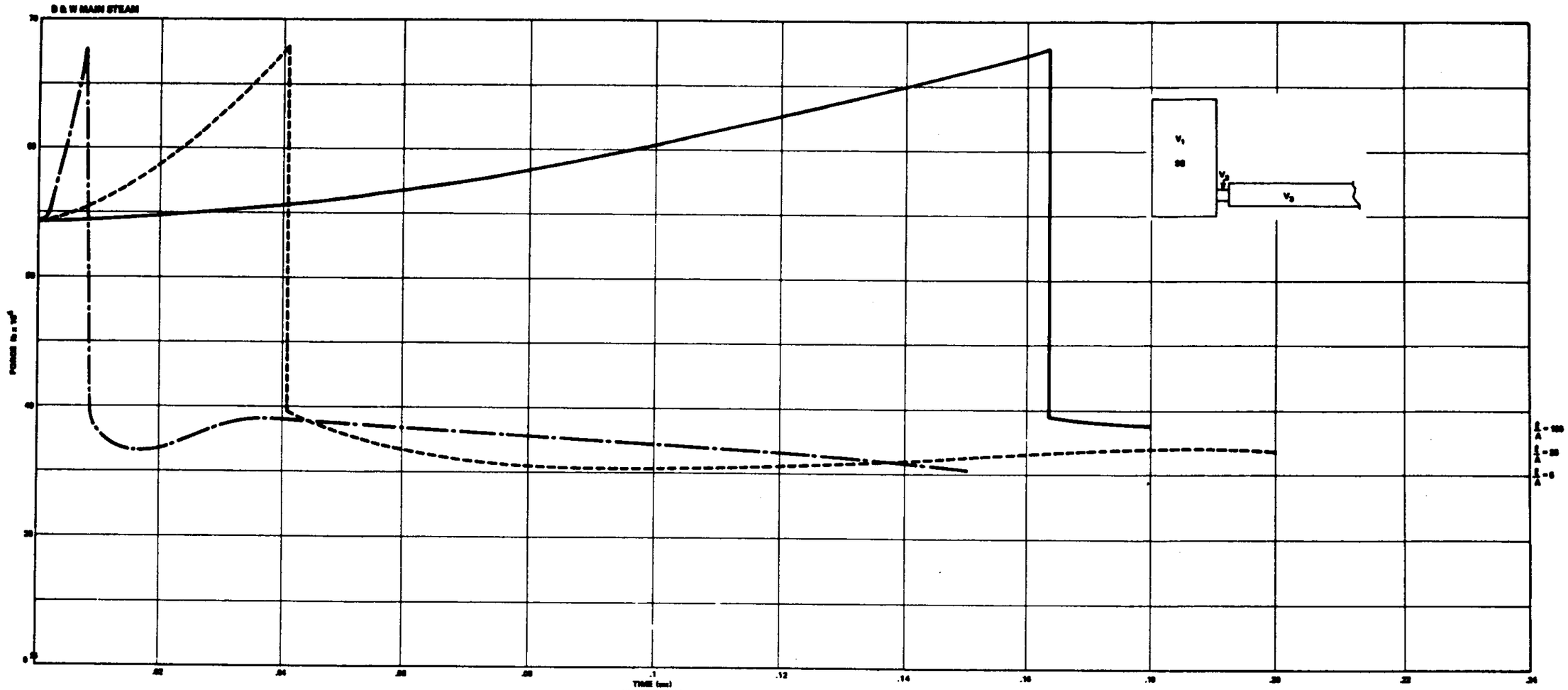


FIGURE 4.14

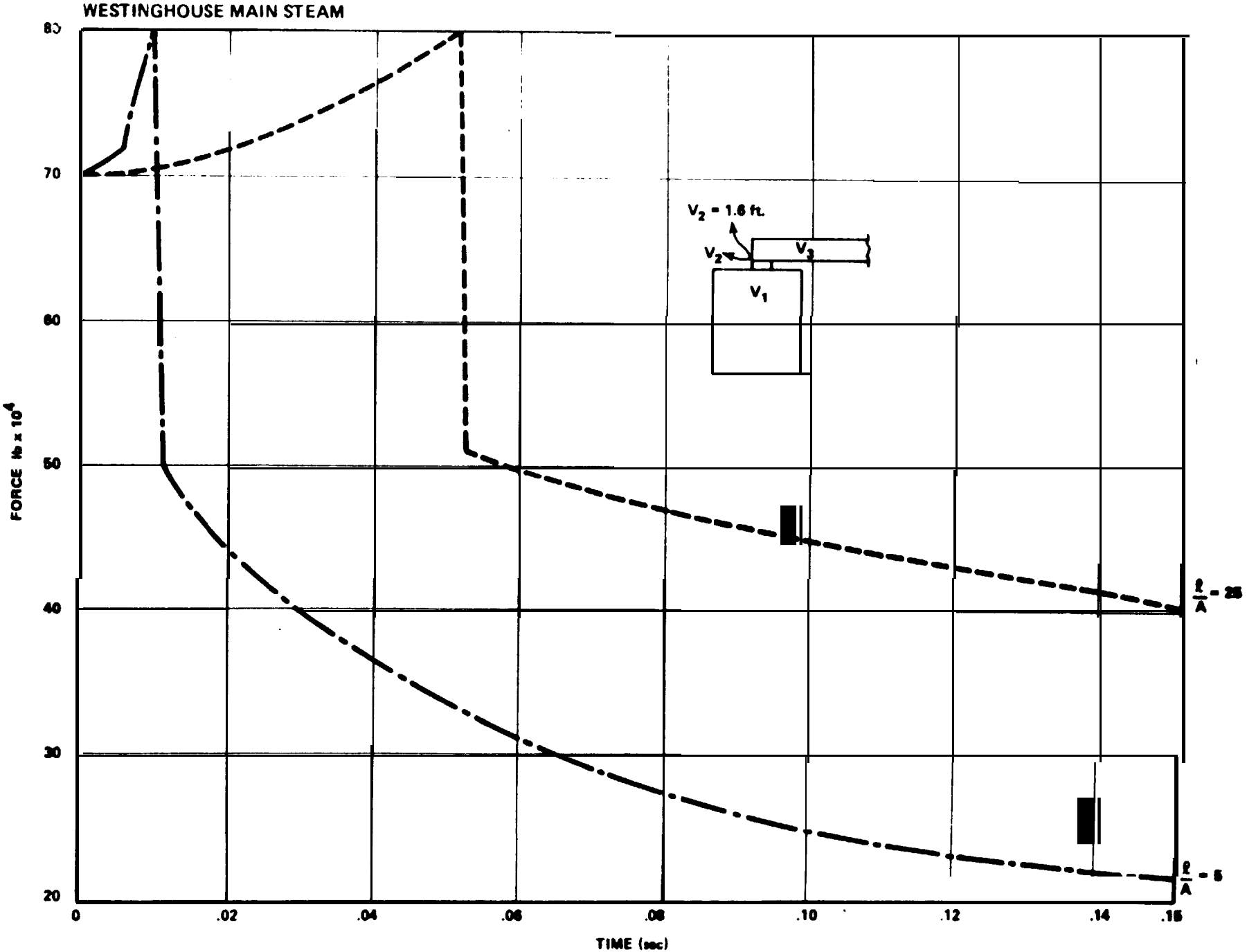

WESTINGHOUSE MAIN STEAM
80
70
60
50
40
30
20
FORCE lb x 10^4
0
.02
.04
.06
.08
.10
.12
.14
.16
TIME (sec)
V2 = 1.6 ft.
V2
V3
V1
ℓ/A = 25
ℓ/A = 5

