APPENDIX

Summary of Test Data

Specimen No. 1

Diameter: 12" (nominal)
Wall Thickness: 3/8"
Length: 20' - 0"
Material: X60

Dent Type **A**

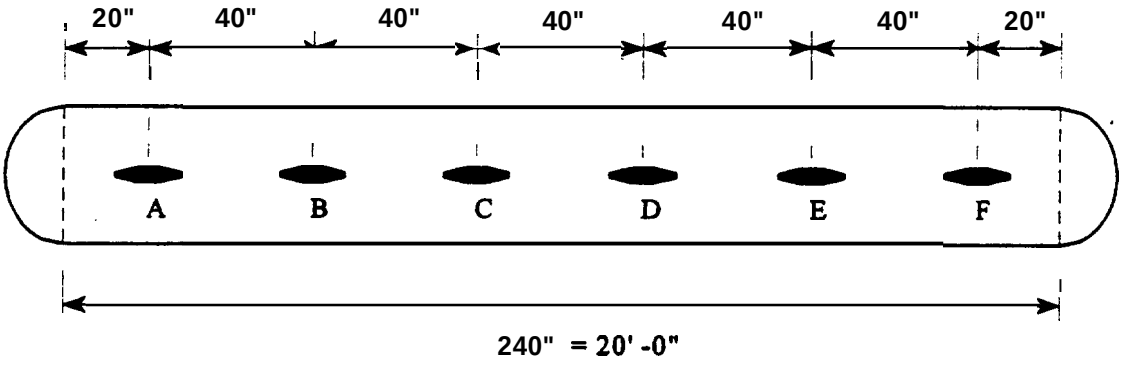


Figure A-1: Dent locations for Specimen No. 1.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	A	No	0.05" x 6"	5	0.6
B	A	No	0.05" x 6"	15	1.8
C	A	No	0.05" x 6"	10	1.2
D	A	Yes	0.05" x 6"	5	0.6
E	A	Yes	0.05" x 6"	15	1.8
F	A	Yes	0.05" x 6"	10	1.2

Table A-1: *Summary* of dent parameters for Specimen 1.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, d (in.) at pressure (psi.)					
				d (in)	d/D (%)	0	250	450	650	850	1050
A	A	No	-	0.6	5	0.20	0.20	0.20	0.20	0.20	0.20
B	A	No	83.6	1.8	15	1.10	1.10	1.10	1.10	1.08	1.08
C	A	No	67.3	1.2	10	0.72	0.70	0.70	0.70	0.68	0.66
D	A	Yes	62.8	0.6	5	0.16	-	-	-	-	
E	A	Yes	88.0	1.8	15	1.06	-	-	-	-	-
F	A	Yes	68.1	1.2	10	0.60	-	-	-	-	-

Table A-2: Denting forces and dent depths for Specimen 1.

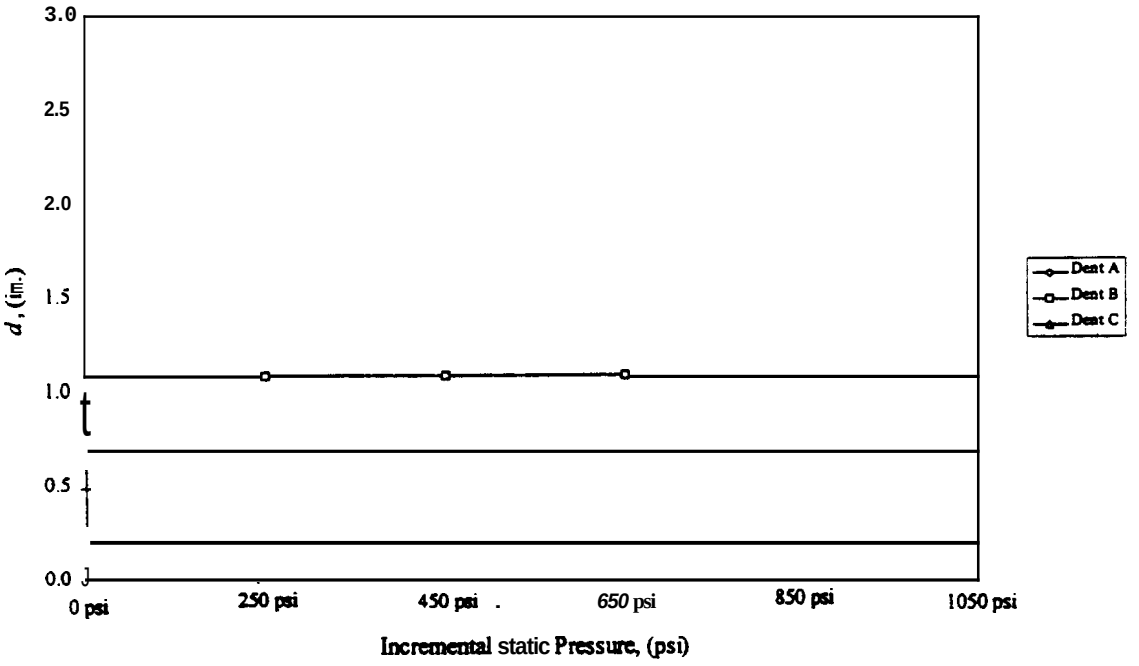


Figure A-2: Dent depth rebound versus internal pressure for Specimen 1.

DentID	Type	Restraint	d/D (%)	Fatigue Failure	Cycles to Failure	Comment
1-A	A	No	5	Yes	94,559	groove crack, center of dent
I-B	A	No	15	Yes	33,521	groove crack, center of dent
1-C	A	No	10	Yes	27,031	groove crack, center of dent
I-D	A	Yes	5	NO	94,559	no cracking
1-E	A	Yes	15	Yes	37,548	groove crack, comer of restraint
1-F	A	Yes	10	Yes	68,456	groove crack, comer of restraint

Table A-3: *Summary* of dent fatigue failures for Specimen 1.

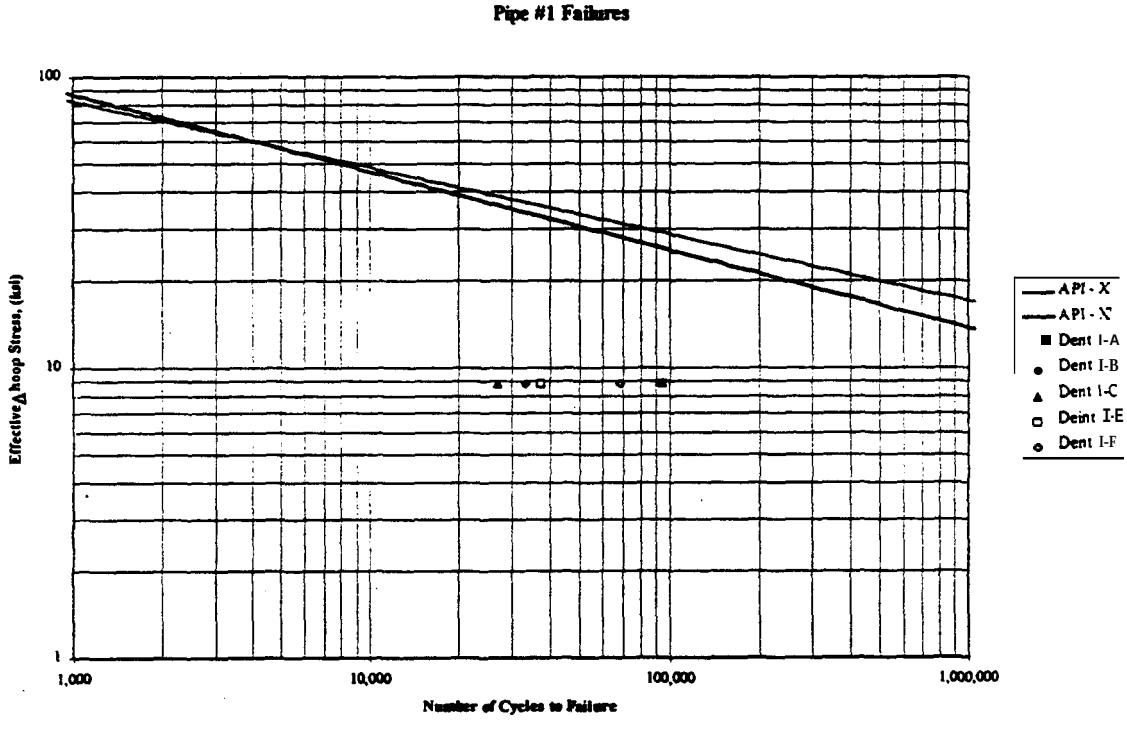


Figure A-3: S-N plot of fatigue failures for Specimen 1.

Specimen No. 2

Diameter: 12" (nominal)
Wall **Thickness:** 3/8"
Length: 20' - 0"
Material: X60

Dent Type BH-L

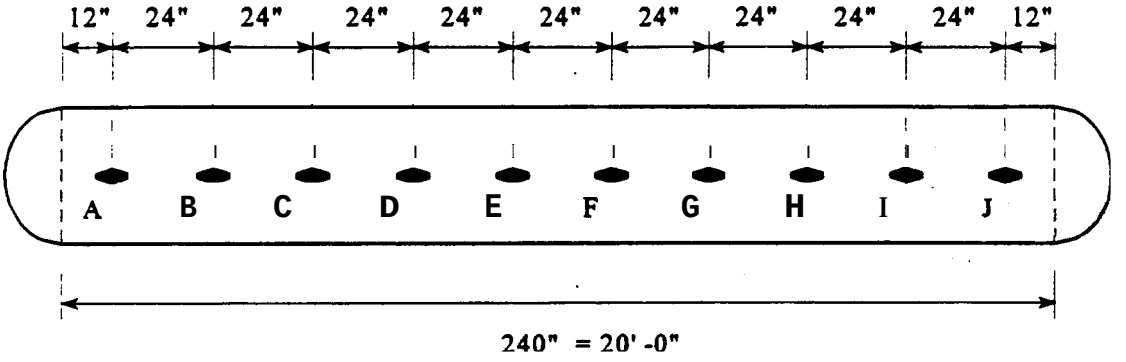


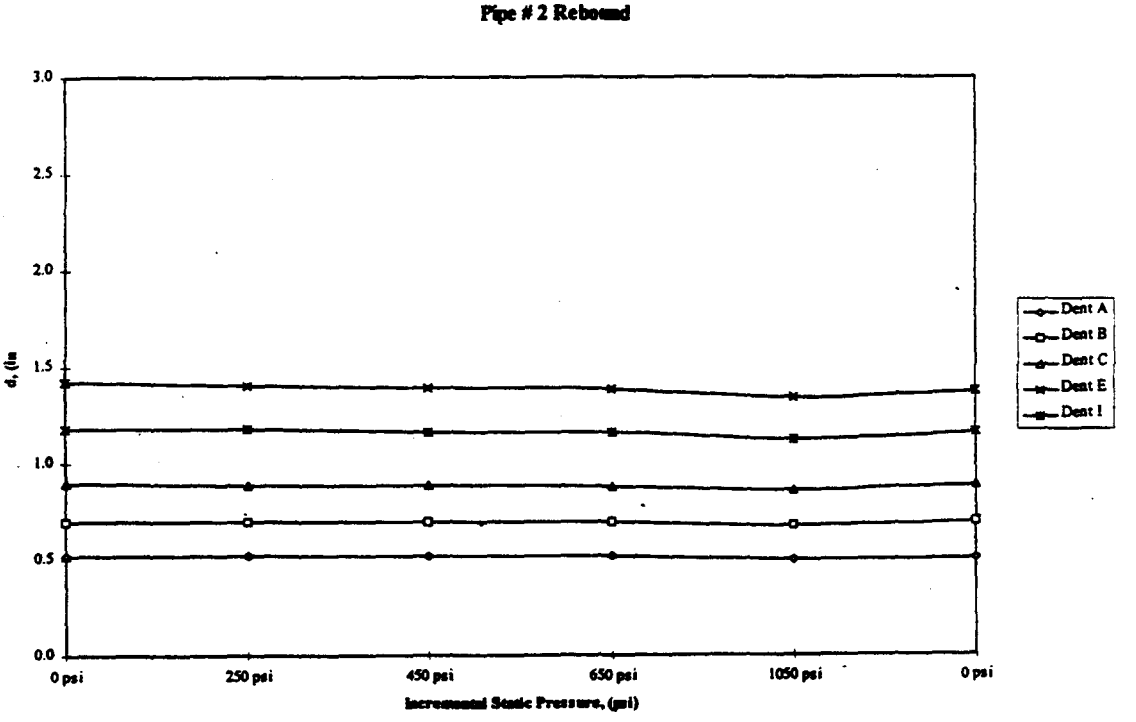
Figure A-4: Dent locations for Specimen No. 2.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/*D* (%)	*d* (in.)
A	BH-L	No	None	7.5	0.9
B	BH-L	No	None	10.0	1.2
C	BH-L	No	None	12.5	1.5
D	BH-L	Yes	None	15.0	1.8
E	BH-L	No	None	17.5	2.1
F	BH-L	Yes	None	17.5	2.1
G	BH-L	Yes	None	10.0	1.2
H	BH-L	Yes	None	12.5	1.5
I	BH-L	No	None	15.0	1.8
J	BH-L	Yes	None	7.5	0.9

Table A-4: Summary of dent parameters for Specimen 2.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth d (in)	Initial Dent Depth d/D (%)	Rebound Dent Depth, d (in.) at pressure (psi.) 0	250	450	650	1050	0
A	BH-L	No	46.0	0.9	7.5	0.52	0.52	0.52	0.52	0.50	0.51
B	BH-L	No	50.7	1.2	10	0.70	0.70	0.70	0.70	0.68	0.70
C	BH-L	No	61.0	1.5	12.5	0.90	0.89	0.89	0.88	0.86	0.89
D	BH-L	Yes	69.0	1.8	15	1.22	-	-	-	-	-
E	BH-L	No	79.0	2.1	17.5	1.42	1.4	1.39	1.38	1.34	1.37
F	BH-L	Yes	80.0	2.1	17.5	1.40	-	-	-	-	-
G	BH-L	Yes	52.5	1.2	10	0.72	-	-	-	-	-
H	BH-L	Yes	62.5	1.5	12.5	0.92	-	-		-	-
I	BH-L	No	71.5	1.8	15	1.18	1.18	1.16	1.16.	1.12	1.16
J	BH-L	Yes	46	0.9	7.5	0.48	-	-			

Table A-5: Denting forces and dent depths for Specimen 2.



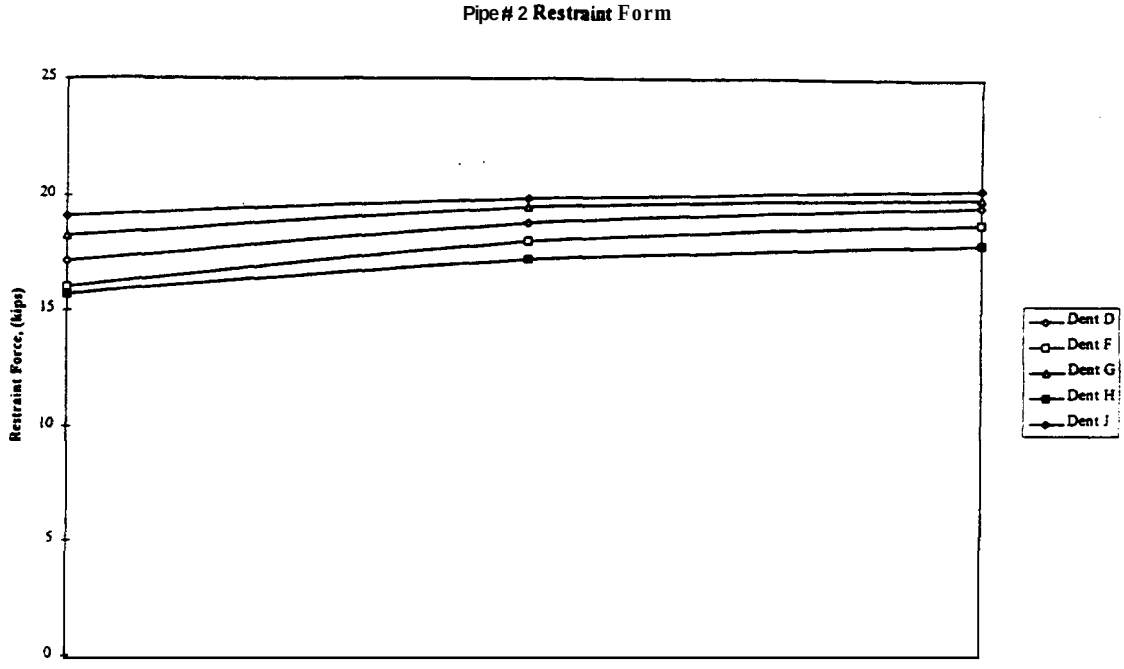


Figure A-6: Measured dent restraint forces for Specimen 2.

