SAE Aerospace
An SAE International Group

AEROSPACE INFORMATION REPORT

SAE AIR1388 | REV. B

Issued 1975-07
Revised 1992-01
Reaffirmed 2013-01

Superseding AIR1388A

Service Damage Limits for Aircraft Hydraulic Tubing

RATIONALE

AIR1388B has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This SAE Aerospace Information Report (AIR) is intended to assist in evaluating the serviceability of damaged hydraulic tubing lines. The performance requirements are outlined to which the defect samples were tested. Test methods and data are described and summarized. Permissible defect limits are listed for 6061-T6 aluminum return lines, 3000 psi hydraulic tubing of 21Cr-6Ni-9Mn SS, 304 1/8 hard, corrosion resistant steel (CRES), as well as 3Al-2.5V CWRS and 3Al-2.5V annealed, seamless titanium tubing. All dimensions are in inches unless otherwise noted.

2. REFERENCES:

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 4943	Tubing, Seamless, Hydraulic, 3.0Al 2.5V, Annealed
AMS 4944	Tubing, Seamless, Hydraulic, 3.0Al 2.5V, Cold Worked, Stress Relieved
AMS 5561	Tubing, Welded and Drawn, High-Pressure Hydraulic, 9.0Mn 20Cr 6.5Ni 0.28N
SAE Paper 730624	Permissible Defects in Hydraulic Tubing (SP-378, SAE G-3 Tubing Symposium, 1973)

2.2 U.S. Government Publications:

Available from Standardization Documents Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

MIL-T-6845	Tubing, Steel, Corrosion Resistant (304) Aerospace Hydraulic System, 1/8 Hard Condition
MIL-T-7081	Tube, Aluminum Alloy, Seamless, Round Drawn, 6061, Aircraft Hydraulic Quality
MIL-F-18280	Fittings, Flareless Tube, Fluid Connection

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AIR1388B

3. TEST REQUIREMENTS:

The tests that were conducted were extremely severe and provided much greater stresses and strains than are normally encountered on aircraft hydraulic plumbing systems. The requirements, however, must be routinely met for the qualification of fittings and hose assemblies. Therefore, as the basis for establishing the extent of permissible damage, the following criteria were imposed on samples of damaged tubing:

a. Hydraulic tubing lines must pass the burst test as described in MIL-F-18280, rupturing at no less than four times the operating pressure.

b. Hydraulic tube lines also must pass 200 000 cycles of hydraulic impulse testing as described in MIL-F-18280.

It is the intention of these tests to establish dimensional limits for serviceability of chafed and dented tubing lines, and to establish a guide on which to base rejection of any tube as functionally unacceptable if the damage is greater than the established dimensional limit.

4. SUMMARY AND CONCLUSION:

Service damage is subdivided into chafing or denting, since each has a different effect on service life.

The evaluation of cracks and chafing or denting was based on the premise that tubing samples with maximum permissible defects should pass the hydraulic impulse and burst test requirements as specified for fitting or hose assemblies. The data presented for dents and chafing are based on testing artificial defects. The defects were selected after evaluation of samples return from service, and after testing different chafe lengths and dent diameters. It is realized that judgement must be used in correlating these data to actual damage on hydraulic tubing. Table 1 is presented as a guide and a conclusion to the data shown in Figures 3 through 15.

5. DESCRIPTION OF TUBING DEFECTS:

Service damage has many forms, and caution and judgement must be used in determining the serviceability of a tube showing damage. In most cases, the depth of such damage can be measured. For this reason, tests were performed to evaluate tubing having defects of different depth. Chafes and dents were selected as typical defects since they are the most frequent cause for tube cracking and leakage in service. Various chafe lengths were evaluated, as well as sharp notches and round dents, to select a severe defect and a valid sample of typical defects for testing.

NOTE: These limits apply only to service damage of the following types, provided they are not on or in the proximity of the tube ends, welded areas, formed transitions, fittings, etc.:

a. Dents and notches that are approximately perpendicular to the tube axis and which have a base or root radius not greater than given in Figures 1 and 2.

b. Chafes that are essentially flat or noncircumferential and which have an axial length not greater than given in Figure 11.

TABLE 1 - Recommended Acceptance Limits for Service-Damaged Aircraft Hydraulic Tubing

Tube Material	Type of Defect	Nominal Tube Outside Diameter .250	Nominal Tube Outside Diameter .375	Nominal Tube Outside Diameter .500	Nominal Tube Outside Diameter .625	Nominal Tube Outside Diameter .750	Nominal Tube Outside Diameter 1.000	Nominal Tube Outside Diameter 1.500
21-6-9 (3000 psi)	Wall Thickness	.016	.020	.026	.033	.039	.052	--
	Chafed	.006	.007	.008	.010	.011	.012	--
	Dented	.005	.007	.010	.015	.018	[a].020	--
304 1/8 hard (3000 psi)	Wall Thickness	.020	.028	.035	.042	.058	.065	--
	Chafed	[a].006	[a].007	[a].008	[a].010	[a].011	[a].012	--
	Dented	[a].005	.010	.020	.030	[a].040	[a].040	--
6061-T6 (1500 psi), except b	Wall Thickness	.035	.035	.035	.035	.035	.035	--
	Chafed	[a].015	.015	.01	.005	.004	.003	--
	Dented	[a].015	.015	.01	.005	[b].015/.005	[b].015/.005	--
3Al-2.5V annealed titanium (3000 psi)	Wall Thickness		.028	.036	.044	.054	.073	[b].042
	Dented		.025	.028	.021	.038	.050	.500
	Notch		.023	.025	.023	.033	.045	.250
	Chafed		.017	.020	.023	.023	.040	.030
3Al-2.5V cold-worked, stress-relieved titanium (3000 psi)	Wall Thickness	.016	.019	.026	.032	.039	.051	--
	Chafed	.006	.007	.008	.010	.011	.012	--
	Dented	.005	.007	.016	.015	.018	.020	--

a = Estimated, no test data.
b = Suction line (1500 psi).

6. TEST RESULTS:

6.1 Notches:

It may be noteworthy that the round dent was found to be more detrimental than the sharp, notch-type dent, such as might be caused by a sharp object. This observation was made for MIL-T-7081 6061-T6 aluminum tubing as well as for AMS 5561 21Cr-6Ni-9Mn (CRES), AMS 4944 3Al-2.5V CWSR, and AMS 4943 3Al-2.5V annealed, (see Figure 13). Typical comparisons of impulse test performance are shown in Figures 1 and 2.

The referenced SAE paper contains additional information.