FIGURE 4.15

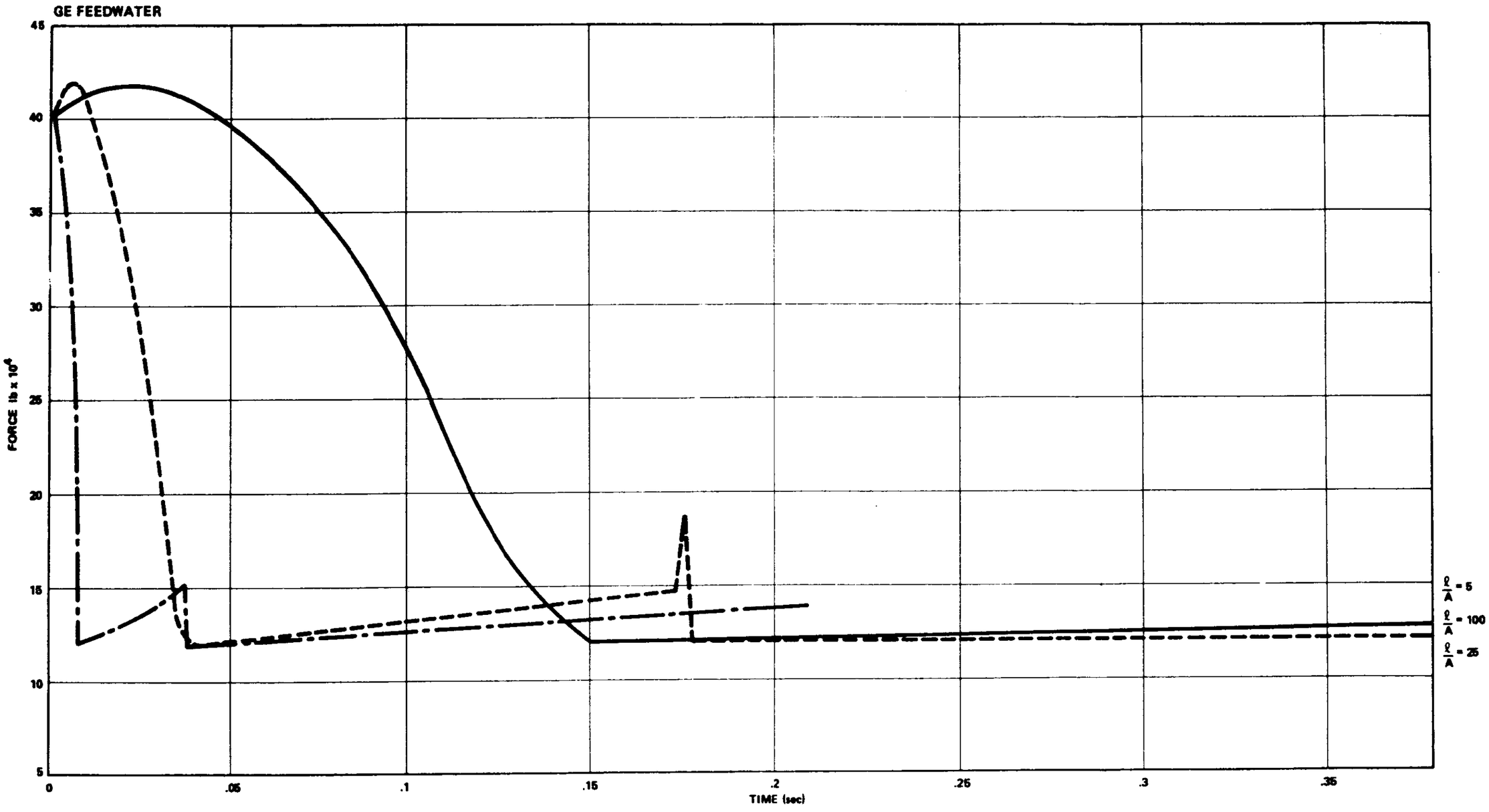

GE FEEDWATER
FORCE lb x 10⁴
45
40
35
30
25
20
15
10
5
0
.05
.1
.15
.2
.25
.3
.35
TIME (sec)
ℓ/A = 5
ℓ/A = 100
ℓ/A = 25