2-B	BH-L	No	10	No	128,732	
2-C	BH-L	No	12.5	No	128,732	
2-D	BH-L	Yes	15	No	128,732	
2-E	BH-L	No	17.5	No	128,732	no cracking
2-F	BH-L	Yes	17.5	No	128,732	no leaks
2-G	BH-L	Yes	10	No	128,732	
2-H	BH-L	Yes	12.5	No	128,732	
2-1	BH-L	No	15	No	128,732	

Table A-6: Summary of dent fatigue failures for Specimen 2.

Specimen No. 3

Diameter: 12" (nominal)
Wail Thickness: 1/4"
Length: 20 - 0"
Material: X42

Dent Type BH-T & R

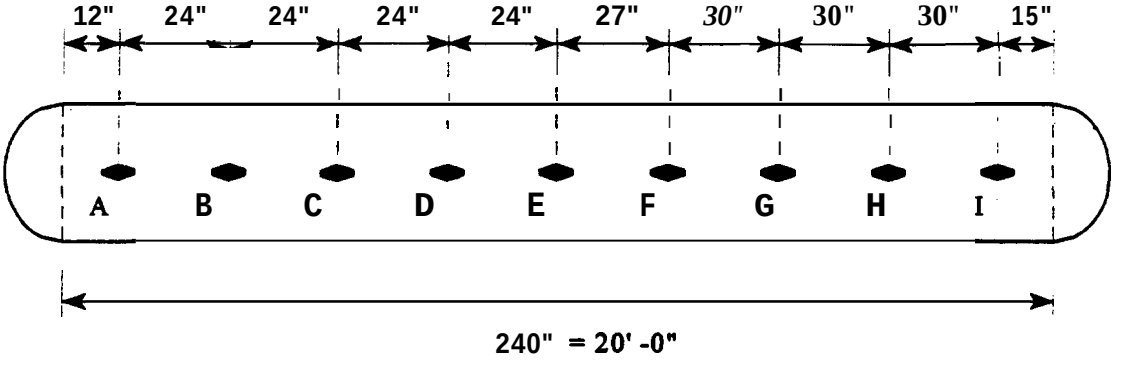


Figure A-7: Dent locations for Specimen No. 3.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	BH-T	No	None	5	0.638
B	BH-T	No	None	7.5	0.956
C	BH-T	No	None	10	1.275
D	BH-T	No	None	12.5	1.594
E	BH-T	No	None	15	1.913
F	R	Yes	None	12.5	1.594
G	R	Yes	None	10	1.275
H	R	Yes	None	7.5	0.956
I	R	yes	None	5	0.638

Table A-7: Summary of dent parameters for Specimen 3.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth. d (in.) at pressure (psi.)					
				d (in)	d/D (%)	0	400	800	1000	1200	0
A	BH-T	**No**	22.0	0.638	5	0.76	0.69	0.60	0.54	0.48	0.53
B	BH-T	No	24.0	0.956	7.5	0.85	0.75	0.67	0.61	0.55	0.60
C	BH-T	No	26.0	1.275	10	0.90	0.83	0.73	0.68	0.60	0.65
D	BH-T	No	30.0	1.594	12.5	1.22	1.09	0.92	0.80	0.72	0.79
E	BH-T	No	34.0	1.913	15	1.55	1.32	1.09	0.95	0.82	0.93
F	R	Yes	27.2	1.594	12.5	1.08	-	-	-	-	-
G	**R**	**Yes**	20.0	1.275	10	0.60	-	-	-	-	-
H	R	Yes	17.8	0.956	7.5	0.78	-	-	-	-	-
I	R	**Yes**	16.2	0.638	5	0.5					-

Table **A-8:** Denting forces and dent depths for Specimen 3.

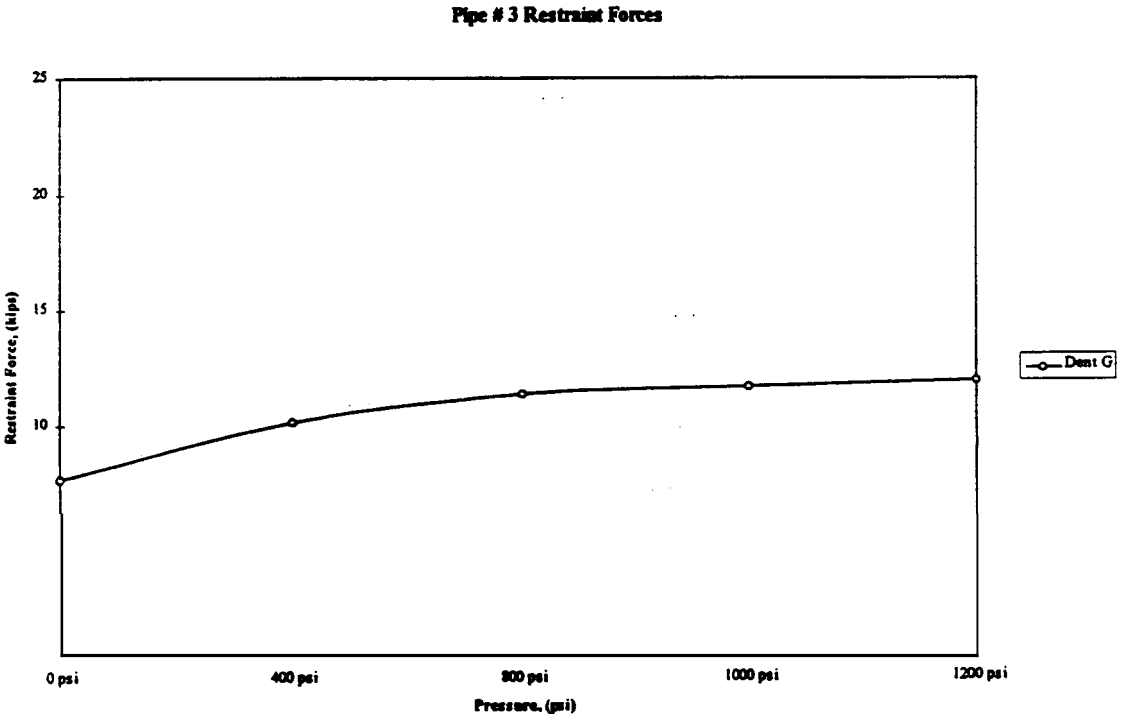


Figure A-8: Measured dent restraint forces for Specimen 3.

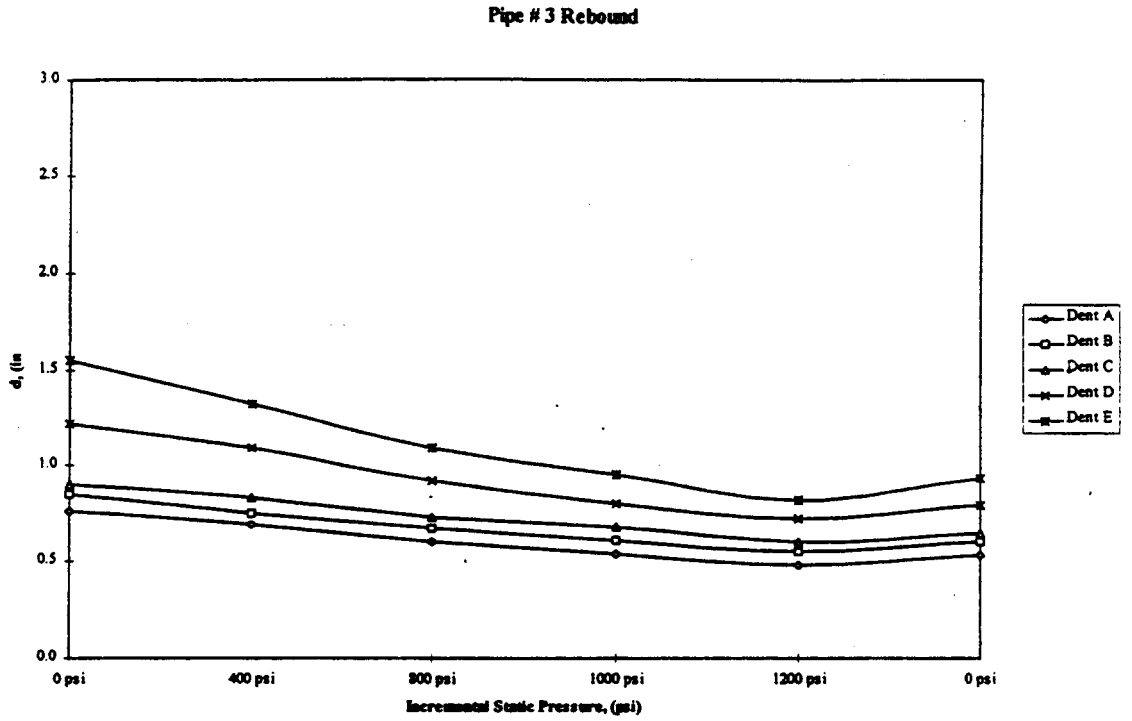


Figure A-9: Dent depth rebound versus internal pressure for Specimen 3.

DentID	Type	Restraint	*d/D* (%)	Fatigue Failure	Cycles to Failure	Comment
3-A	BH-T	No	5	No	100,943	shallow peripheral, post proof
3-B	BH-T	No	7.5	No	100,943	shallow peripheral, post proof
3-C	BH-T	No	10	No	100,943	shallow peripheral, post proof
3-D	BH-T	N0-	12.5	Yes	89,684	peripheral leak
3-E	BH-T	No	15	Yes	80,880	peripheral leak
3-F	R	Yes	12.5	Yes	100,943	peripheralleak
3-G	R	Yes	10	No	100,943	nocracking
3-H	R	Yes	7.5	No	100,943	no cracking
3-I	R	Yes	5	No	100,943	nocracking

Table A-9: *Summary* of dent fatigue failures for Spechen 3.

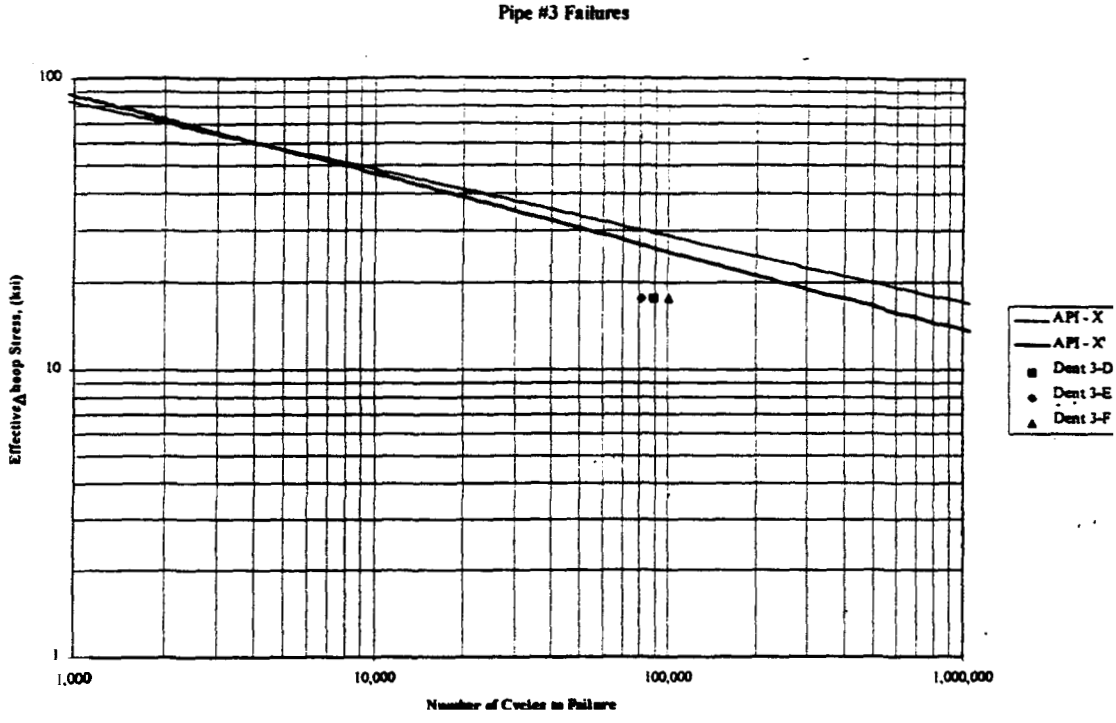


Figure A-10: S-N fatigue test data for Specimen 3.

Specimen No. 4

Diameter: 16" (nominal)
Wall **Thickness:** 1/4"
Length: 20' - 0"
Material: X60

Dent Type **A**

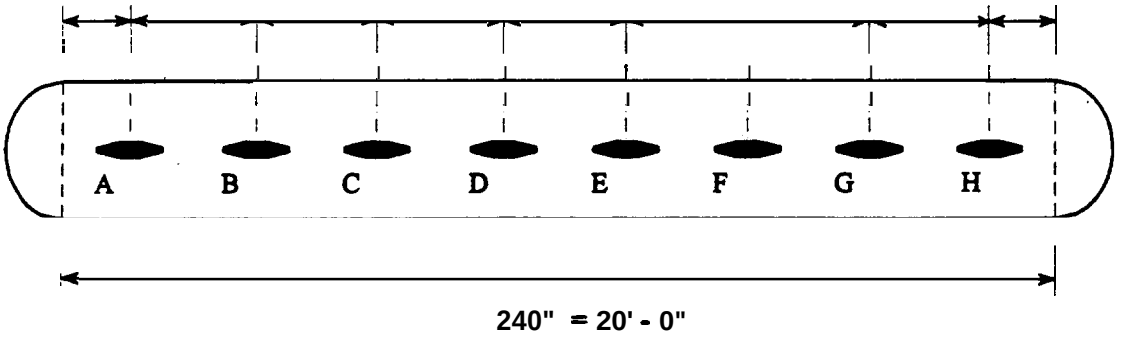


Figure A-11: Dent locations for Spechen No. 4.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	A	No	0.024" x 5"	5.0	0.8
B	A	No	0.024" x 5"	18.8	3.0
C	A	No	0.024" x 5"	10.0	1.6
D	A	No	0.024" x 5"	15.0	2.4
E	A	Yes	0.024" x 5"	18.8	3.0
F	A	Yes	0.024" x 5"	10.0	1.6
G	A	Yes	0.024" x 5"	15.0	2.4
H	A	Yes	0.024" x 5"	5.0	0.8

Table A-10: Summary of dent parameters for Specimen 4.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth d (in)	Initial Dent Depth d/D (%)	Rebound Dent Depth, d (in.) at pressure (psi.) 0	100	250	450	650	850	1050	850	1050	1050
A	A	No	18.4	0.8	5	0.20	0.19	0.17	0.17	0.14	0.14	0.12	0.15	0.12	0.15
B	A	No	37.1	2.8	17.5	1.49	1.41	1.25	1.03	0.74	0.32	0.19	0.30	0.18	0.27
C	A	No	23.6	1.6	10	0.67	0.65	0.59	0.49	0.41	0.34	*0.29*	0.34	0.28	0.33
D	A	No	32.6	2.4	15	1.16	1.11	1.01	0.82	0.58	*0.46*	0.38	0.43	0.37	0.43
E	A	Yes	38.0	2.8	17.5	-									
F	A	Yes	23.4	1.6	10	-									
G	A	Yes	31.9	2.4	15	-									
H	A	Yes	18.7	0.8	5										

Table A-11: Denting forces and dent depths for Specimen 4.