6.2 Chafing and Denting Depth:

The data in Figures 3 through 15 indicate a sudden drop in the test performance when a critical defect depth is reached, thus permitting a conservative selection of acceptable defect levels. Figures 3 through 12 contain a compilation of impulse test data for 21Cr-6Ni-9Mn, 304 1/8 hard CRES, 3Al-2.5V CWSR 3000 psi, and 3Al-2.5V annealed 3000 psi tubing, having dents, notches, and chafes of varying depth. They illustrate the basis for the permissible limits recommended in Table 1, and for estimating the defect limits in tubing sizes that were not tested. Figures 13 and 14 indicate that dents and chafes severely reduce the impulse life of aluminum return line tubing in the larger sizes. Figures 11 and 12 contains the test results for chafing damage in 21-6-9 3000 psi hydraulic tubing. No burst tests for chafed 304 1/8 hard tubing were conducted; instead, the chafing limits are recommended for 21Cr-6Ni-9Mn were calculated to be more than safe for use with 304 1/8 hard tubing also. The effect of chafing and denting on 3Al-2.5V CWSR tubing was tested in all sizes used in 3000 psi systems. Figure 15 compares the effect of tube size and defect type on 3Al-2.5V titanium tubing.

7. RECOMMENDATION:

In evaluating service defects it is imperative to identify the cause and to correct the basic problem that caused the defect. Actual repair of the defect is not required if the depth of the object does not exceed the values listed in Table 1 of this AIR.

PREPARED BY SAE SUBCOMMITTEE G-3E, AEROSPACE TUBING INSTALLATION
OF SAE COMMITTEE G-3, AEROSPACE COUPLINGS, FITTINGS, HOSE AND
TUBING ASSEMBLIES

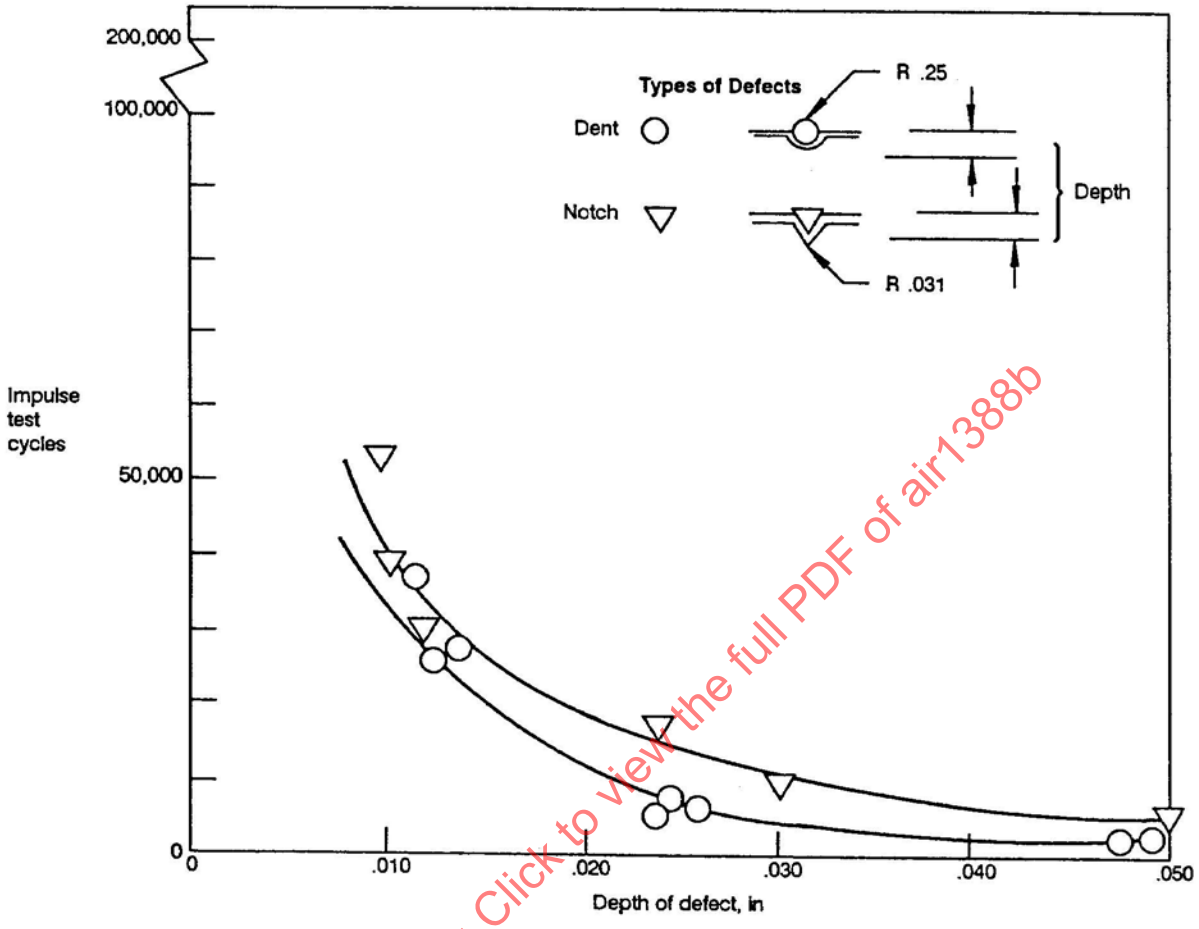


FIGURE 1 - Impulse Test Performance of ϕ.375 by .018 Wall 3Al-2.5V CWSR Titanium Tubing With Various Defects