FIGURE 4.16

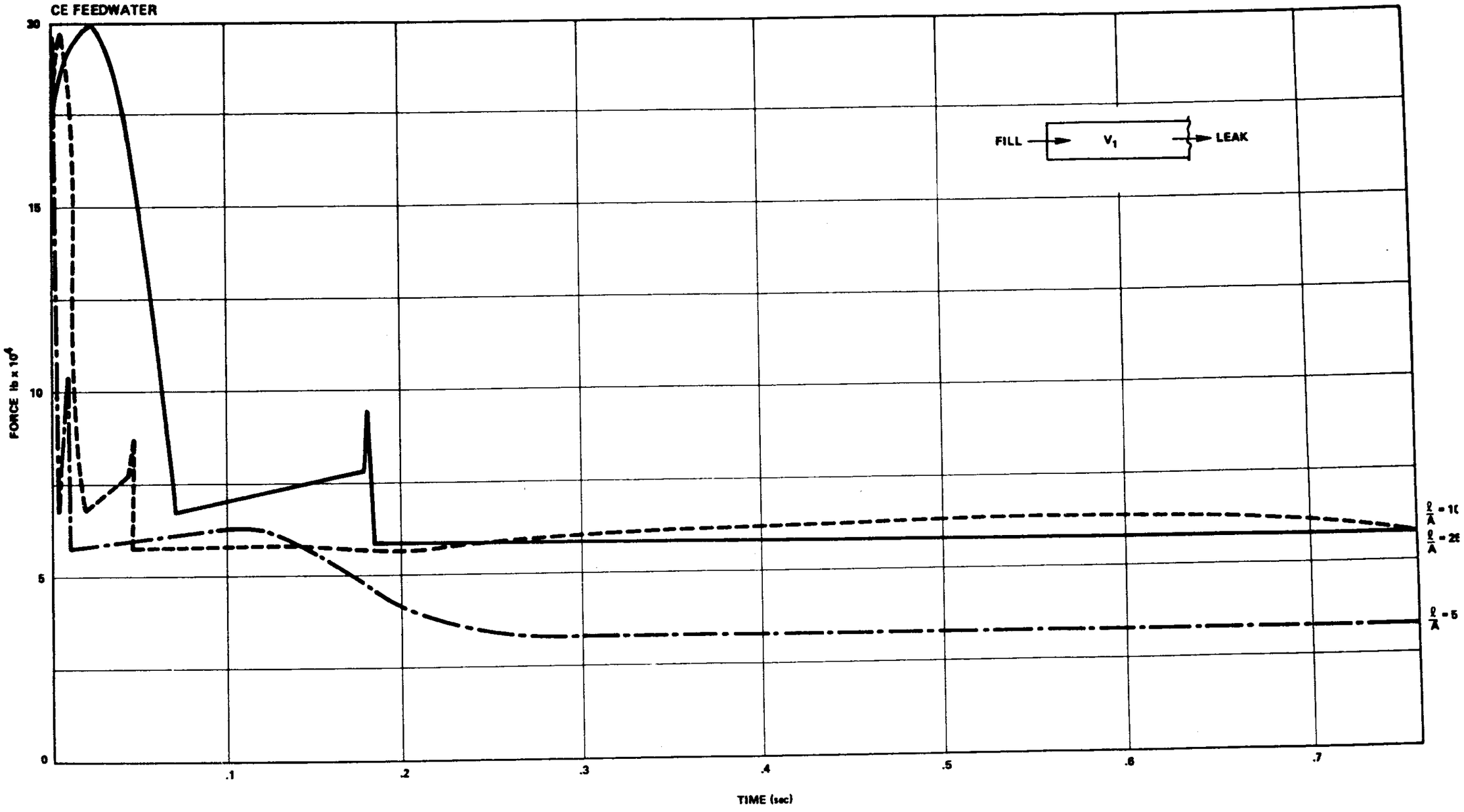

CE FEEDWATER
FILL
V_1
LEAK
FORCE lb x 10^4
30
15
10
5
0
.1
.2
.3
.4
.5
.6
.7
TIME (sec)
$\frac{\rho}{A}$ = 1(
$\frac{\rho}{A}$ = 2(
$\frac{\rho}{A}$ = 5