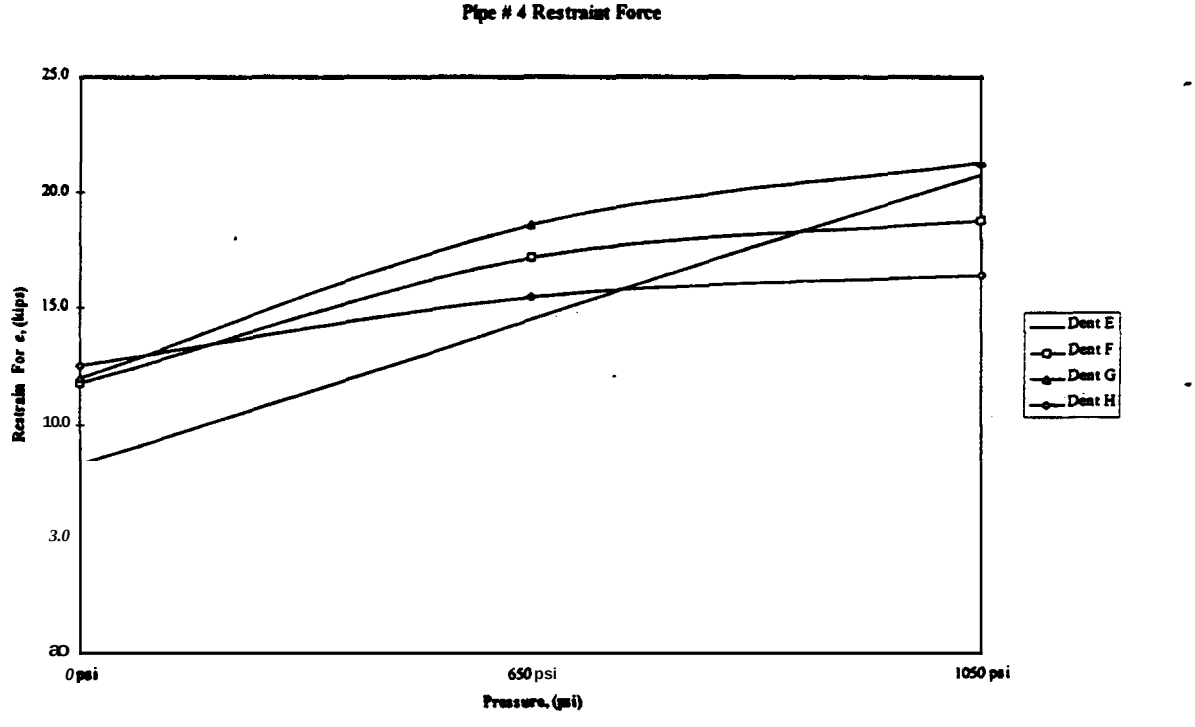


Figure A-12: Measured dent restraint forces for Specimen 4.

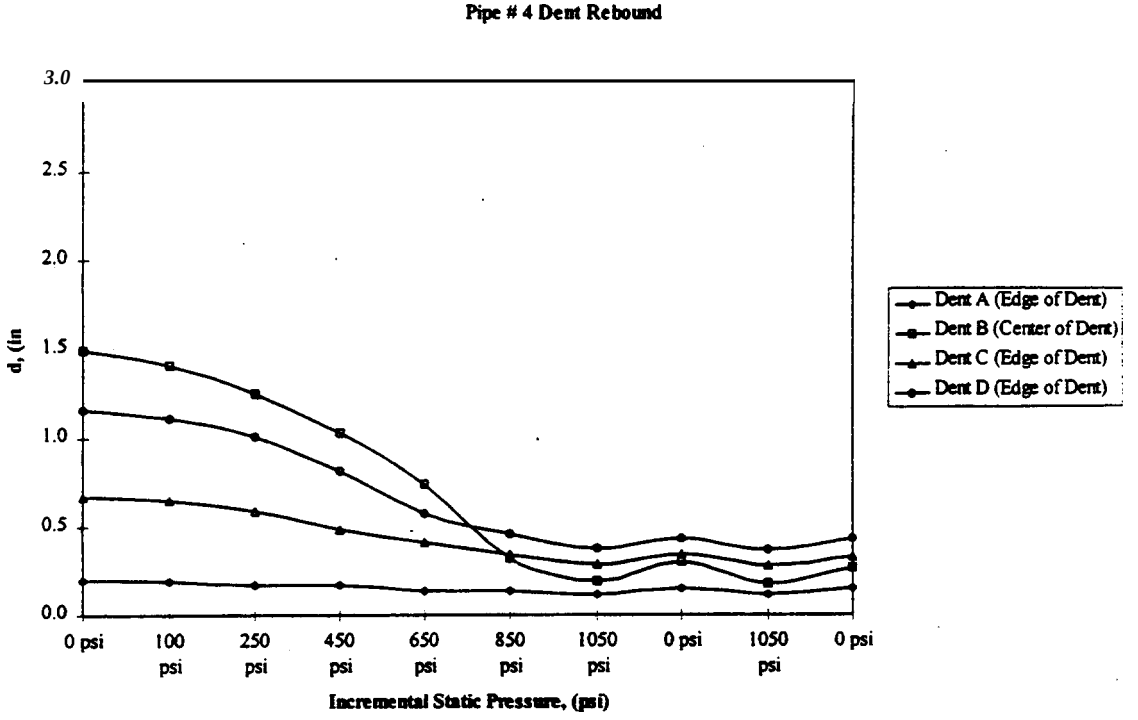


Figure A-13: Dent depth rebound versus internal pressure for Specimen 4.

DentID	Type	Restraint	*d/D* (%)	Fatigue Failure	Cycles to Failure	Comment
4-A	A	No	5	Yes	44,286	groove leak, center of dent
4-B	A	No	18.75	Yes	2,515	groove leak, center of dent
4-C	A	No	10	Yes	7,600	groove leak, center of dent
4-D	A	No	15	Yes	2,515	groove leak, center of dent
4-E	A	Yes	18.75	Yes	62,668	peripheralleak
4 F	A	Yes	10	No	92,398	nocracking
4-G	A	Yes	15	Yes	92,398	peripheralcrack
4-H	A	Yes	5	No	92,398	nocracking

Table A-12: Summary of dent fatigue failures for Specimen 4.

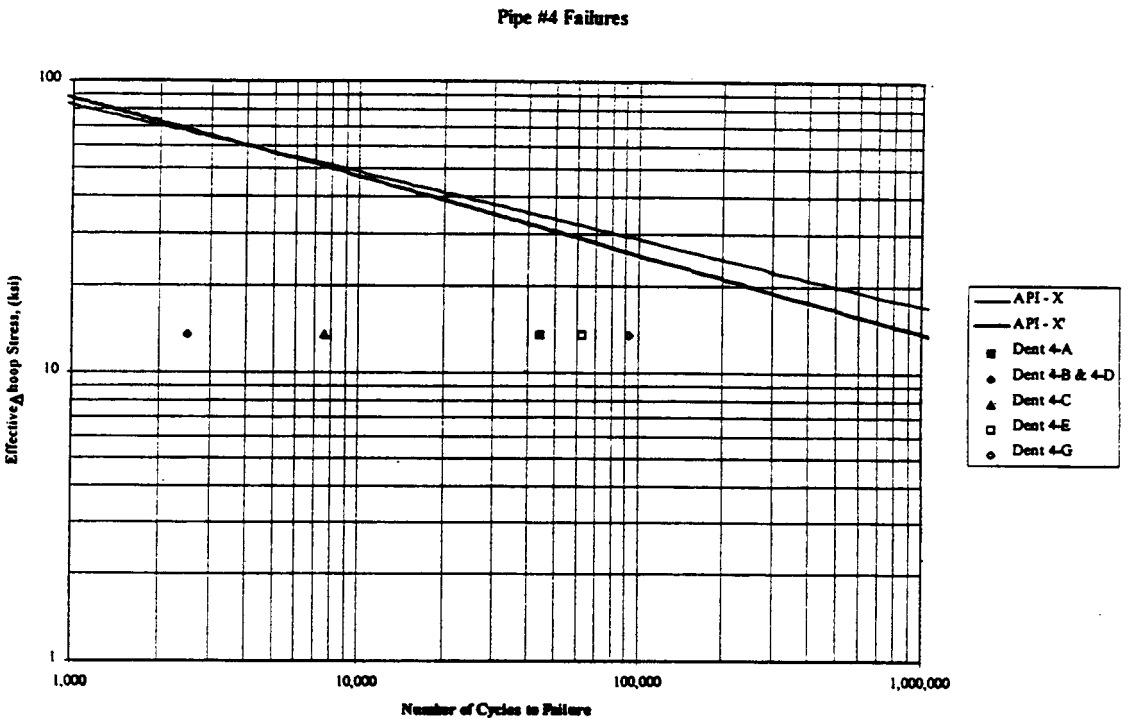


Figure A-14: S-N plot of fatigue failure for Specimen 4.

Specimen No. 5

Diameter: 16" (nominal)
Wail Thickness: 1/4"
Length: 20' - 0"
Material: X42

Dent Type BH-T, BH-L, & R

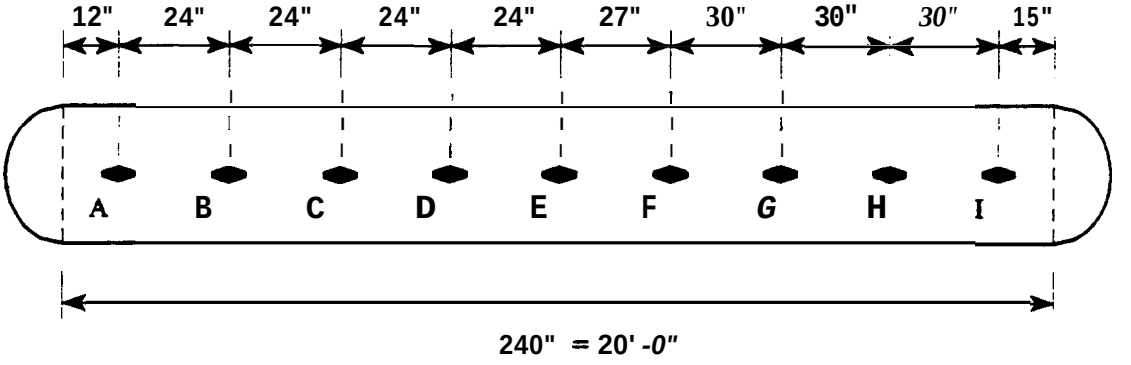


Figure A-15: Dent locations for Specimen No. 5.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	d (in.)
A	BH-T	No	None	5.0	0.8
B	BH-T	No	None	10.0	1.6
C	BH-T	No	None	15.0	2.4
D	BH-L	No	None	10.0	1.6
E	BH-L	No	None	15.0	2.4
F	R	Yes	None	15.0	2.4
G	R	Yes	None	10.0	1.6
H	R	Yes	None	7.5	1.2
I	R	Yes	None	5.0	0.8

Table A-13: Summary of dent parameters for Specimen 5.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, d (in.) at pressure (psi.)						
				d (in)	*d/D* (%)	0	271	542	677	813	948	0
A	BH-T	No	21.8	1.2	5	0.68	0.62	0.56	0.53	0.51	0.47	0.52
B	**BH-T**	No	28.2	2.4	10	1.14	0.68	0.62	0.56	0.53	0.51	0.47
C	BH-T	No	35.2	3.6	15	1.68	1.14	0.96	0.82	0.76	0.69	0.62
D	**BH-L**	No	27	2.4	10	0.99	1.68	1.32	1.05	0.95	0.86	0.77
E	**BH-L**	No	33.8	3.6	15	1.61	0.99	0.89	0.80	0.73	0.68	0.63
F	R	Yes	32.8	3.6	15	1.47	1.61	1.23	0.99	0.89	0.80	0.73
G	R	Yes	24.2	2.4	10	0.86	1.47	-	-	-	-	-
H	R	Yes	21.8	1.8	7.5	0.76	0.86	-	-	-	-	-
I	R	Yes	18.4	1.2	5	0.62	0.76	-	-	-	-	-

Table **A-14:** Denting forces and dent depths for **Specimen 5.**

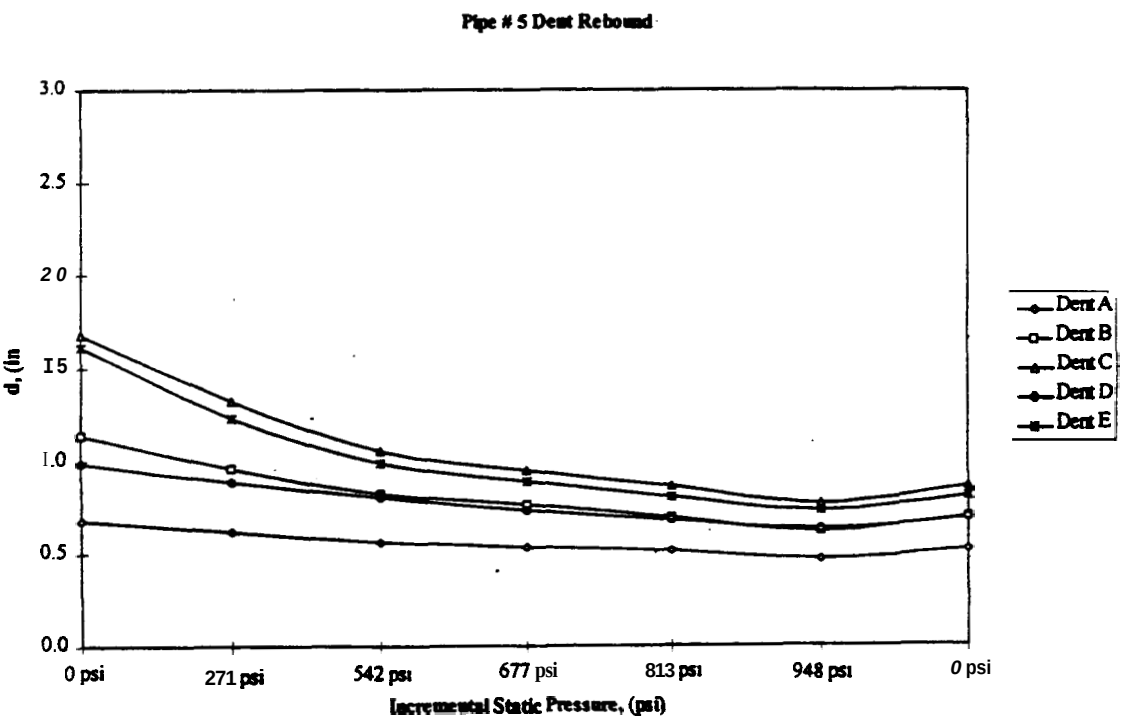


Figure A-16: Dent depth rebound versus internal pressure for Specimen **5.**

DentID	Type	Restraint	d/D (%)	Fatigue Failure	Cycles to Failure	Comment
5-A	BH-T	No	5	No	98,079	minor periphery cracking
5-B	BH-T	No	10	Yes	98,079	peripheral leak
5-C	BH-T	No	15	No	98,079	peripheral crack after proof test
5-D	BH-L	No	10	Yes	62,970	peripheral leak
5-E	BH-L	No	15	Yes	73,977	peripheral leak
5-F	R	Yes	15	Yes	67,620	peripheral leak (rock fractured)
5-G	R	Yes	10	No	98,079	no cracking
5-H	R	Yes	7.5	NO	98,079	no cracking
5-I	R	Yes	5	No	98,079	no cracking

Table A-15: *Summary* of dent fatigue failures for Specimen 5.

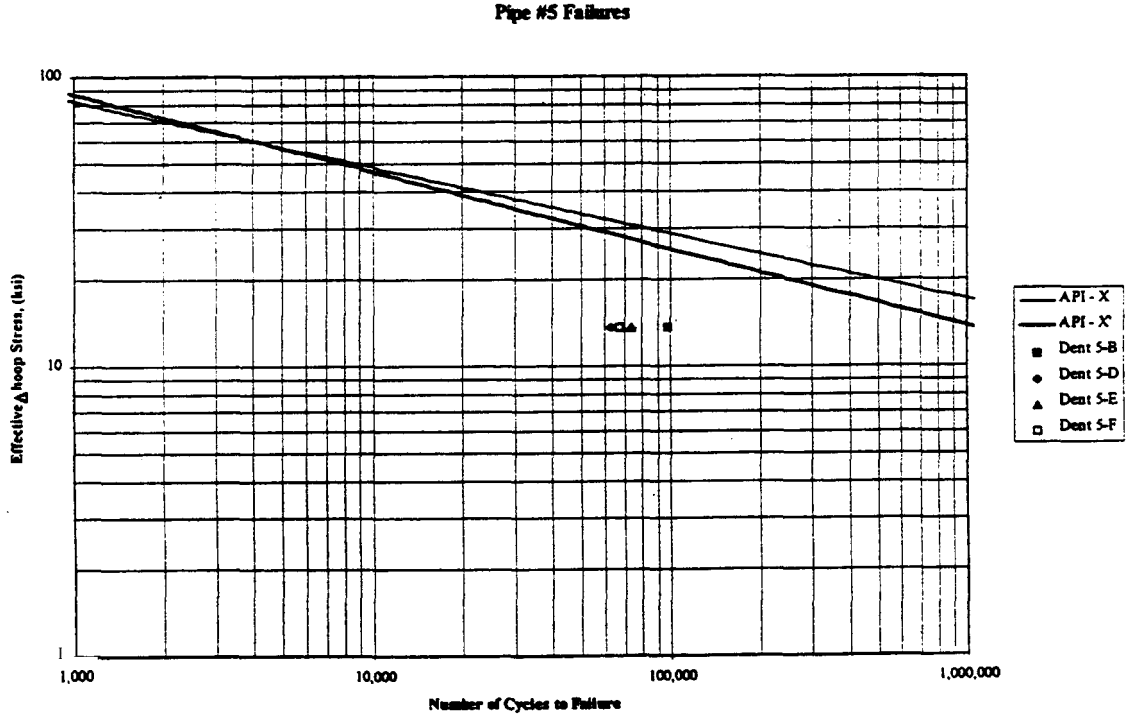


Figure A-17: S-N fatigue test data for Specimen 5.