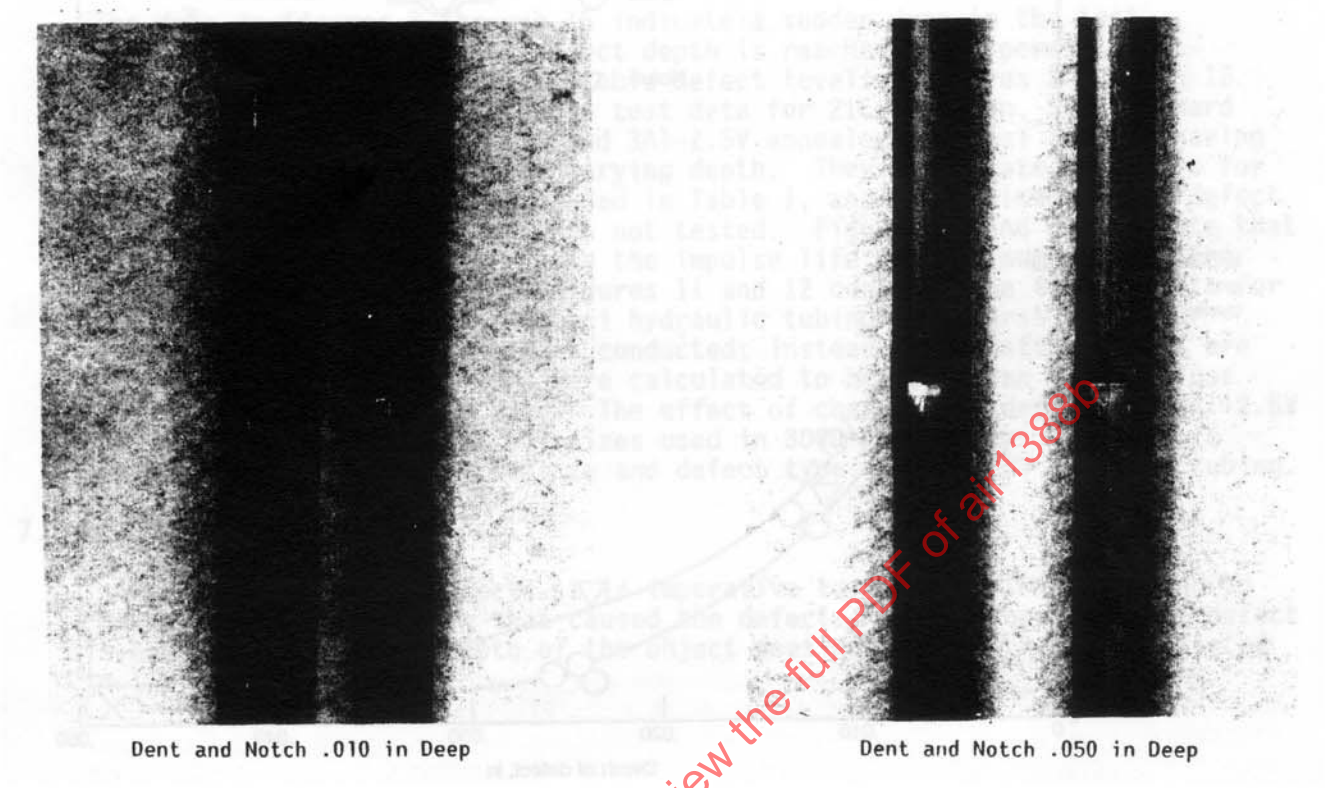


FIGURE 1 (Continued)

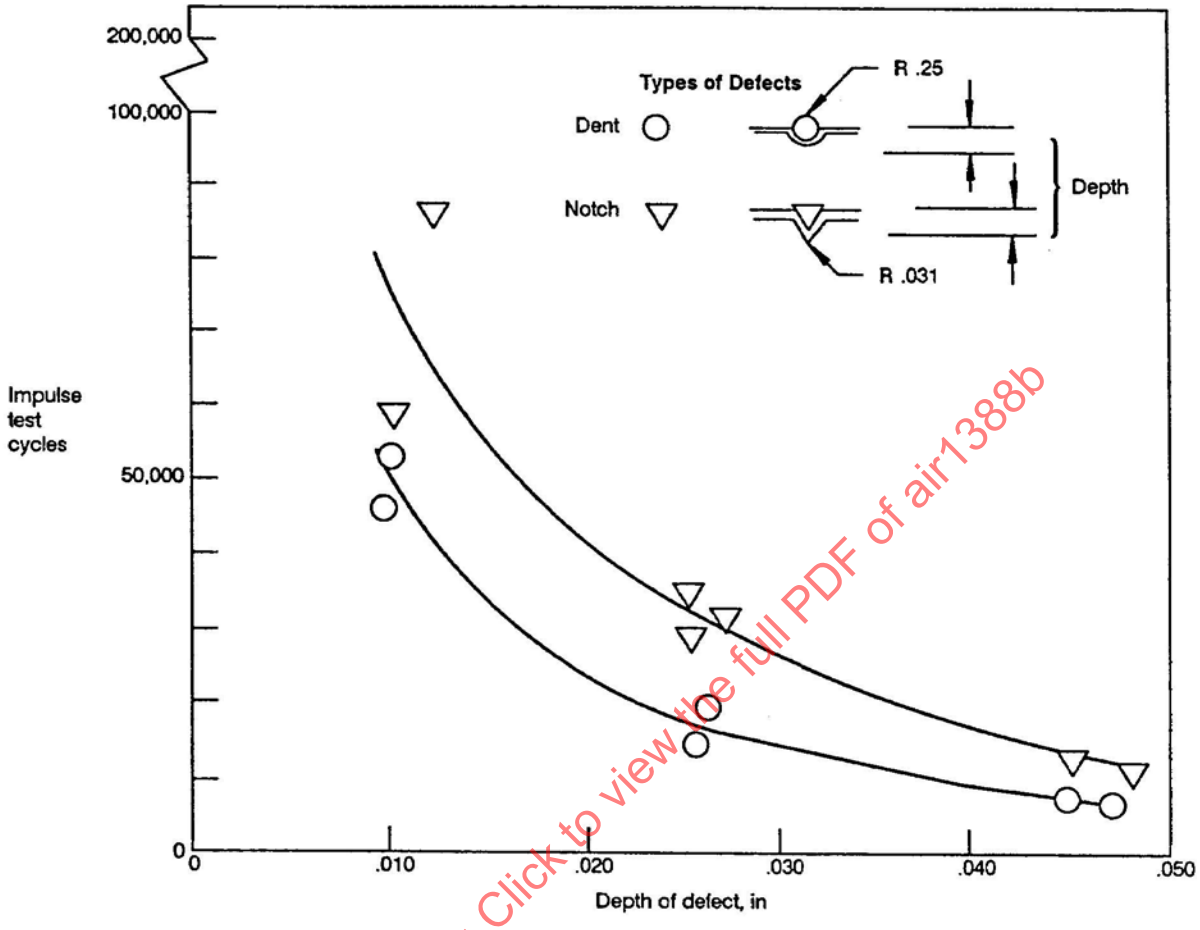
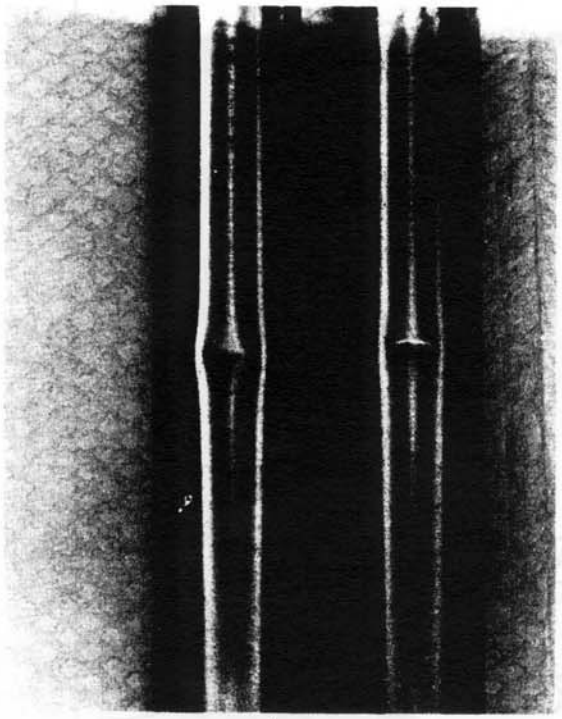