FIGURE 4.17

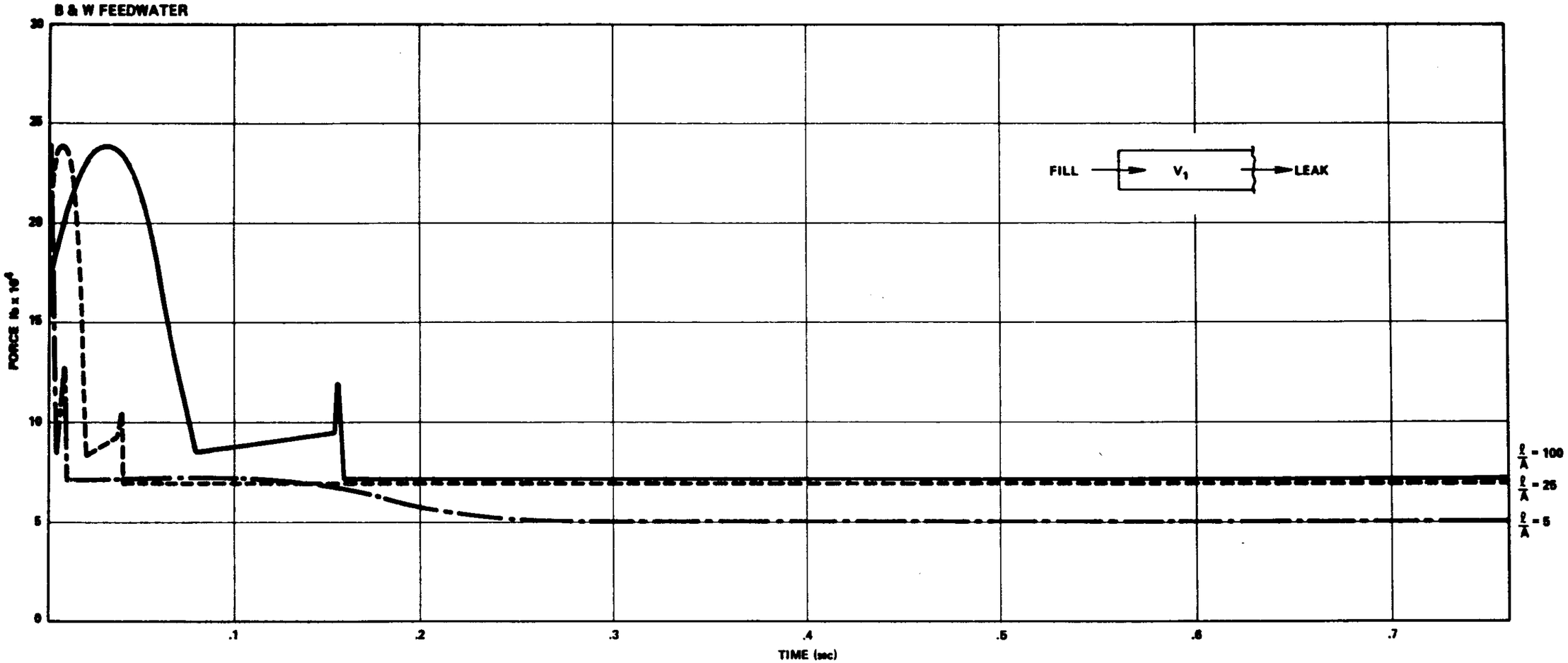

B & W FEEDWATER
FORCE lb x 10⁴
30
25
20
15
10
5
0
.1
.2
.3
.4
.5
.6
.7
TIME (sec)
FILL
V1
LEAK
ρ/A = 100
ρ/A = 25
ρ/A = 5