Specimen No. 6

Diameter: 18" (nominal)
Wall **Thickness:** 1/4"
Length: 20' - 0"
Material: X42

Dent Type **A**

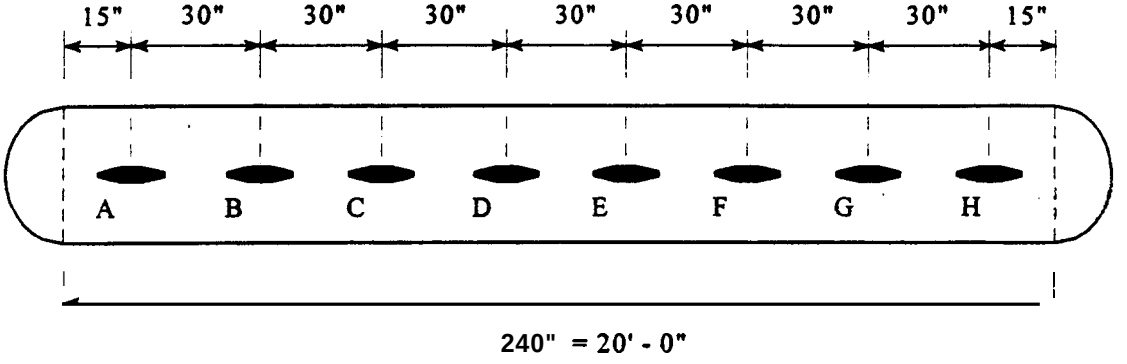


Figure A-18: Dent locations for Specimen No. 6.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	A	Yes	Scratch	5	0.9
B	A	Yes	Scratch	10	1.8
C	A	Yes	Scratch	7.5	1.35
D	A	Yes	Scratch	15	2.7
E	A	No	Scratch	5	0.9
F	A	No	Scratch	10	1.8
G	A	No	Scratch	7.5	1.35
H	A	No	Scratch	15	2.7

Table A-16: Summary of dent parameters for Specimen 6.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth d (in)	Initial Dent Depth d/D (%)	Rebound Dent Depth, d (in.) at pressure (psi.) 0	120	240	480	600	0	720	840	0
A	A	Yes	24.2	0.9	5	0.81	-	-	-	-	-	-	-	-
B	A	Yes	33	1.8	10	1.24	-	-	-	-	-	-	-	-
C	A	Yes	30	1.35	7.5	0.98	-	-	-	-	-	-	-	-
D	A	Yes	43	2.7	15	1.87	-	-	-	-	-	-	-	-
E	A	No	23.6	0.9	5	0.58	0.53	0.45	0.27	0.22	0.27	0.16	0.14	0.17
F	A	No	32.4	1.8	10	1.23	1.11	0.99	0.71	0.41	0.55	0.26	0.17	0.24
G	A	No	30	1.35	7.5	0.97	0.90	0.77	0.48	0.32	0.42	0.24	0.16	0.24
H	A	No	42	2.7	15	2.57	2.10	1.57	1.10	0.88	1.03	0.66	0.28	0.43

Table A-17: Denting forces and dent depths for Specimen 6.

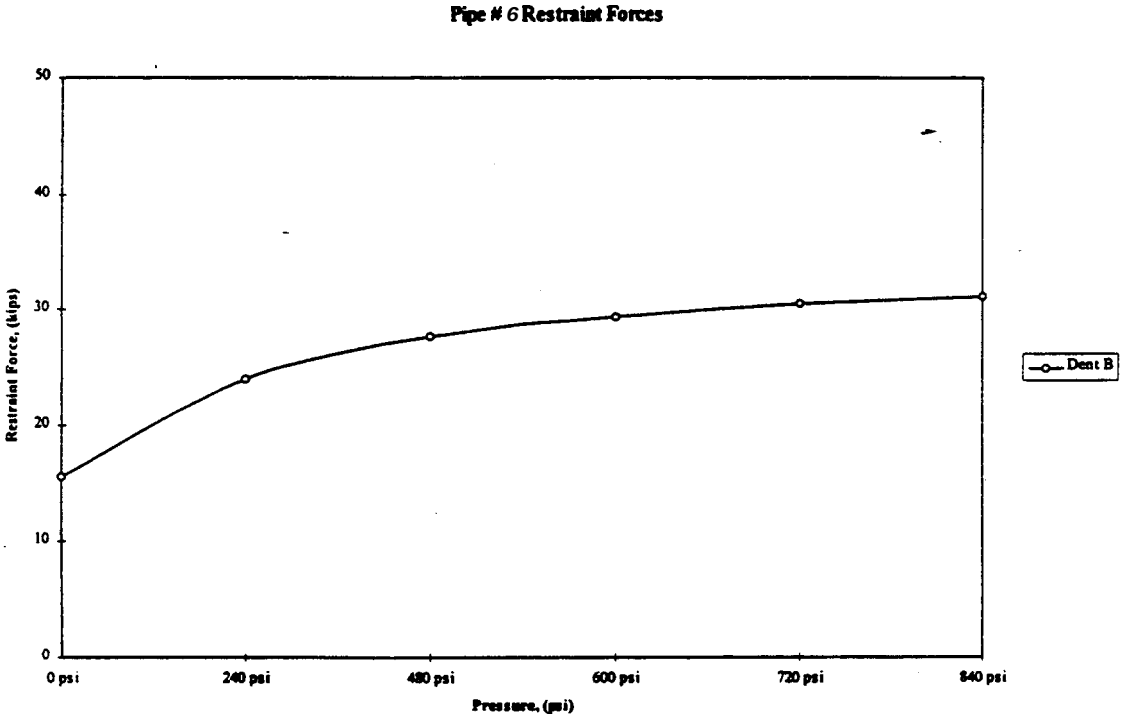


Figure A-19: Measured restraint force forces for Specimen 6.

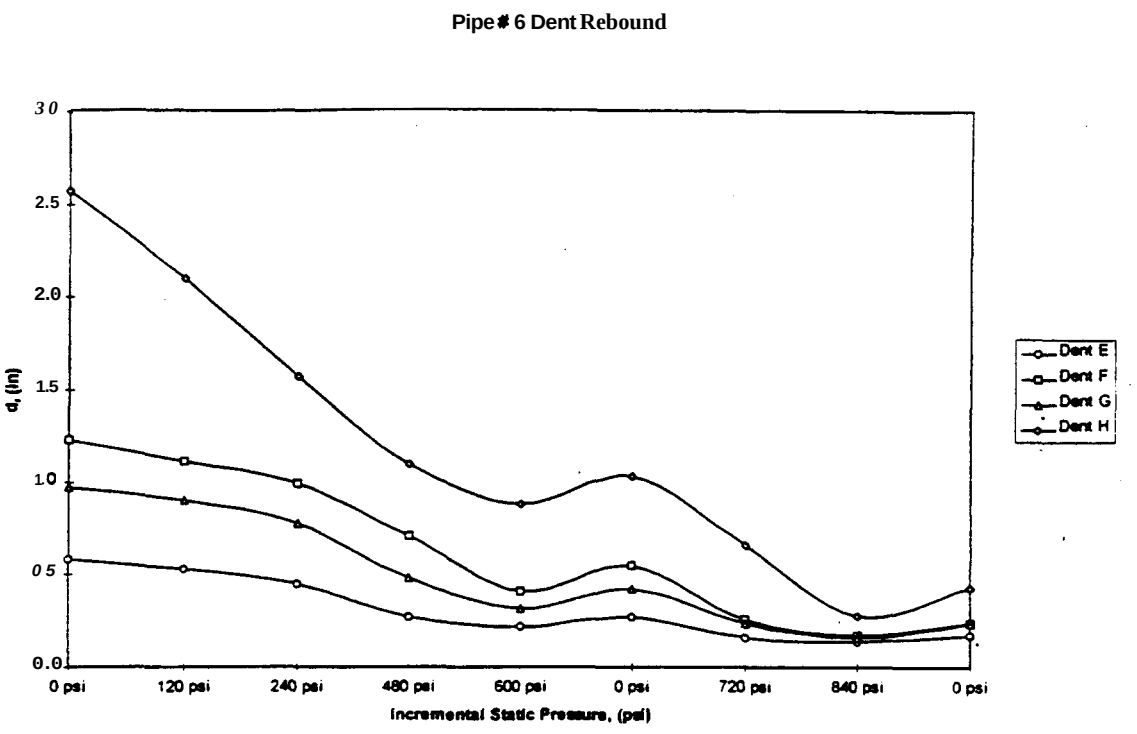


Figure A-20: Dent depth rebound versus internal pressure for Specimen 6.

DentID	Type	Restraint	d/D (%)	Fatigue Failure	Cycles to Failure	Comment
6-A	A	Yes	5	No	90,922	nocracking
6-B	A	Yes	10	Yes	78,222	peripheralleak
6-C	A	Yes	7.5	Yes	90,922	peripheralleak
6-D	A	Yes	15	Yes	40,253	peripheralleak
6-E	A	No	5	Yes	21,541	groove leak, center of dent
6-F	A	No	10	Yes	8,349	groove leak, center of dent
6-G	A	No	7.5	Yes	11,791	groove leak, center of dent
6-H	A	No	15	Yes	3,785	groove leak, center of dent

Table A-18: *Summary* of dent fatigue failures for Specimen 6.

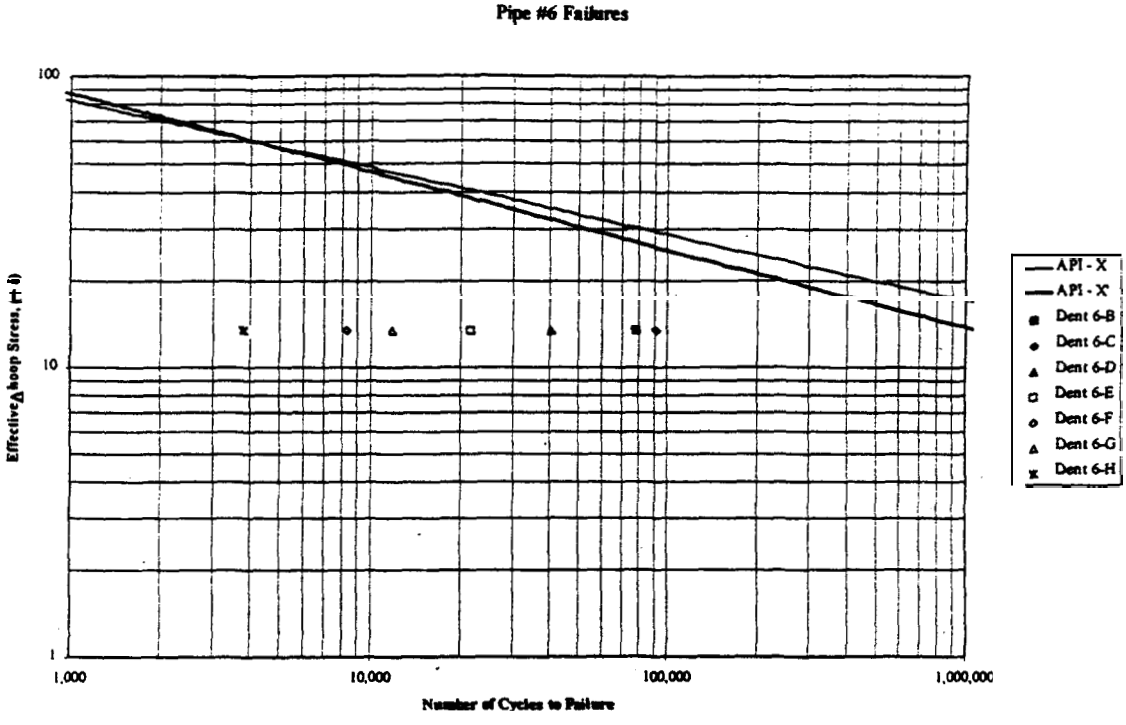


Figure A-21: S-N plot of fatigue failures for Specimen *6*.

Specimen No. 7

Diameter: 18" (nominal)
Wall Thickness: 1/4"
Length: 20' - 0"
Material: X60

Dent Type BH-L

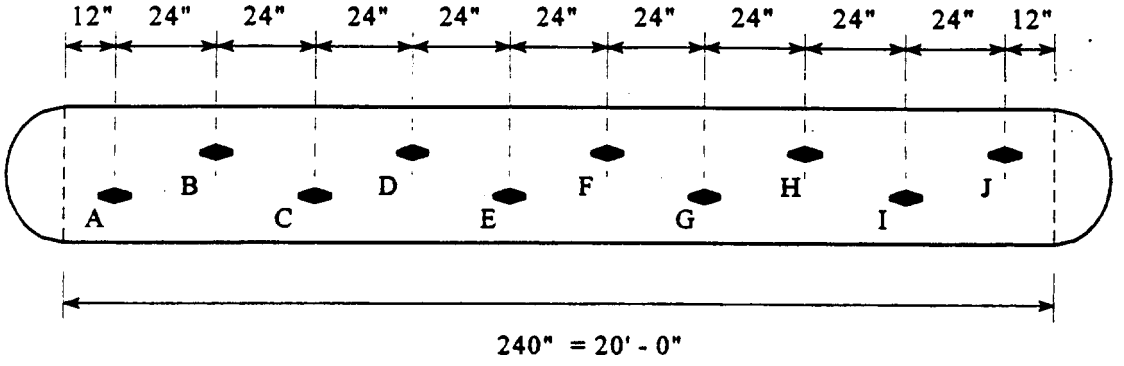


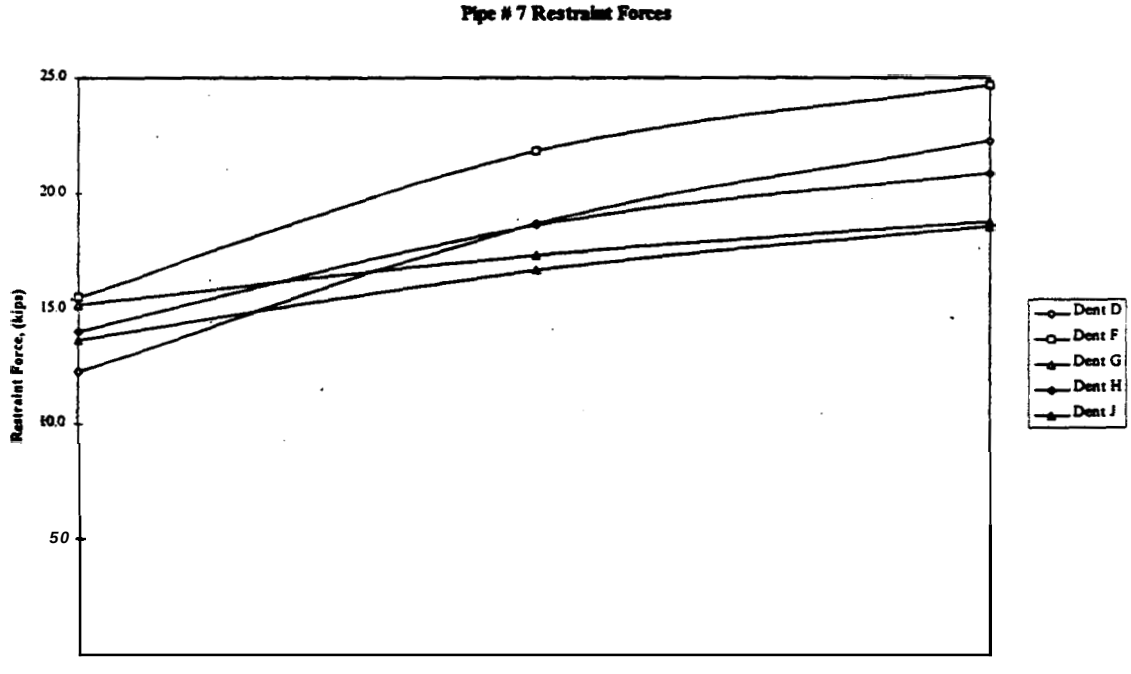
Figure A-22: Dent locations for Specimen No. 7.