FIGURE 2 - Impulse Test Performance of ϕ.750 by .039 Wall 3Al-2.5V CWSR Titanium Tubing With Various Defects



Dent and Notch .025 in Deep

Dent and Notch .050 in Deep

FIGURE 2 (Continued)

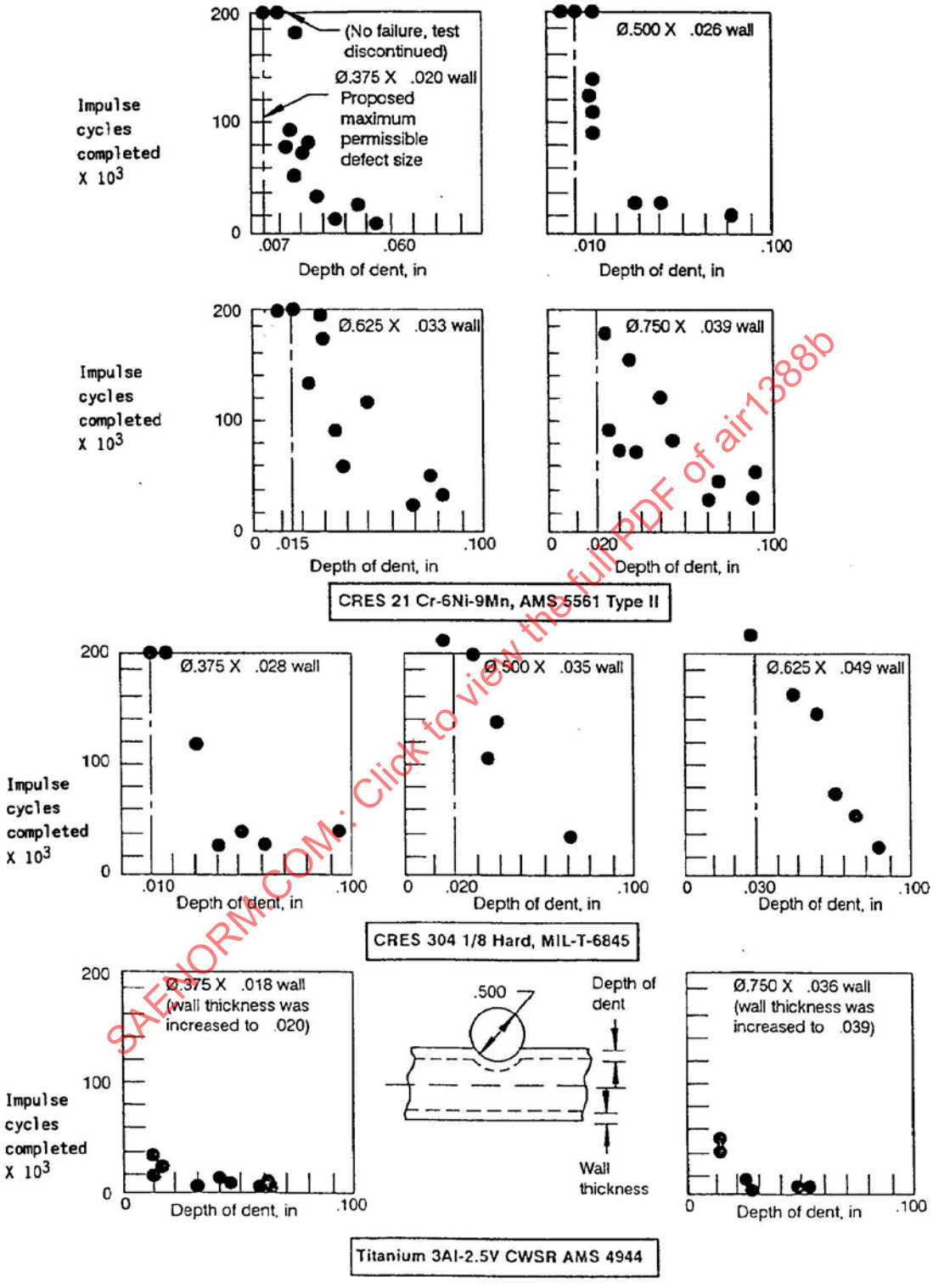