FIGURE 4.18

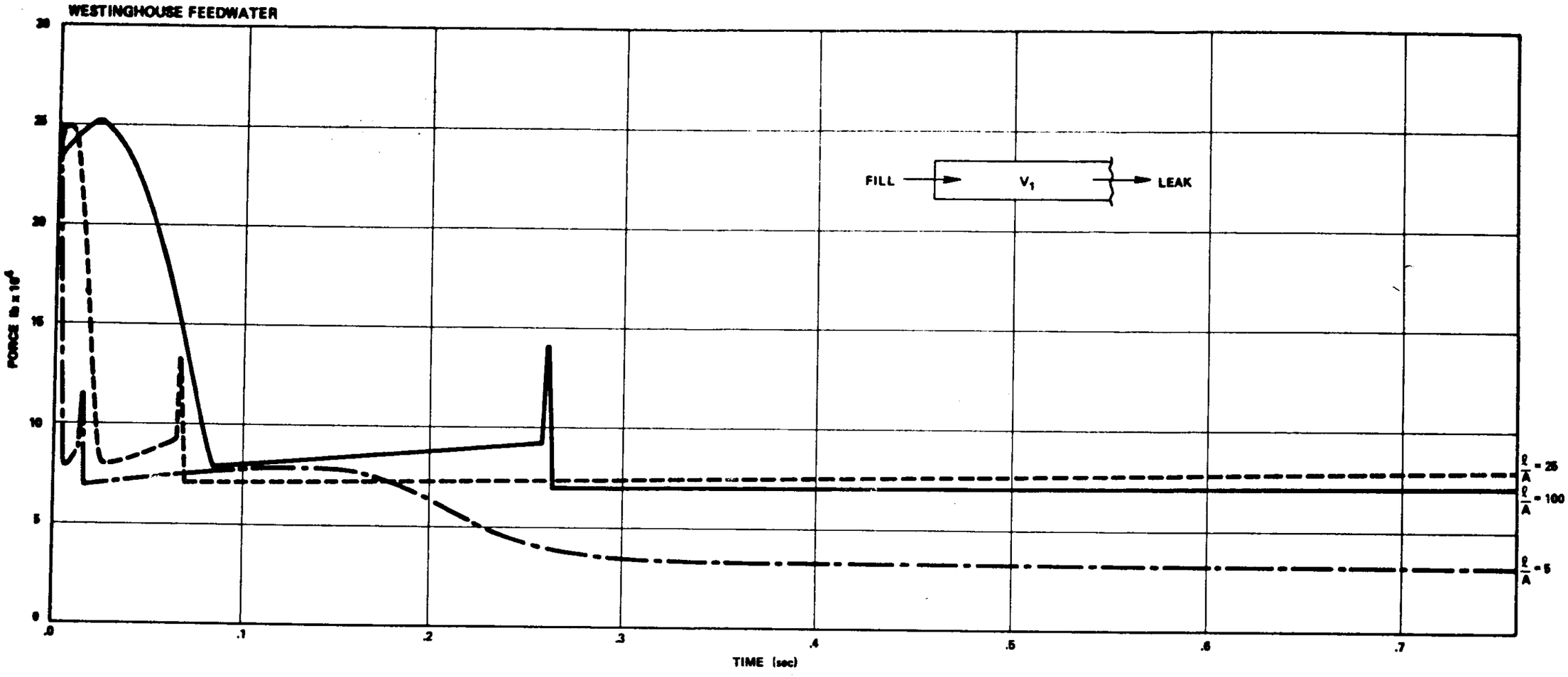

WESTINGHOUSE FEEDWATER
FILL
V_1
LEAK
FORCE lb x 10^4
TIME (sec)
$\frac{\ell}{A}$ = 25
$\frac{\ell}{A}$ = 100
$\frac{\ell}{A}$ = 5

FIGURE 4.19