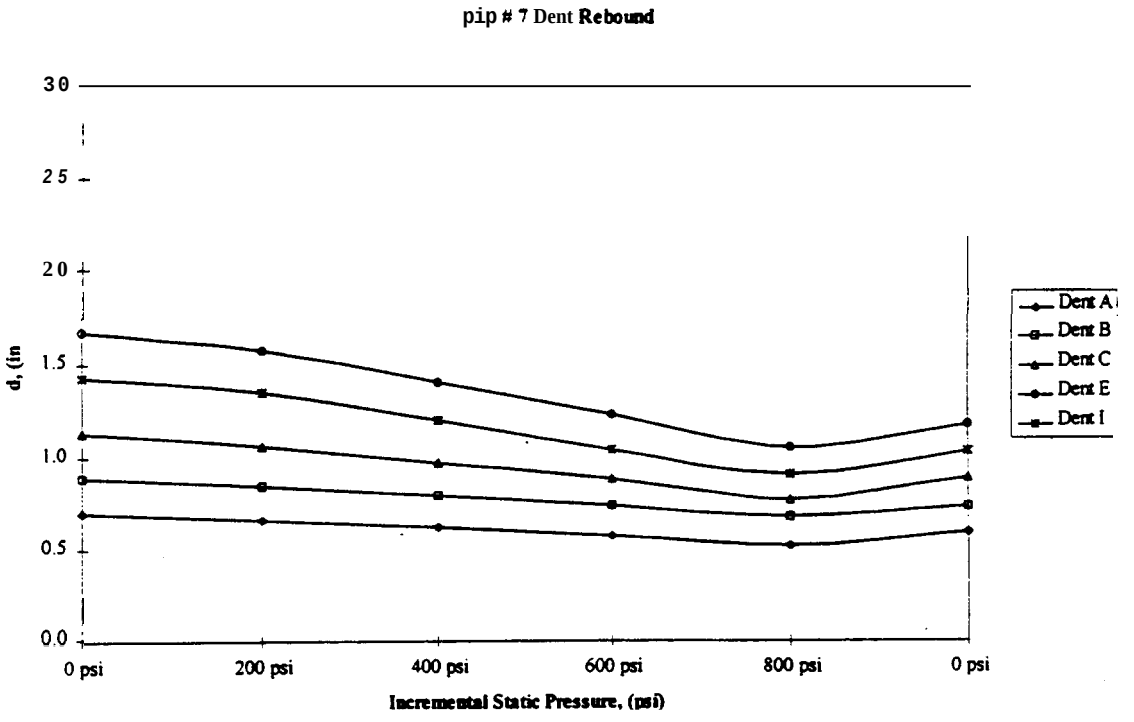
Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	BH-L	No	None	1.35	7.5
B	BH-L	No	None	1.8	10
C	BH-L	No	None	2.25	12.5
D	BH-L	Yes	None	2.7	15
E	BH-L	No	None	3.15	17.5
F	BH-L	Yes	None	3.15	17.5
G	BH-L	Yes	None	1.8	10
H	BH-L	Yes	None	2.25	12.5
I	BH-L	No	None	2.7	15
J	BH-L	Yes	None	1.35	7.5

Table A-19: Summary of dent parameters for Specimen 7.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, *d* (in.) at pressure (psi.)					
				d (in)	*d/D* (%)	0	200	400	600	800	0
A	BH-L	No	21.1	1.35	7.5	0.70	0.66	0.62	0.57	0.52	0.59
B	BH-L	No	23.7	1.8	10	0.89	0.84	0.79	0.74	0.68	0.73
C	BH-L	No	29.7	2.25	12.5	1.13	1.06	0.97	0.88	0.77	0.89
D	BH-L	Yes	32.9	2.7	15	-	-	-	-	-	-
E	BH-L	No	40	3.15	17.5	1.67	1.57	1.40	1.23	1.05	1.18
F	BH-L	Yes	37	3.15	17.5	-	-	-	-	-	-
G	BH-L	Yes	25	1.8	10'	-		-	-	-	-
H	BH-L	Yes	28.1	2.25	12.5	-	-	-	-	-	-
I	BH-L	No	34.9	2.7	15	1.43	1.35	1.20	1.04	0.91	1.03
J	BH-L	Yes	21.4	1.35	7.5						

Table A-20: Denting forces and dent depths for Specimen 7.





Figure! **A-24:** Dent depth rebound **versus** internal **pressure Specimen** 7.

DentID	Type	Restraint	*d/D* (%)	Fatigue Failure	Cycles **to** Failure	Comment
7-A	BH-L	No	7.5	No	103,100	nocracking
7-B	BH-L	No	10	No	103,100	nocracking
7-C	BH-L	**No**	12.5	No	103,100	peripheral cracking, proof test
7-D	BH-L	**Yes**	15	No	103,100	peripheral cracking, proof test
7-E	BH-L	**No**	17.5	No	103,100	peripheral cracking, proof test
7-F	BH-L	Yes	17.5	No	103,100	peripheral leak, proof test.
7-G	BH-L	Yes	10	No	103,100	**no** cracking
7-H	BH-L	Yes	12.5	No	103,100	nocracking
7-I	BH-L	No	15	No	103,100	peripheral cracking, proof test
7-J	BH-L	**Yes**	7.5	No	103,100	no **cracking**

Table **A-21:** ***Summary*** of dent fatigue failures for Specimen **7.**

Specimen No. 8

Diameter: 18" (nominal)
Wall Thickness: 1/4"
Length: 20' - 0"
Material: X60

Dent Type BH-T & R

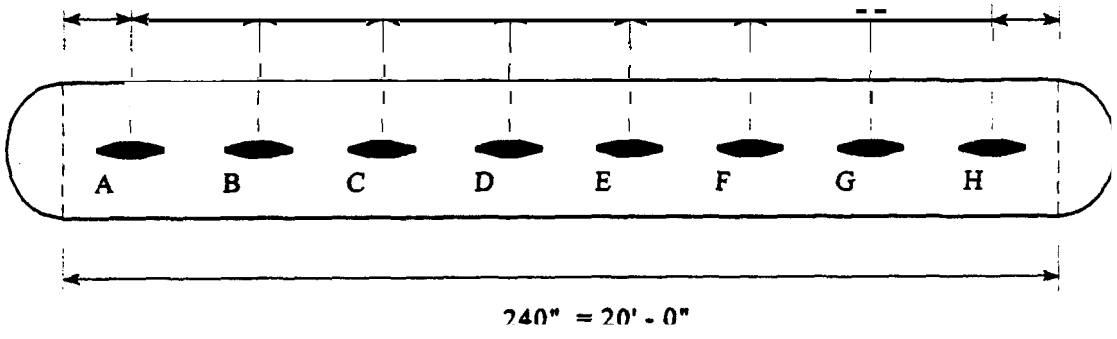


Figure A-25: Dent locations for Specimen No. 8.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	BH-T	Yes	None	15.0	2.7
B	BH-T	No	None	15.0	2.7
C	BH-T	Yes	None	17.5	3.2
D	BH-T	No	None	17.5	3.2
E	R	Yes	None		
F	R	Yes	None		
G	R	Yes	None		
H	R	Yes	None		

Table A-22: Summary of dent parameters for Specimen 8.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, d (in.) at pressure (psi.)					
				d (in)	*d/D* (%)	0	200	400	600	800	0
A	BH-T	Yes	33.4	2.7	15	-	-	-	-	-	-
B	BH-T	No	34.9	2.7	15	1.33	1.07	0.95	0.85	0.77	0.85
C	BH-T	Yes	40.1	3.15	17.5	-	-	-	-	-	-
D	BH-T	No	40.3	3.15	17.5	1.60	1.20	0.99	0.89	0.80	0.88
E	R	Yes	-	-	-	-	-	-	-	-	-
F	R	Yes	-	-	-	-	-	-	-	-	-
G	R	Yes	-	-	-	-	-	-	-	-	-
H	R	Yes	-	-	-	-	-	-	-	-	-

Table A-23: Denting forces and dent depths for Specimen 8.

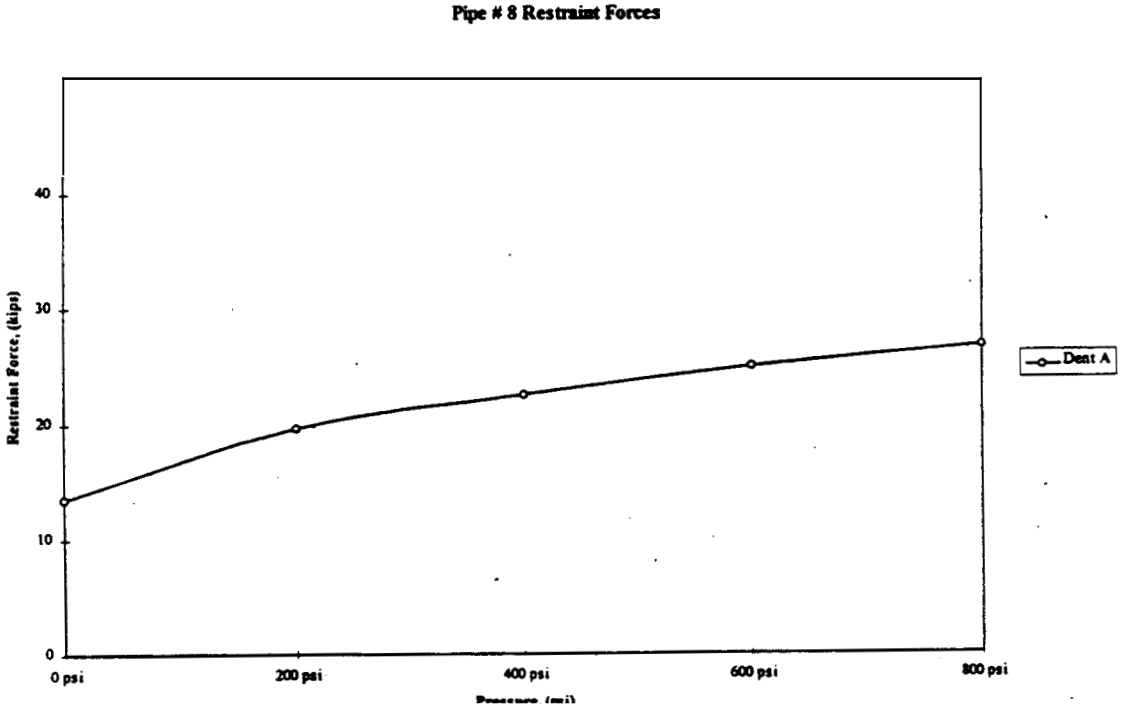


Figure A-26: Measured dent restraint forces for Specimen 8.

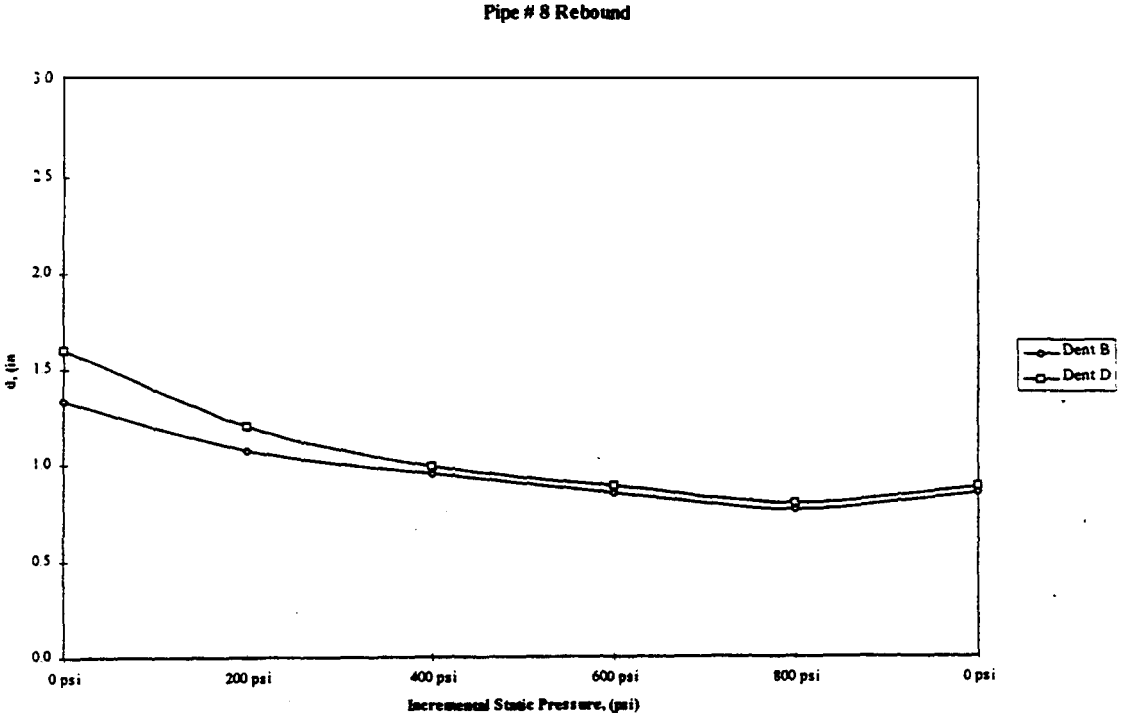


Figure A-27: Dent depth rebound versus internal pressure for Specimen 8.

DentID	Type	Restraint	*d/D* (%)	Fatigue Failure	Cycles to Failure	Comment
8-A	BH-T	Yes	15	No	101,587	shallow peripheral crack
8-B	BH-T	No	15	No	101,587	shallow peripheral crack
8-C	BH-T	Yes	17.5	No	101,587	shallow peripheral crack
8-D	BH-T	No	17.7	No	101,587	shallow peripheral crack
8-E	R	Yes	N.A.	Yes	68,264	internal surface leak under rock & peripheral crack
8-F	R	Yes	N.A.	No	101,587	deep peripheral leak & internal surface crack, post proof
8-G	R	Yes	N.A.	Yes	61,295	internal surface crack under rock
8-H	R	Yes	N.A.	No	101,587	peripheral cracking

Table A-24: *Summary* of dent fatigue failures for Specimen 8.

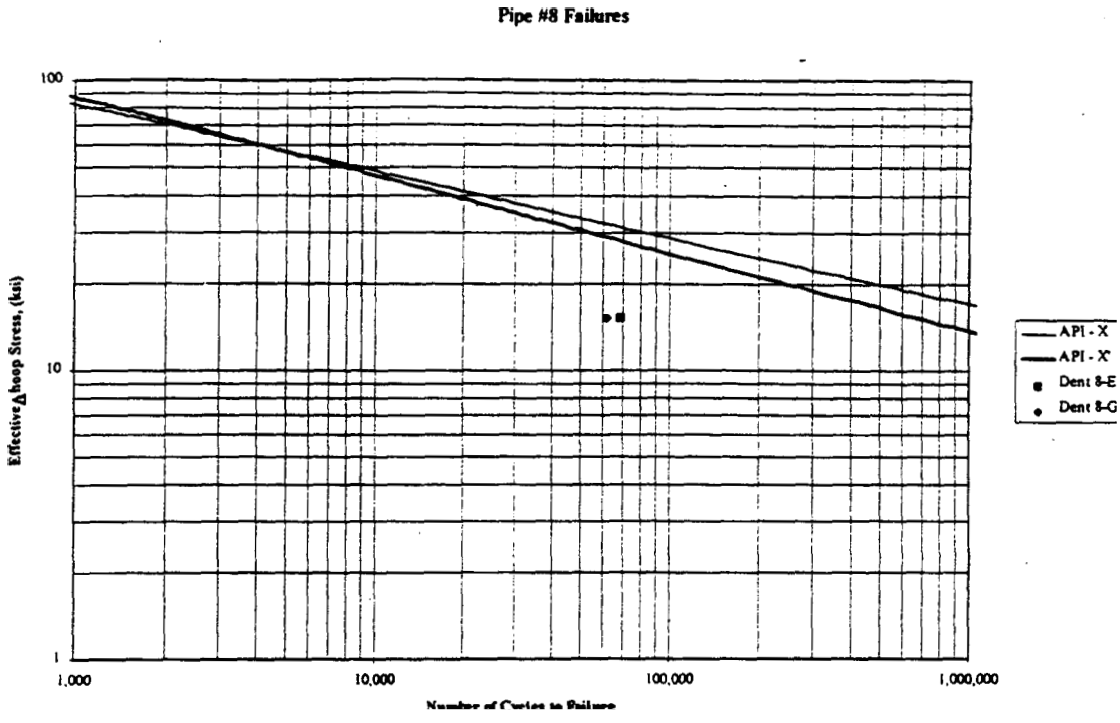


Figure A-28: S-N fatigue test data for Specimen 8.