FIGURE 3 - Impulse Test Data, Dented Tubing, 3000 psi System

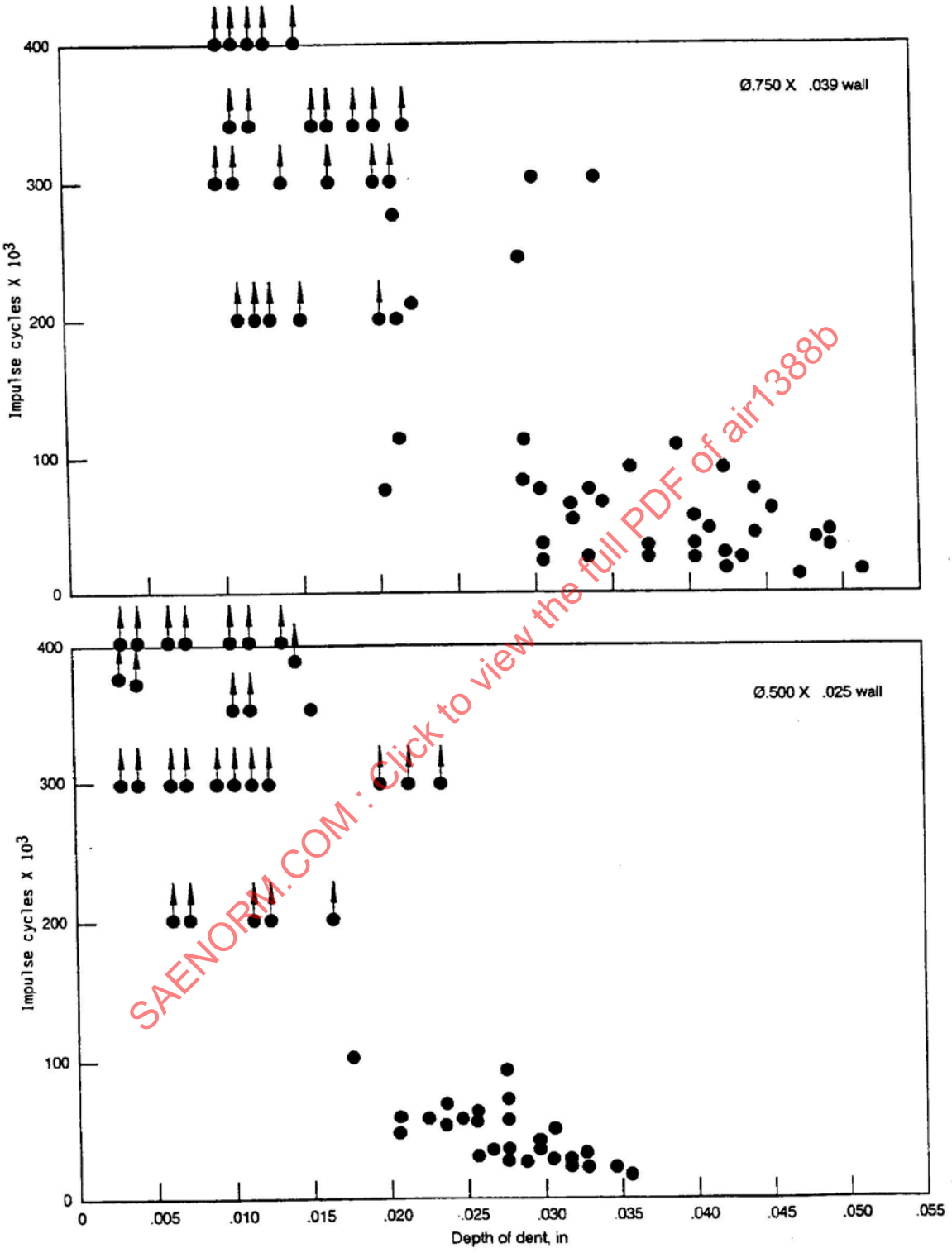


FIGURE 4 - Impulse Test Data, Dented Tubing, Ti-3Al-2.5V CWSR Tubing