Specimen No. 9

Diameter: 24" (nominal)
Wall Thickness: 1/4"
Length: 13' - 4"
Material: X60

Dent Type A

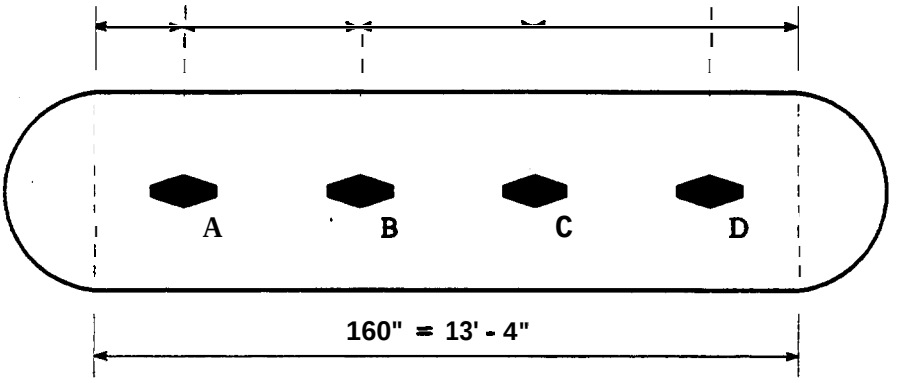


Figure A-29: Dent locations for Specimen No. 9.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/*D* (%)	*d* (in.)
A	A	No	Scratch	10.0	2.4
B	A	No	Scratch	5.0	1.2
C	A	No	Scratch	7.5	1.8
D	A	Yes	Scratch	10.0	2.4

Table A-25: Summary of dent parameters for Specimen 9.

Dent	Type	Restraint	indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, *d* (in.) at pressure (psi.)								
				d (in)	*d/D* (%)	0	100	200	300	400	500	600	626	0
A	A	No	36	2.4	10	1.14	1.04	0.91	0.78	0.63	0.43	0.31	0.27	0.44
B	A	No	28	1.2	5	0.67	0.58	0.46	0.38	0.31	0.25	0.2	0.2	0.29
C	A	No	32	1.8	7.5	0.82	0.71	0.6	0.49	0.36	0.28	0.23	0.22	0.33
D	A	Yes	36	2.4	10	1.14	-	-	-	-	-	-	-	-

Table A-26: Denting forces and dent depths for Specimen 9.

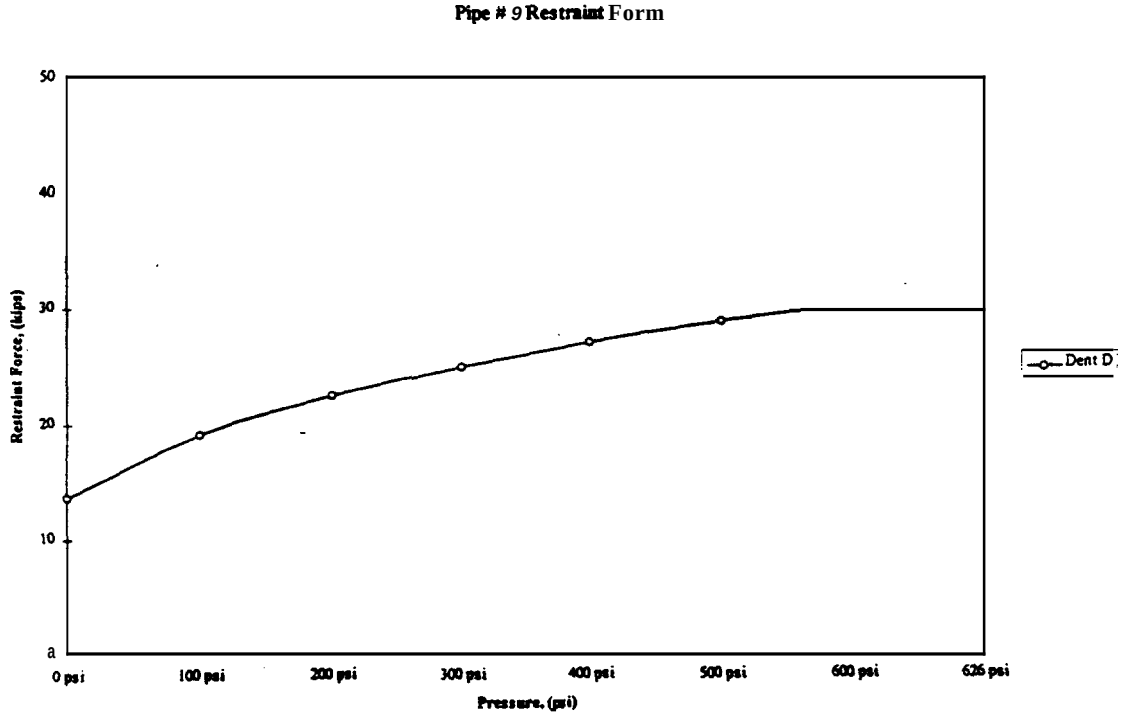


Figure A-30: Measured dent restraint forces for Specimen 9.

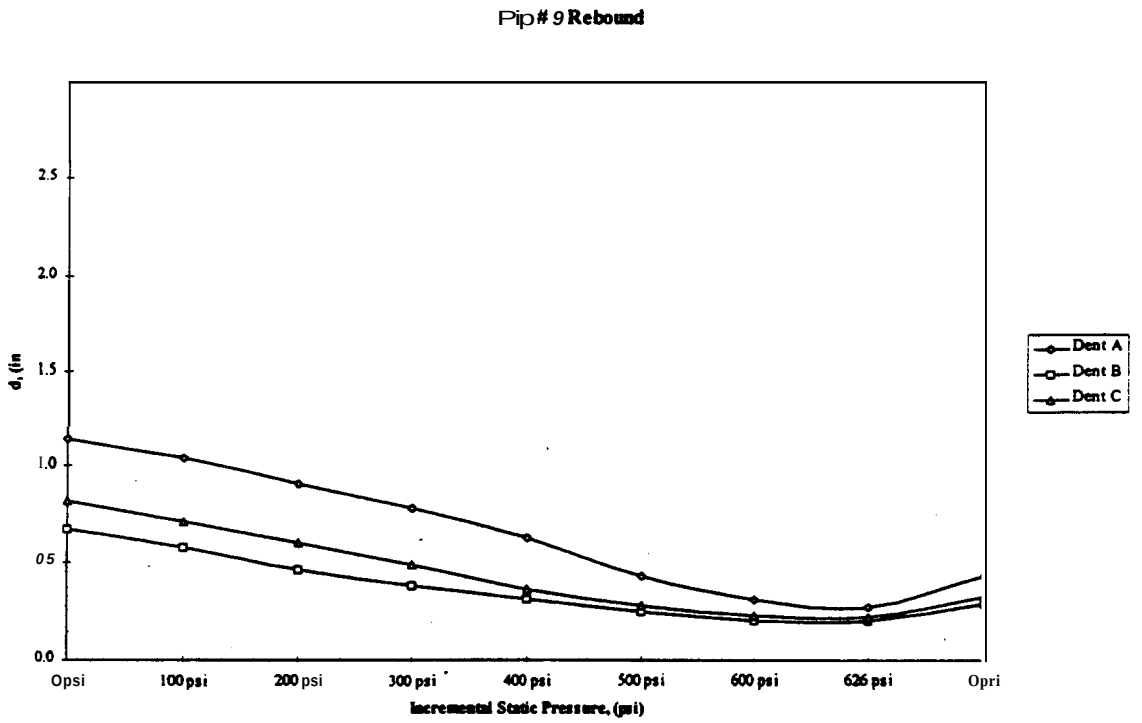


Figure A-31: Dent depth rebound versus internal pressure for Specimen 9.

DentID	Type	Restraint	*d/D* (%)	Fatigue Failure	Cycles to Failure	Comment
9-A	A	No	10	Yes	12,711	groove crack, center of dent
9-B	A	No	5	Yes	30,108	groove crack, center of dent
9-c	A	No	7.5	Yes	18,608	groove crack, center of dent
9-D	A	Yes	10	No	100,258	peripheral cracking, proof test

Table A-27: Summary of dent fatigue failures for Specimen 9.

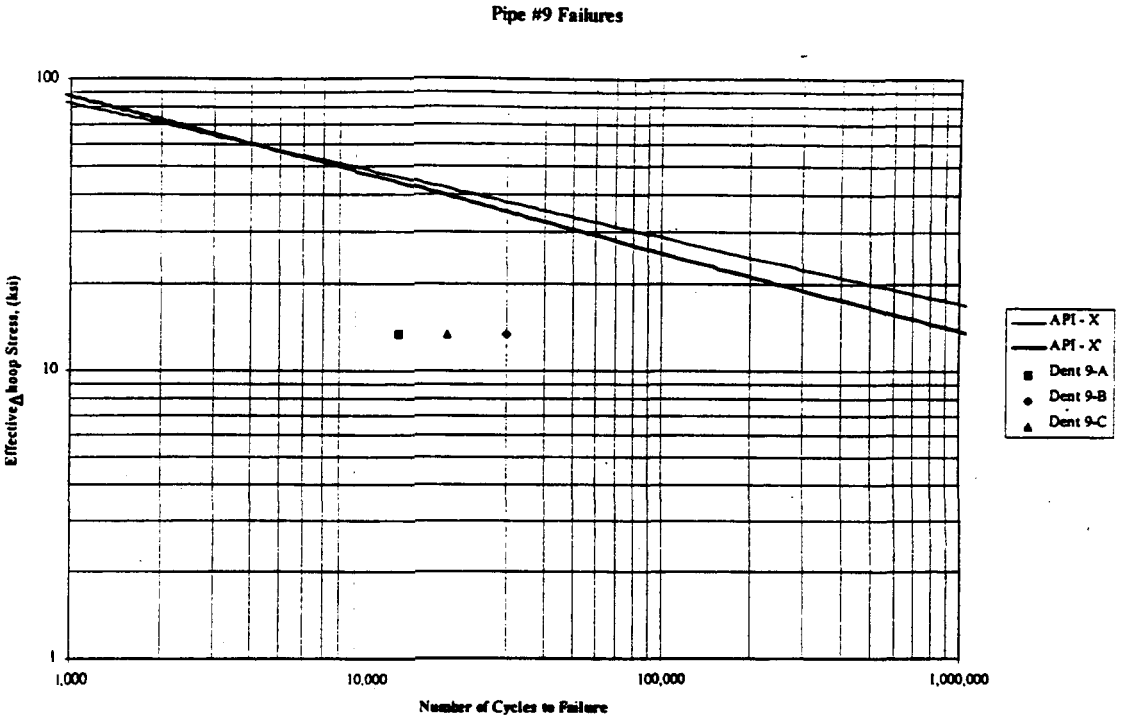


Figure A-32: S-N plot of fatigue failures for Specimen 9.

Specimen No. 10

Diameter: 24" (nominal)
Wall **Thickness:** 1/4"
Length: 13' - 4"
Material: X60

Dent Type BH-L & BH-T

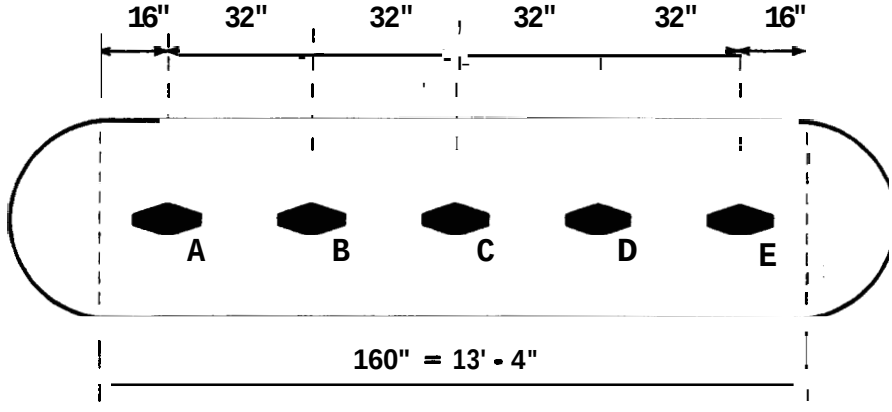


Figure A-33: Dent locations for Specimen No. 10.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	d (in.)
A	BH-T	No	none	10.0	2.4
B	BH-L	No	none	10.0	2.4
C	BH-T	No	none	7.5	1.8
D	BH-T	No	none	5.0	1.2
E	BH-L	No	none	5.0	1.2

Table A-28: *Summary* of dent parameters for Specimen 10.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, d (in.) at pressure (psi.)										
				d (in)	*d/D* (%)	0	100	200	300	400	500	600	626	0	626	0
A	BH-T	No	42	2.4	10	1.67	1.58	1.43	1.27	1.14	1.04	0.95	0.94	1.08	0.92	1.06
B	BH-L	No	42	2.4	10	1.69	1.47	1.27	1.12	1.03	0.94	0.87	0.85	1.00	0.85	0.98
C	BH-T	No	34	1.8	7.5	1.08	0.96	0.86	0.80	0.74	0.70	0.65	0.65	0.74	0.63	0.73
D	BH-T	No	28	1.2	5	0.82	0.74	0.69	0.63	0.61	0.57	0.54	0.53	0.61	0.53	0.60
E	BH-L	No	28	1.2	5	0.83	0.80	0.73	0.70	0.67	0.62	0.57	0.57	0.66	0.56	0.66

Table **A-29:** Denting forces and dent depths for Specimen **10.**

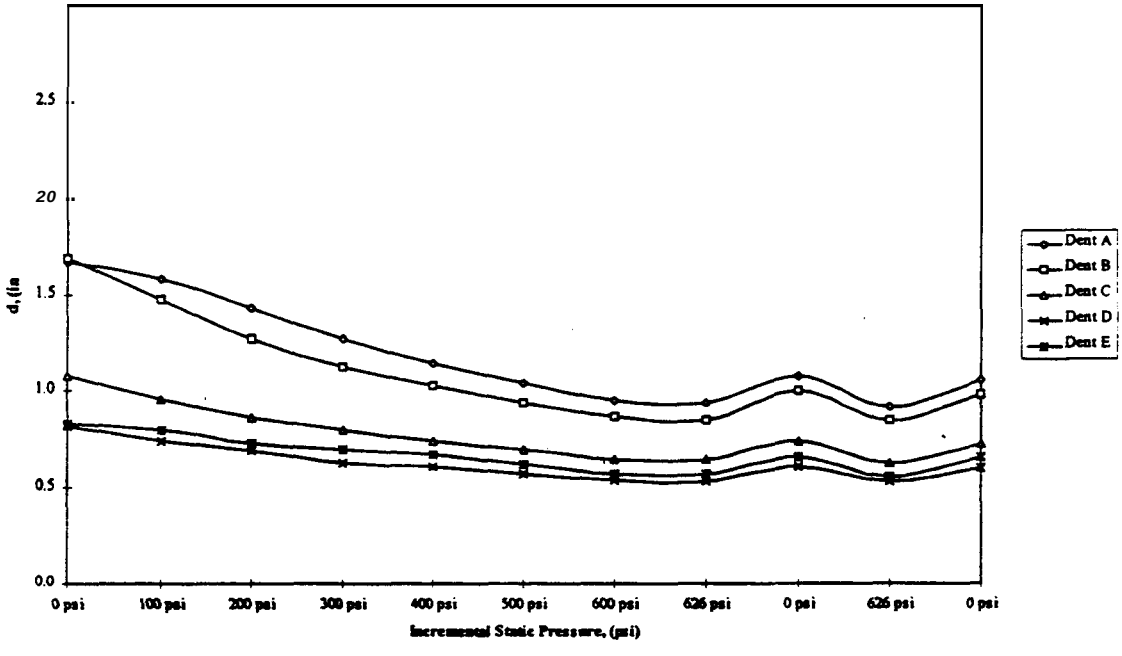


Figure **A-34:** Dent depth rebound **versus** internal pressure for Specimen 10.

DentID	Type	Restraint	d/D (%)	Fatigue Failure	Cycles to Failure	Comment
10-A	BH-T	No	10	No	109,332	peripheral cracking, proof test
10-B	BH-L	No	10	Yes	109,332	peripheral leak
10-C	BH-T	No	7.5	No	109,332	peripheral cracking, proof test
10-D	BH-T	No	5	No	109,332	nocracking
10-E	BH-L	No	5	No	109,332	no cracking

Table A-30: *Summary* **of dent fatigue failures for Specimen 10.**

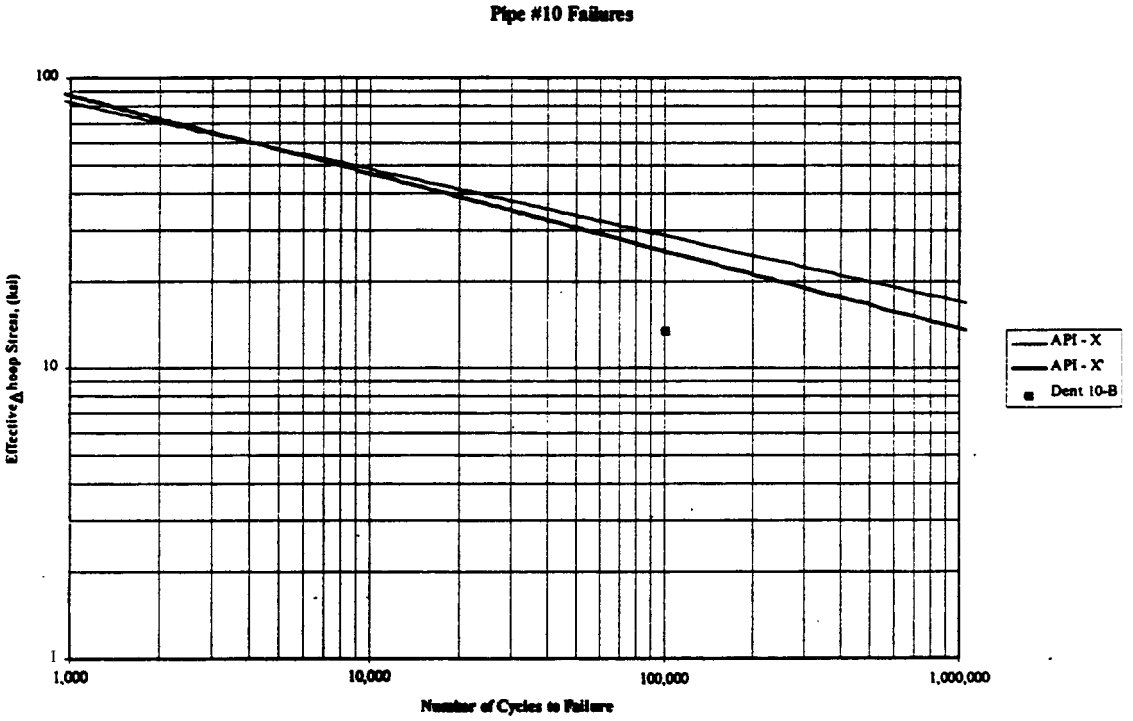


Figure A-35: S-N fatigue test data for Specimen 10.

Specimen No. 11

Diameter: 24" (nominal)
Wall **Thickness:** 1/4"
Length: 13' - 4"
Material: X60

Dent Type R

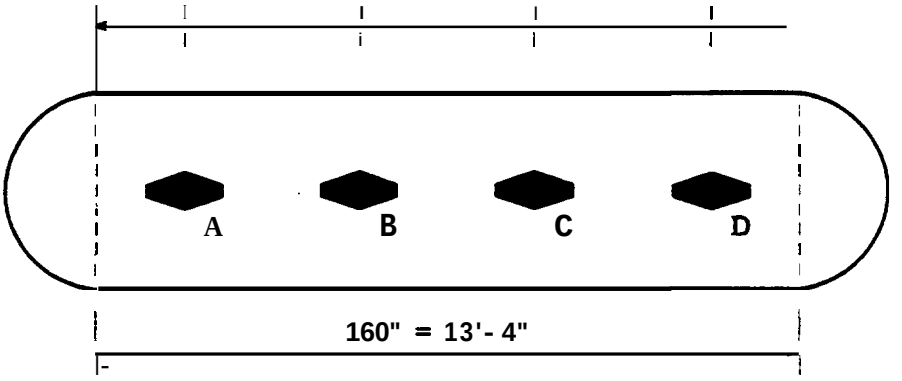


Figure A-36: Dent locations for Specimen No. 11.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	R	Yes	None	5.0	1.2
B	R	Yes	None	7.5	1.8
C	R	Yes	None	12.5	3.0
D	R	Yes	None	10.0	2.4

Table A-31: *Summary* of dent parameters for Specimen 11.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound, d (in.)
				d (in)	d/D (%)	
A	R	Yes	24	1.2	5	0.65
B	R	Yes	26	1.8	7.5	0.99
C	R	Yes	41	3	12.5	1.35
D	R	Yes	32	2.4	10	1.06

Table A-32: Denting forces and dent depths for Specimen 11

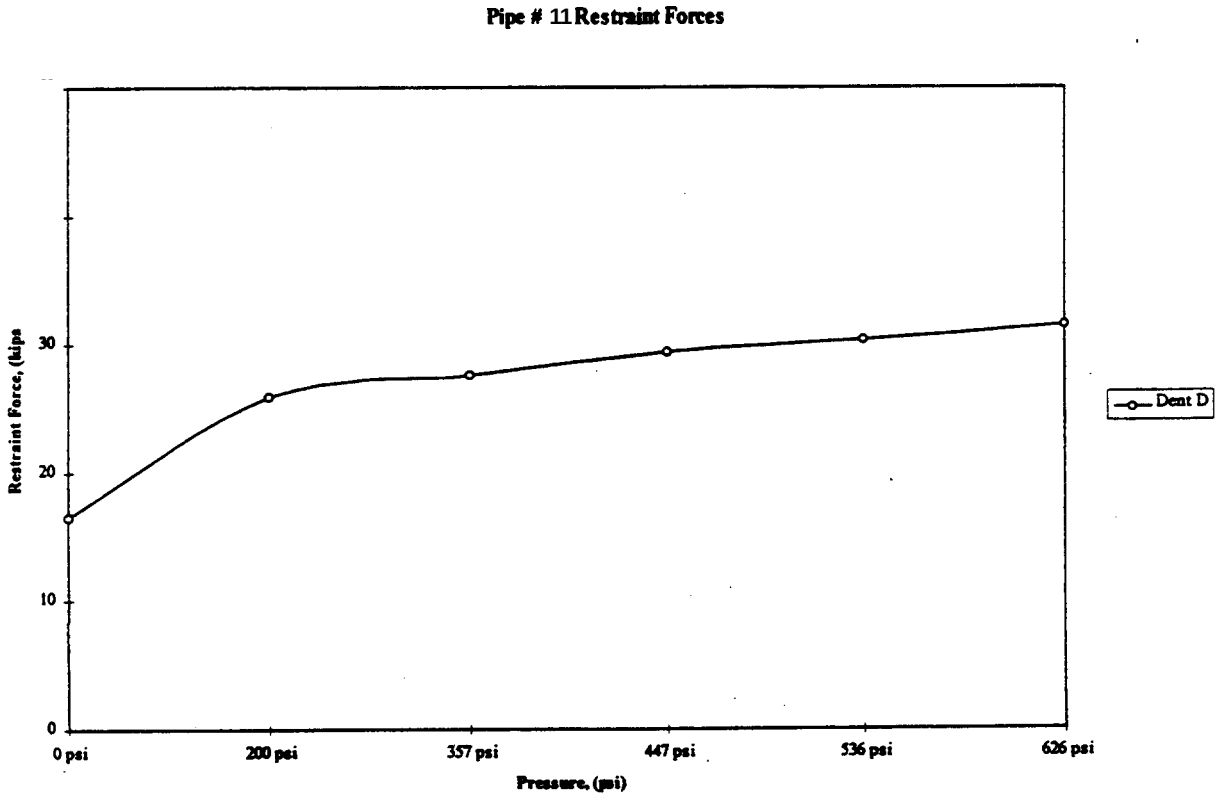


Figure A-37: Measured dent restraint forces for Specimen 11.

DentID	Type	Restraint	d/D (%)	Fatigue Failure	Cycles to Failure	Comment
11-A	R	Yes	5	No	110,600	nocracking
11-B	R	Yes	7.5	No	110,600	nocracking
11-C	R	Yes	12.5	No	110,600	peripheral cracking
11-D	R	Yes	10	No	110,600	nocracking

Table A-33: Summary of dent fatigue failures for Specimen 11.

Specimen No. 12

Diameter:	30" (nominal)
Wall Thickness:	3/8"
Length:	10' - 0"
Material:	Gr. B

Dent Type A

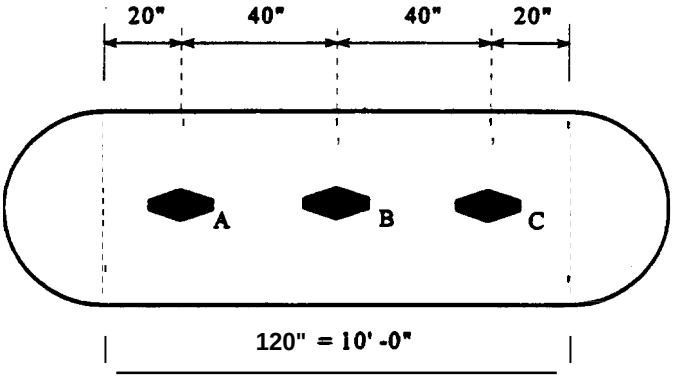


Figure A-38: Dent locations for Specimen No. 12

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	A	No	Scratch	5.0	1.5
B	A	No	Scratch	7.5	2.3
C	A	No	Scratch	10.0	3.0

Table A-34: Summary of dent parameters for Specimen 12.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, *d* (in.) at pressure (psi.)								
				d (in)	*d*/*D* (%)	0	100	200	300	400	500	600	626	0
A	A	No	36	1.5	5	1.00	0.91	0.88	0.79	0.69	0.57	0.46	0.43	0.53
B	A	No	44	2.25	7.5	1.41	1.26	1.20	1.07	0.94	0.80	0.64	0.60	0.72
C	A	No	52	3	10	1.86	1.66	1.59	1.40	1.20	1.01	0.83	0.77	0.92

Table A-35: Denting forces and dent depths for Specimen 12.

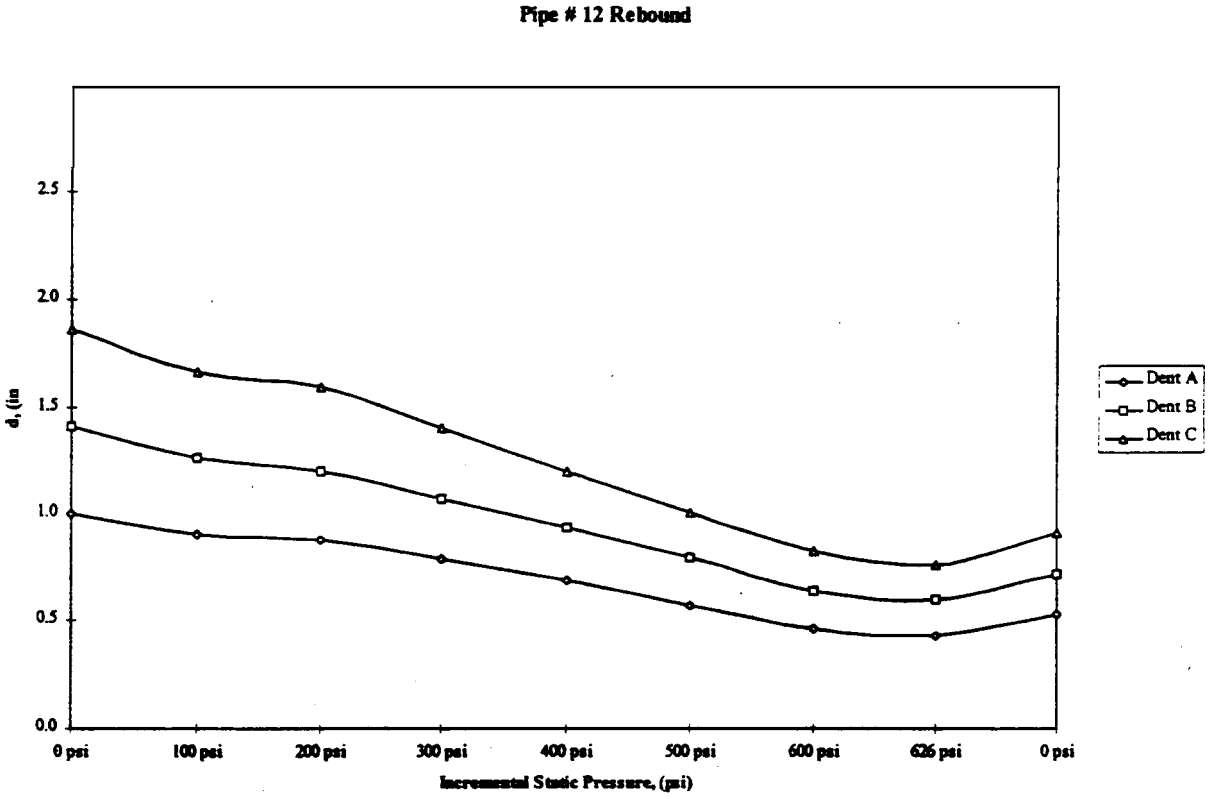


Figure A-39: Dent depth rebound versus internal pressure for Specimen 12.

DentID	Type	Restraint	d/D (%)	Fatigue Failure	Cycles to Failure	Comment
12-A	R	No	5	Yes	44,484	groove leak, center of dent
12-B	R	No	7.5	Yes	60,891	groove leak, center of dent
12-c	R	No	10	No	100,891	small center crack, proof test

Table A-36: Summary of dent fatigue failures for Specimen 12.

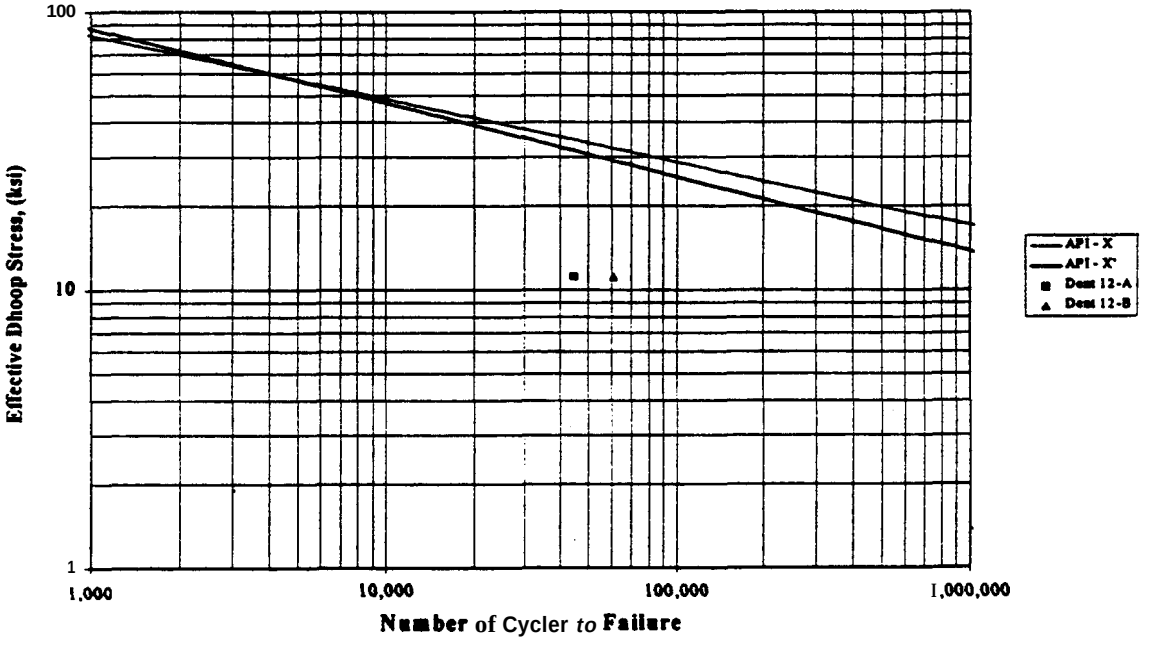


Figure A-40: S-N plot of fatigue failures for Specimen 12.