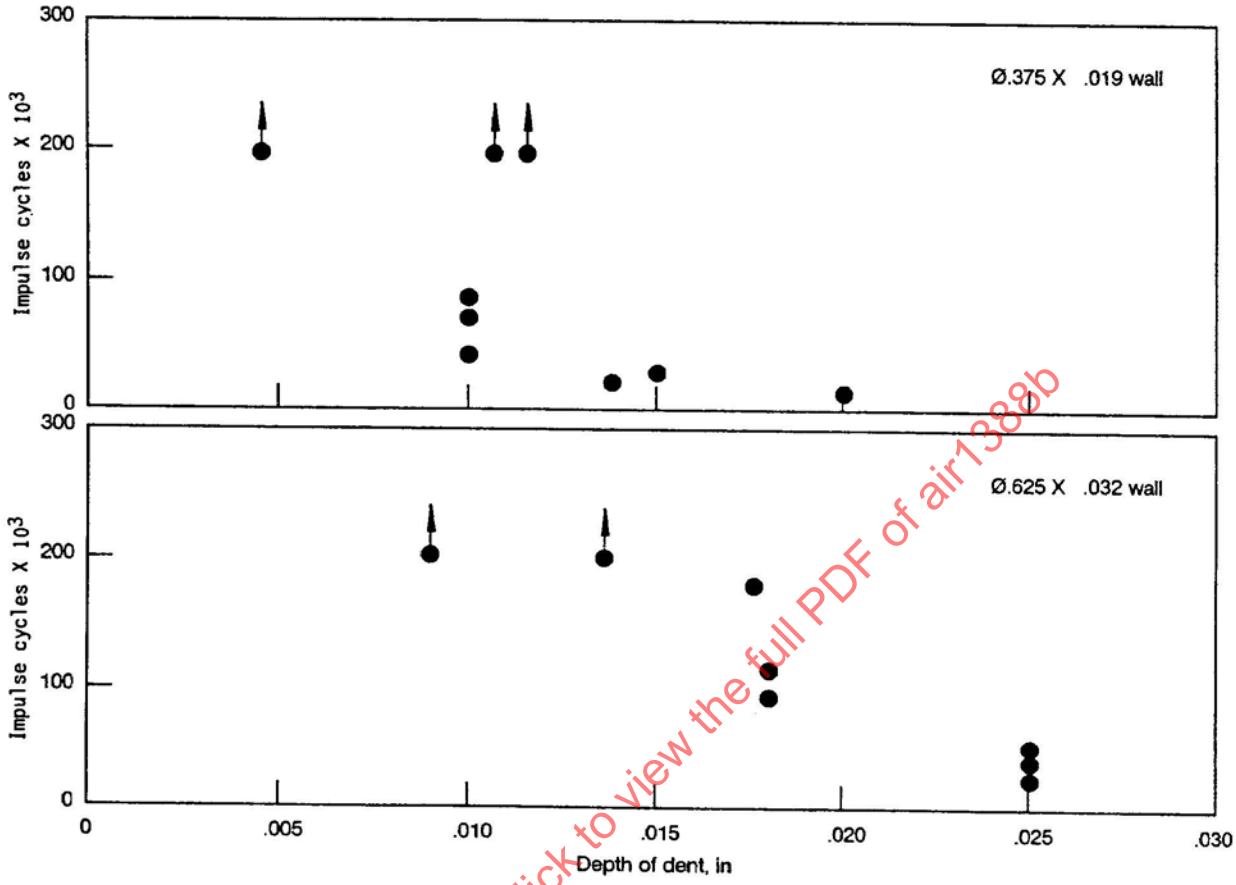


FIGURE 5 - Impulse Test Data, Dented Tubing, Ti-3Al-2.5V CWSR

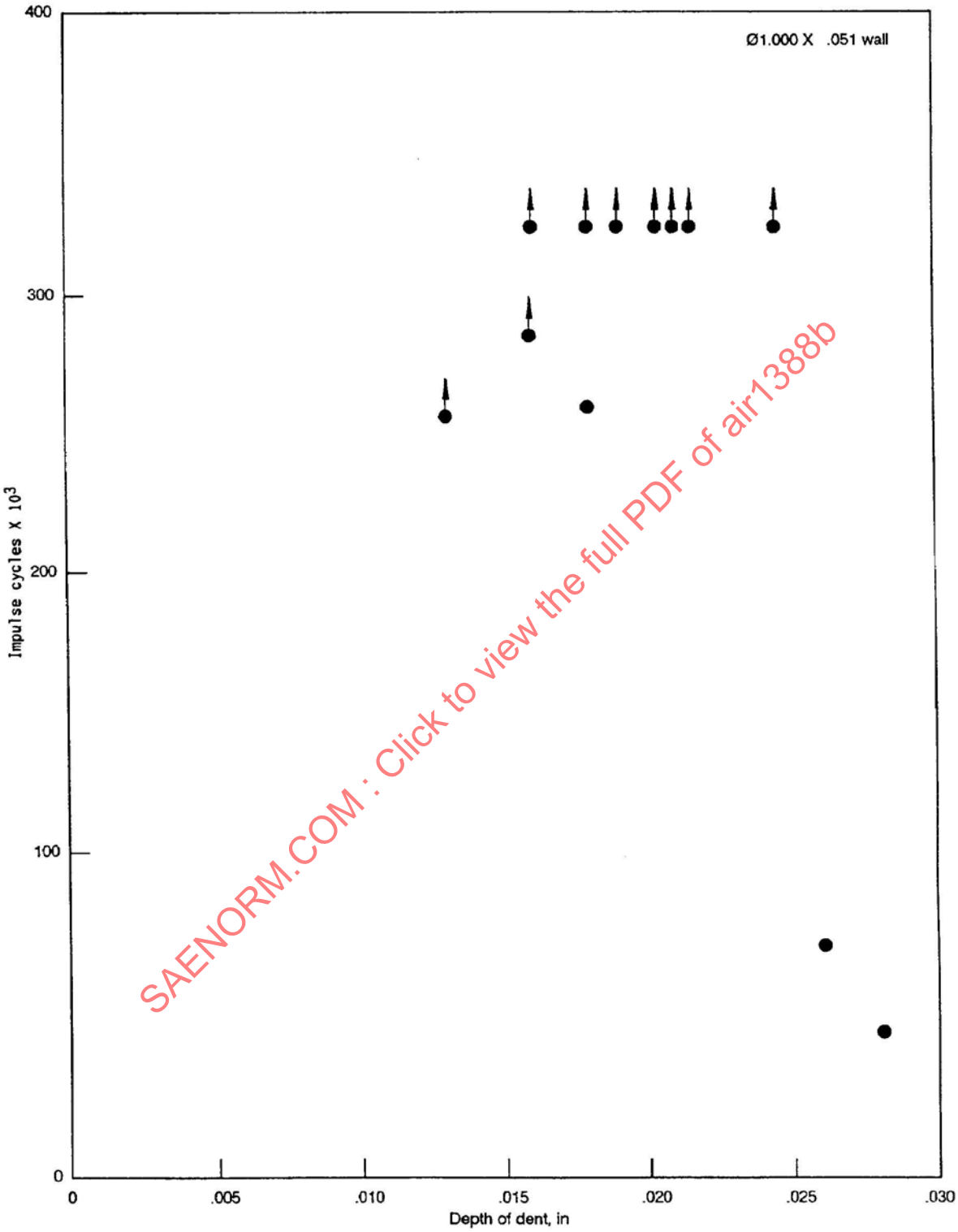


FIGURE 6 - Impulse Test Data, Dented Tubing, Ti-3Al-2.5V CWSR

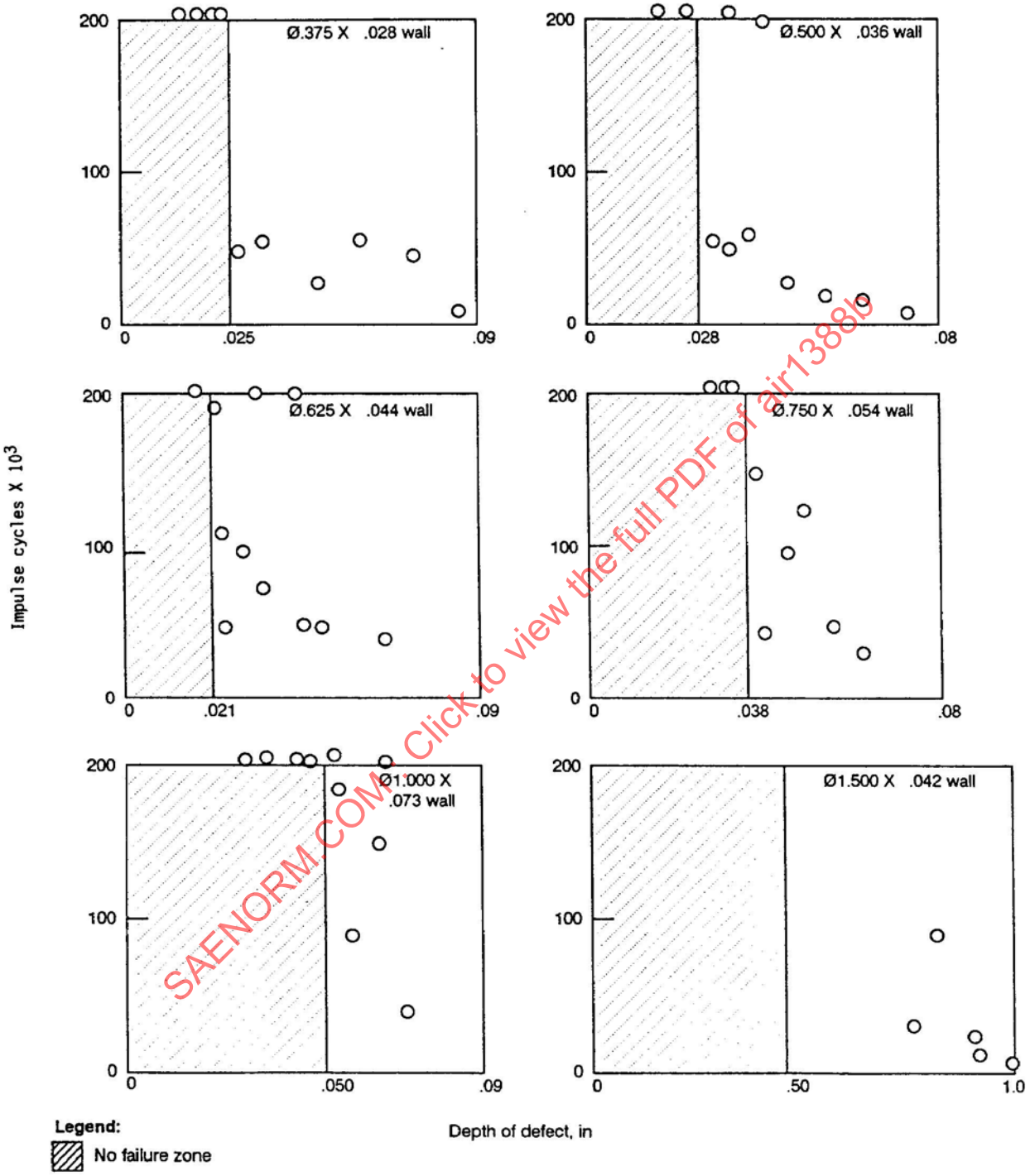


FIGURE 7 - Defect Limits: Dent, Seamless, Annealed, 3Al-2.5V Tubing

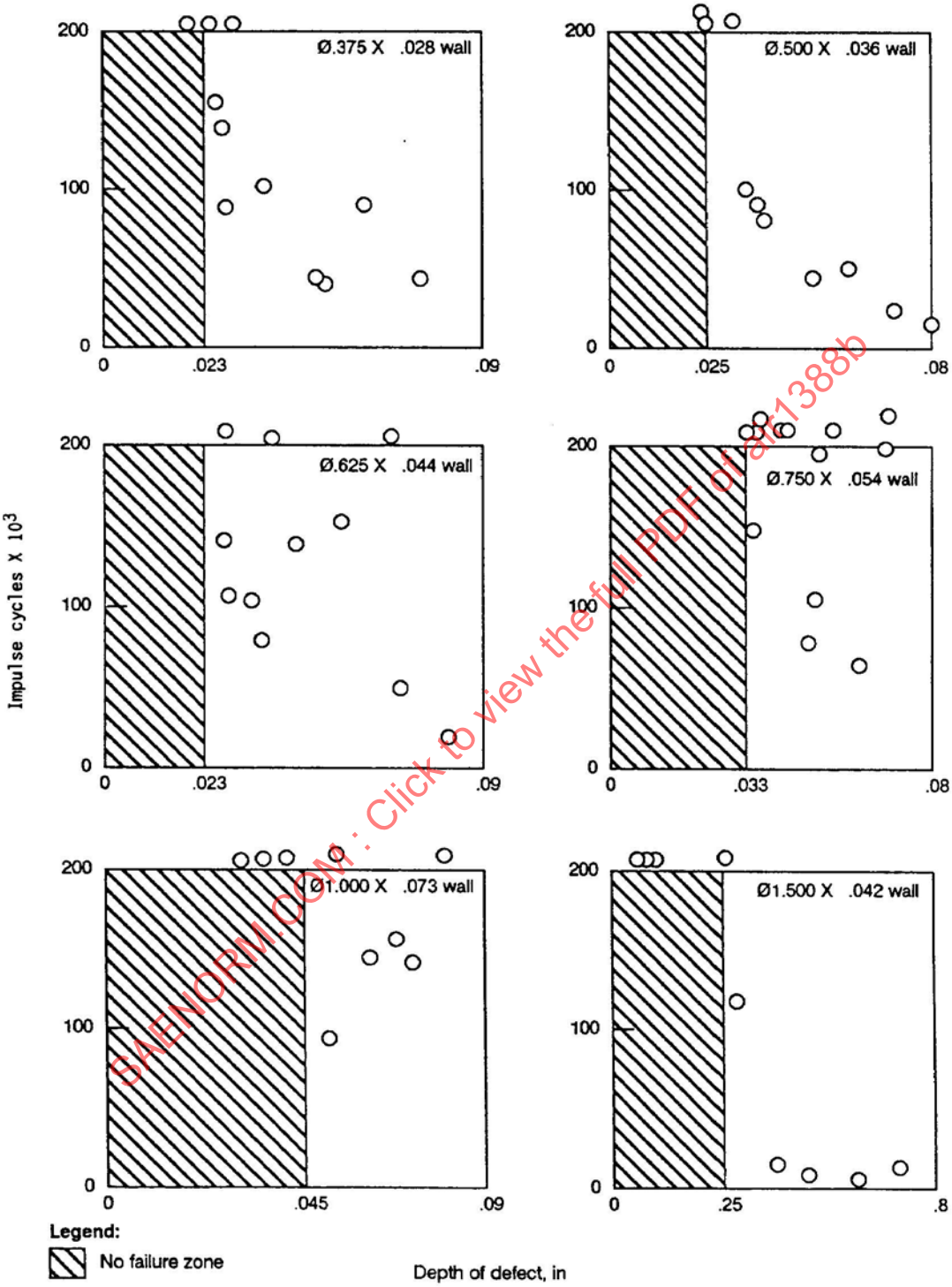


FIGURE 8 - Defect Limits: Notch, Seamless, Annealed, 3Al-2.5V Tubing