Specimen No. 13

Diameter:	30" (nominal)
Wall Thickness:	3/8"
Length:	10' - 0"
Material:	Gr. B

Dent Type BH-L

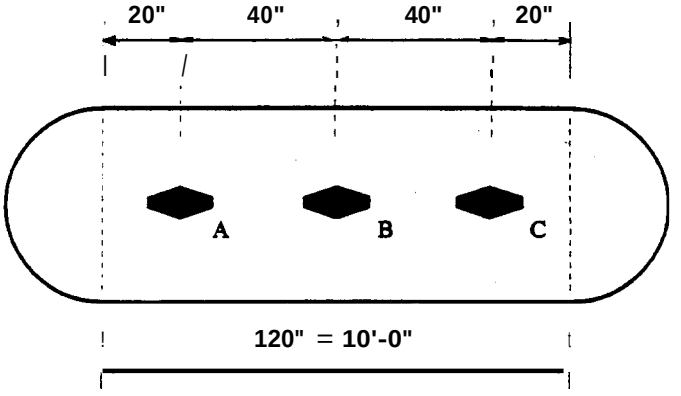


Figure A-41: Dent locations for Spechen No. 13.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	BH-L	No	None	5.0	1.5
B	BH-L	No	None	10.0	3.0
C	BH-L	No	None	7.5	2.3

Table A-37 Summary of dent parameters for Specimen 13.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth d (in)	Initial Dent Depth d/D (%)	Rebound Dent Depth, d (in.) at pressure (psi.) 0	100	200	300	400	500	600	626	0
A	BH-L	No	40	1.5	5	1.31	1.27	1.20	1.12	1.04	0.98	0.90	0.87	0.97
B	BH-L	No	52	3	10	2.56	2.29	2.00	1.75	1.60	1.46	1.31	1.27	1.42
C	BH-L	No	50	2.25	7.5	2.07	1.97	1.81	1.64	1.51	1.35	1.22	1.18	1.31

Table A-38: Denting forces and dent depths for Specimen 13.

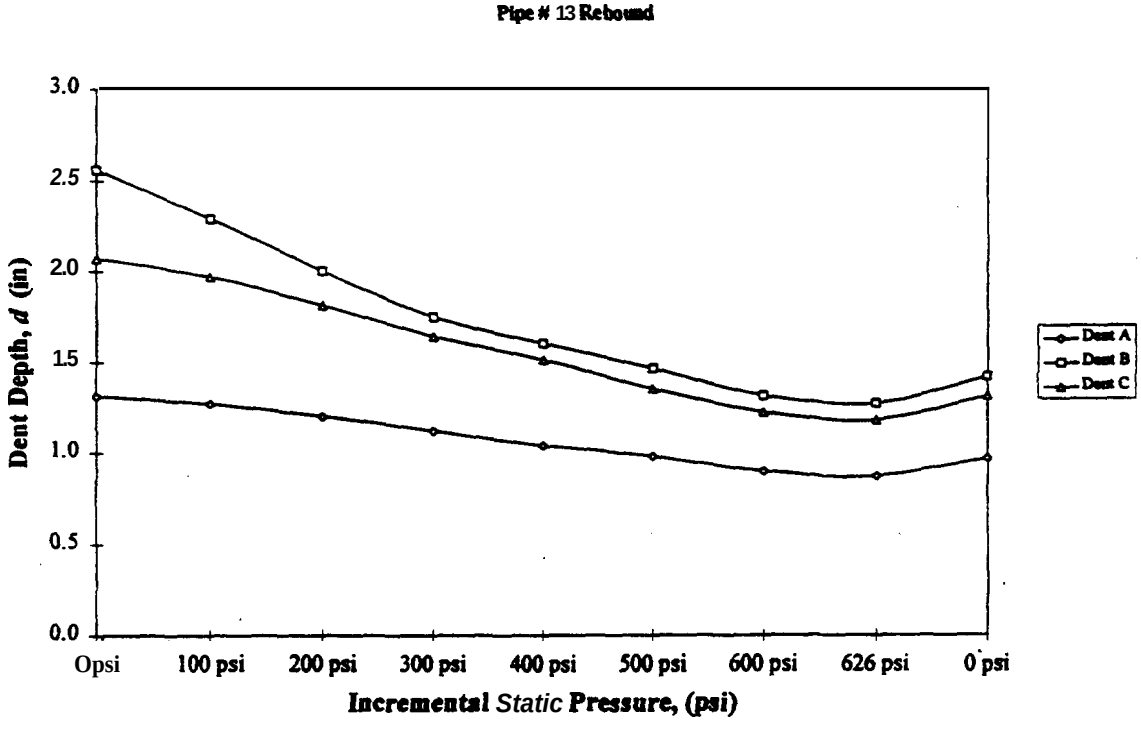


Figure A42: Dent depth rebound versus internal pressure for Specimen 13.

DentID	Type	Restraint	d/D (%)	Fatigue Failure	Cycles to Failure	Comment
13-A	BH-L	No	5	Yes	100,050	nocracking
13-B	BH-L	No	10.0	Yes	100,050	nocracking
13-C	BH-L	No	7.5	No	100,050	slight peripheral cracking, at design pressure prior to proof test

Table A-39: Summary of dent fatigue failures for Specimen 13.

Specimen No. 14

Diameter: 36" (nominal)
Wall **Thickness:** 3/8"
Length: 10' - 0"
Material: Gr.B

Dent Type **A**

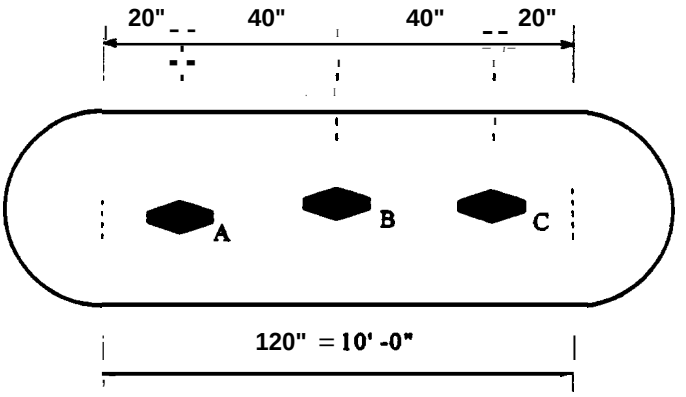


Figure A-43: Dent **locations for Specimen No. 14**

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	*d* (in.)
A	A	No	Scratch	5.0	1.8
B	A	No	Scratch	15.0	5.4
C	A	No	Scratch	10.0	3.6

Tabk A-40: *Summary* **of dent parameters for Specimen 14.**

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth		Rebound Dent Depth, d (in.) at pressure (psi.)					
				d (in)	d/D (%)	0	149	298	447	521	0
A	A	No	35	1.8	5	0.81	0.73	0.61	0.48	0.42	0.50
B	A	No	56	5.4	15	2.40	1.86	1.4	1.10	0.98	1.16
C	A	No	55	3.6	10	1.91	1.70	1.35	1.04	0.88	1.08

Table A-41: Denting forces and dent depths for Specimen 14.

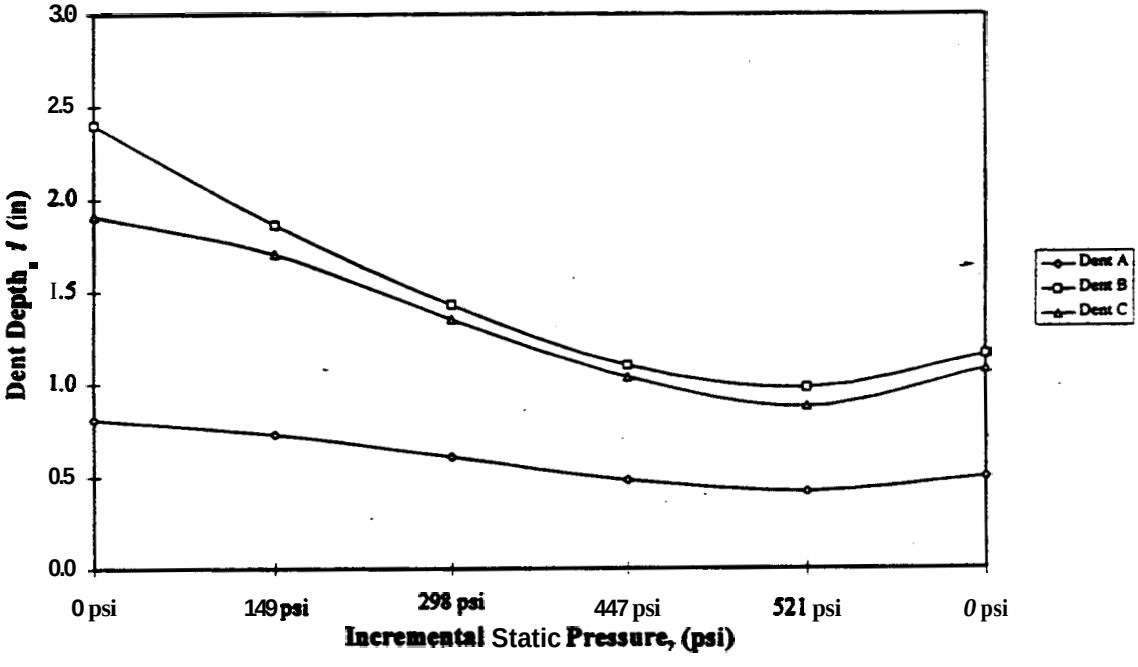


Figure A-44: Dent depth rebound versus internal pressure for Specimen 14.

Specimen No. 15

Diameter: 36" (nominal)
Wall Thickness: 3/8"
Length: 10'-0"
Material: Gr. B

Dent Type BH-L

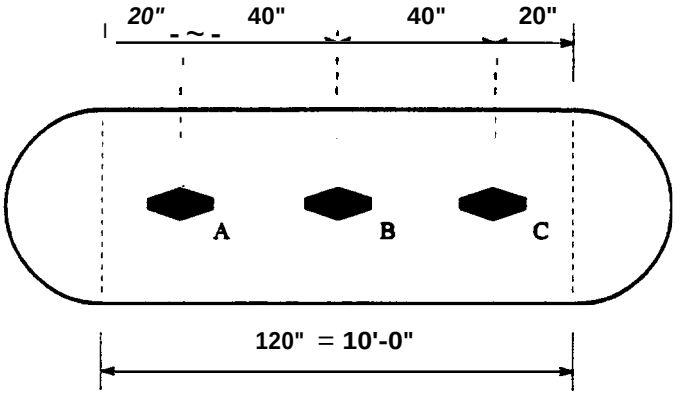


Figure A-46: Dent locations for Specimen No. 15.

Dent	Dent Type	Restraint	Defect	Initial Dent Depth	
				d/D (%)	d (in.)
A	BH-L	No	None	5.0	1.8
B	BH-L	No	None	10.0	3.6
C	BH-L	No	None	15.0	5.4

Table A-37 Summary of dent parameters for Specimen 15.

Dent	Type	Restraint	Indenter Force (kips)	Initial Dent Depth d (in)	Initial Dent Depth d/D (%)	Rebound Dent Depth, d (in.) at pressure (psi.) 0	149	298	447	521	0
A	BH-L	No	34	1.8	5	1.01	0.94	0.86	0.78	0.73	0.81
B	BH-L	No	45	3.6	10	1.68	1.50	1.33	1.17	1.08	1.18
C	BH-L	No	60	5.4	51	2.76	2.39	1.93	1.59	1.41	1.65

Table A-38: Denting forces and dent depths for Specimen 15.

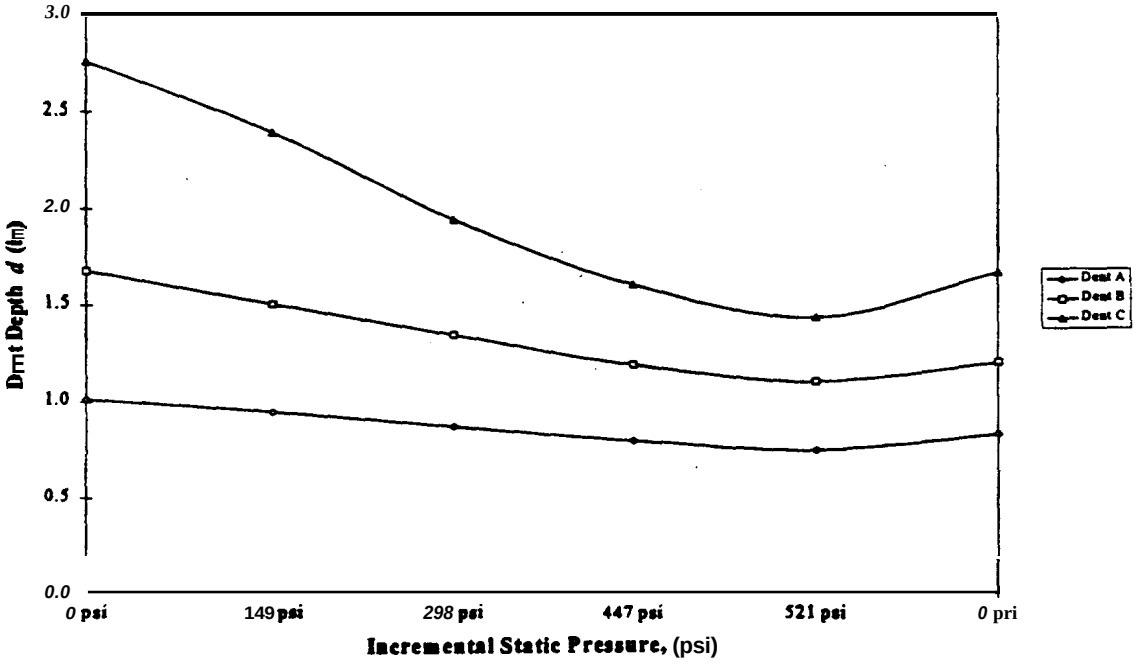


Figure A-47: Dent depth rebound versus internal pressure for Specimen 15.

DentID	Type	Restraint	*d/D* (%)	Fatigue Failure	Cycles to Failure	Comment
15-A	BH-L	No	5	No	111,425	groove crack, 2390 large cycles after proof test
15-B	BH-L	No	10	No	111,425	peripheral leak, proof test
15-C	BH-L	No	15	Yes	111,425	no cracking

Table A-39: Summary of dent fatigue failures for Specimen 15.

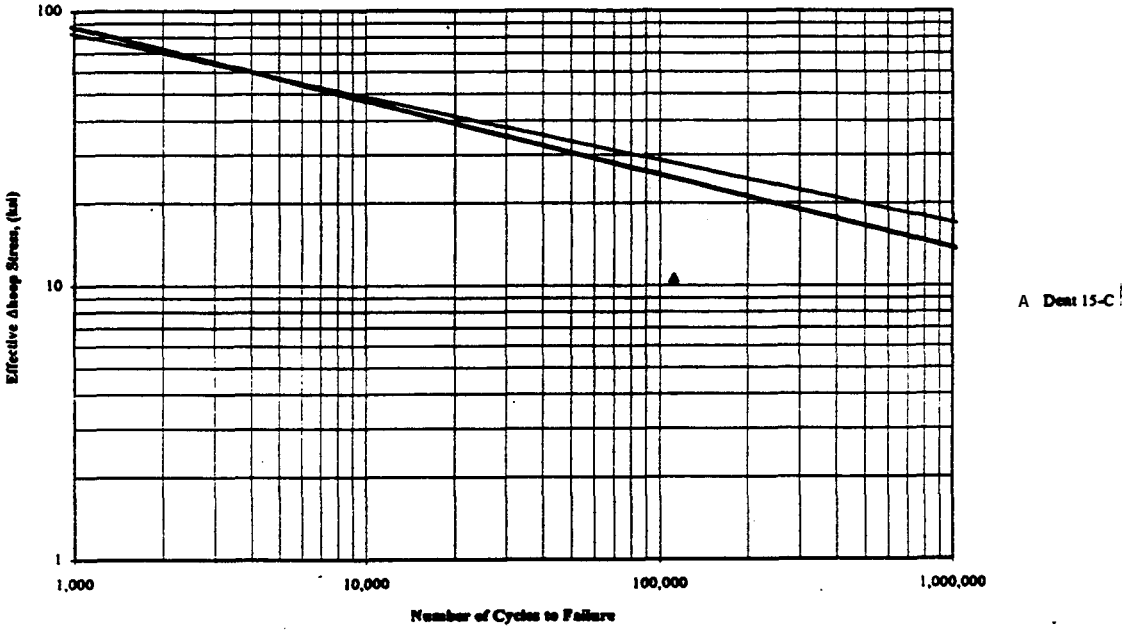


Figure A-48: S-N plot of fatigue failures for Specimen 15.