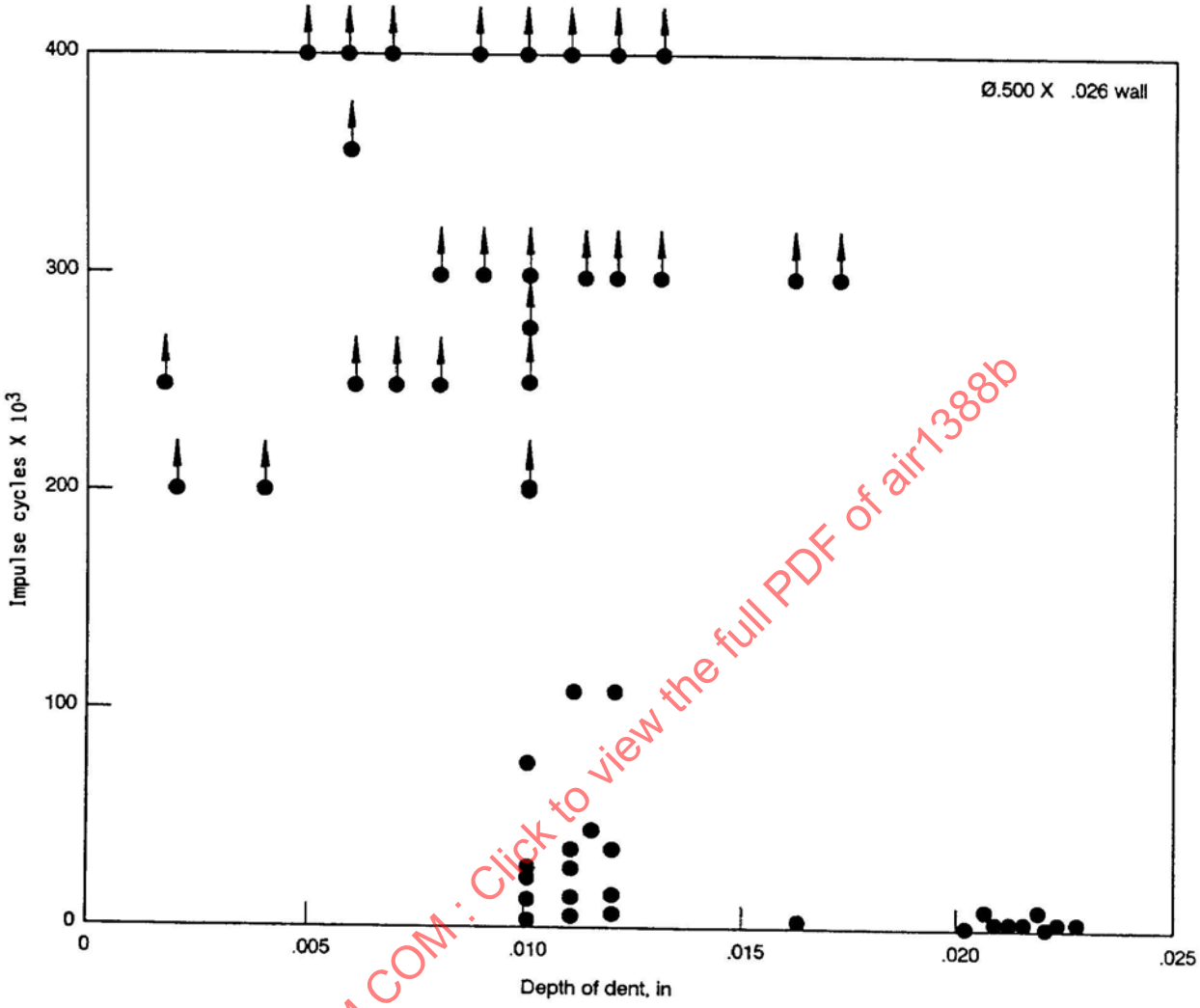


FIGURE 9 - Impulse Test Data, Chafed Tubing, Ti-3Al-2.5V CWSR Tubing

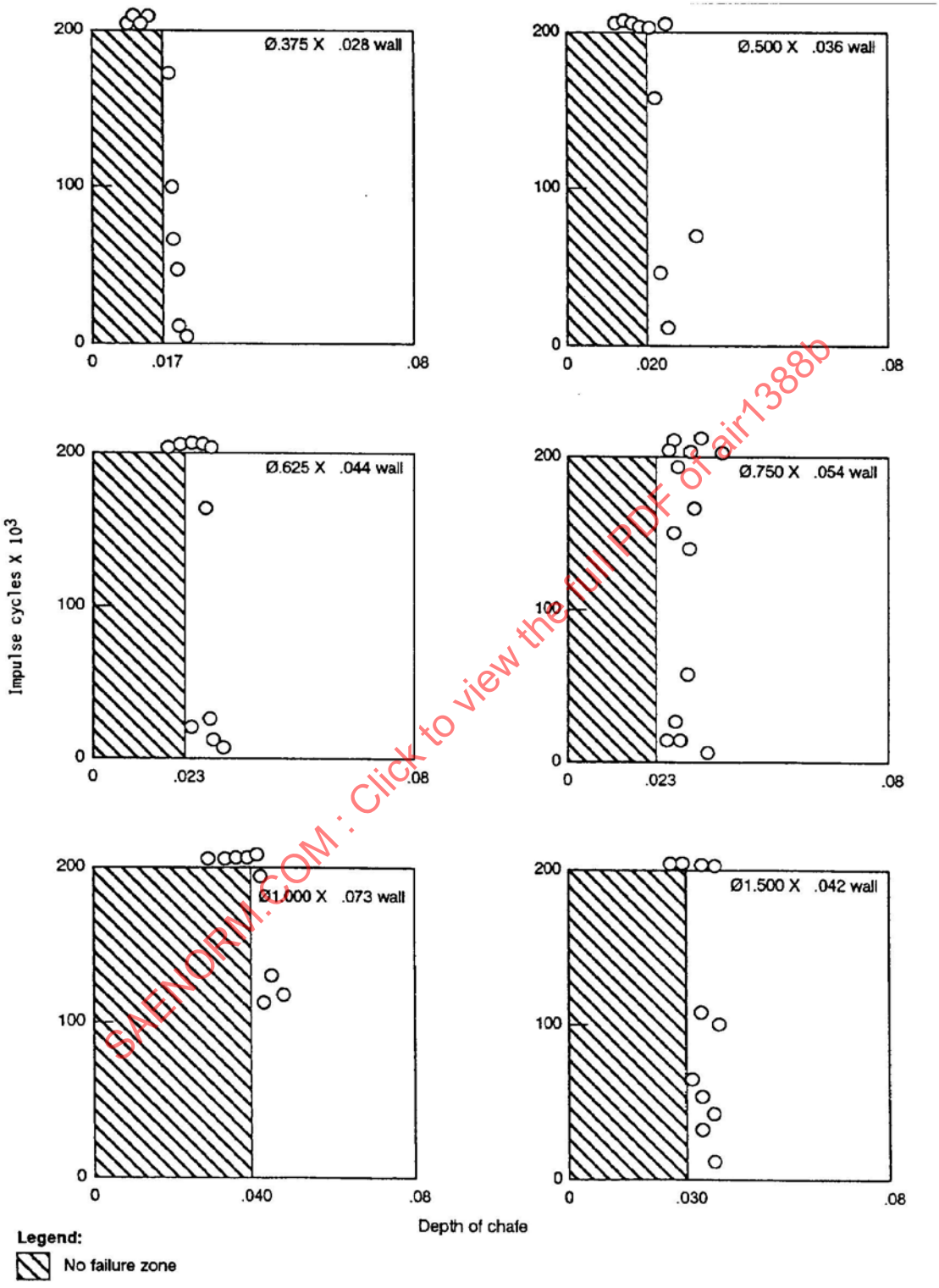


FIGURE 10 - Defect Limits: Chafe, Seamless, Annealed 3Al-2.5V Tubing