Designation: F2634 – 15

Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method[1]

This standard is issued under the fixed designation F2634; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This is a tensile impact test method that develops enough tensile impact energy at specific rates of strain to rupture standard tensile impact specimens of butt fused plastic pipe. It is used to determine the quality of PE butt fusion joints made in the field or in qualification testing. It can also be used to determine the optimum butt fusion joining parameters of PE materials.

1.2 This test method is applicable for testing pipe specimens with a diameter 2.37 in. (60.3 mm) and larger with a wall thickness from 0.25 in. (6.3 mm) and larger.

NOTE 1—This test method is similar to ISO 13953.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 This test method may be used alone or together with other test methods, to evaluate the quality of the butt fused joints. When this test, conducted at laboratory temperatures per 9.2, is combined with the elevated temperature, sustained pressure test in Specification D3035, both the short term and long term strength of the PE butt fusion joint will be verified.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D883 Terminology Relating to Plastics

D2513 Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standard*[3]

ISO 13953 Polyethylene (PE) pipes and fittings - Determination of the tensile strength and failure mode of test pieces from a butt-fused joint

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *brittle rupture* —A brittle rupture in a butt fusion joint specimen consists of a clean or nearly clean part between the joining surfaces resulting in a smooth surface on both sides. (See Fig. 1.)

3.1.2 *ductile rupture*—A ductile rupture in a butt fusion joint specimen consists of either an elongation rupture of the machined pipe outside the joint area (see Fig. 2) or adjacent to the butt fusion joint interface but resulting in considerable material tearing between the pipe end surfaces (see Fig. 3).

3.1.3 *maximum force*—the maximum force obtained during the test.

3.1.4 *rupture energy*—the energy required to rupture the coupon.

3.1.5 *yield point* —The point on the force/time curve where significant plastic deformation begins to occur. For the purposes of this standard, this is defined as occurring at zero slope point on the force/time curve.

3.1.6 *yield energy* —The energy imparted to the coupon by the yield point.

3.1.7 *average velocity*—The average velocity is the average crosshead speed for the duration (until coupon rupture) of the tensile test (inches/ sec.)

[1] This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

***A Summary of Changes section appears at the end of this standard**

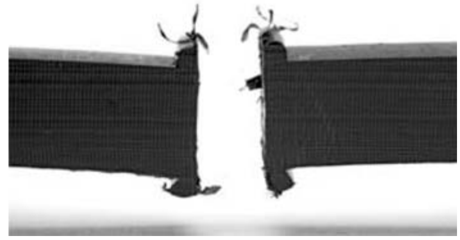


FIG. 1 Brittle Rupture

FIG. 2 Ductile Rupture Outside Fusion Interface

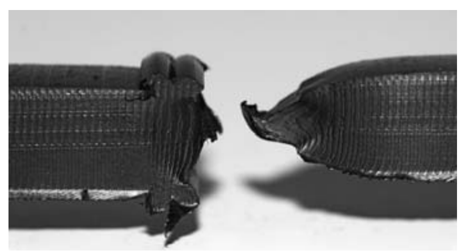


FIG. 3 Ductile Rupture Adjacent to Fusion Interface

3.1.8 *instantaneous velocity*—The crosshead velocity at any discrete point during the test. This may be plotted to show the consistency of the velocity profile through the duration of the test.

3.1.9 *yield stress*—The stress value corresponding to the yield point.

3.1.9.1 *Discussion*—Additional definitions of terms applying to tensile test methods appear in Terminology D883.

4. Significance and Use

4.1 This test method is designed to impart tensile impact energy to a butt fused plastic pipe specimen, record the energy to fail the specimen and plot the load over time curve of the tensile test. Energy recorded at yield and rupture and the rupture mode (brittle or ductile) are used as criteria in the evaluation of the butt fusion joint. The evaluation of the force/time curve not only makes it possible to compare different butt fusion parameters but also to evaluate the rupture mode of the specimen to determine joint integrity. Each coupon's test results will usually be compared to test results for coupons machined from the base pipe material, un-fused.

4.1.1 These data are also useful for qualitative characterization and for research and development. For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method.

4.2 Tensile properties may vary with specimen preparation and with speed and environment of testing. Consequently, where precise comparative results are desired, these factors must be carefully controlled.

4.2.1 It is realized that a material cannot be tested without also testing the method of preparation of that material. Hence, when comparative tests of materials per se are desired, the greatest care must be exercised to ensure that all specimens are prepared in exactly the same way, unless the test is to include the effects of specimen preparation. While care must be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling, the exact dimensions of the test specimens are entered into the Data Acquisition System (DAS) before initiating the test.

5. Apparatus

5.1 *Testing Machine,* A testing machine of the controlled rate-of-crosshead-movement type and comprising essentially the following:

5.1.1 *Fixed Member,* a fixed or essentially stationary member with tooling to pin a standard pipe specimen configuration.

5.1.2 *Movable Member,* a movable member with tooling to pin a standard pipe specimen configuration.

5.1.3 *Tooling for specimens,* Fixed clevis members attached to the testing machine for pinning the test specimen between the fixed member and the movable member of the testing machine. When the test specimen is inserted and pinned into the tooling, the long axis of the test specimen will coincide with the direction of pull through the centerline of the assembly.

5.1.4 *Drive Mechanism,* a drive mechanism for imparting to the movable member a uniform, controlled velocity with respect to the stationary member, with this velocity to be regulated as specified in Section 6.3.

5.1.5 *Recording Mechanism (not shown),* The testing machine shall have sensors and data entry instrumentation to record the date, specimen number, pipe size, pipe material, force curve, energy curve, velocity curve to compare the butt fused specimen to a control specimen of the pipe material or another butt fusion specimen. The minimum sampling rate of the DAS shall be 1 KHz.

5.1.6 *Load Indicator,* A suitable load-indicating instrument capable of showing the total tensile load carried by the test specimen when held by the tooling. This mechanism shall indicate the load with an accuracy of ±1 % of the indicated value, or better.

5.1.7 *Impact Mechanism,* The impact load is imparted by allowing 0.25 in. (6.4 mm) minimum free movement of the drive mechanism before applying the load to the specimen.

5.1.8 *Position Indicator (not shown),* A suitable position indicating instrument capable of indicating position. This mechanism shall indicate the position of the movable member with an accuracy of ±1 % of the indicated value, or better.

5.2 *Measuring Instrument,* Apparatus for measuring the width and thickness of the test specimen shall maintain an accuracy within .001 in. of gage.

6. Test Specimens

6.1 *Butt Fusion and Pipe Specimen*—The test specimen shall conform to the dimensions shown in Fig. 4 depending on the wall thickness of the specimen. Test specimens of butt fused pipe shall have the bead remain on the outside and inside.

6.1.1 *Preparation*—Test specimens shall be prepared by machining operations on butt fused sections of pipe and on the pipe itself. The machining operations shall result in a smooth surface on both sides of the reduced area with no notches or gouges.

6.2 *Finishing*—All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. Marks left by coarse machining operations shall be carefully removed with a fine file or abrasive, and the filed surfaces shall then be smoothed with abrasive paper (600 grit or finer). The finishing sanding strokes shall be made in a direction parallel to the longitudinal axis of the test specimen. In machining a specimen, undercuts that would exceed the dimensional tolerances shall be scrupulously avoided.

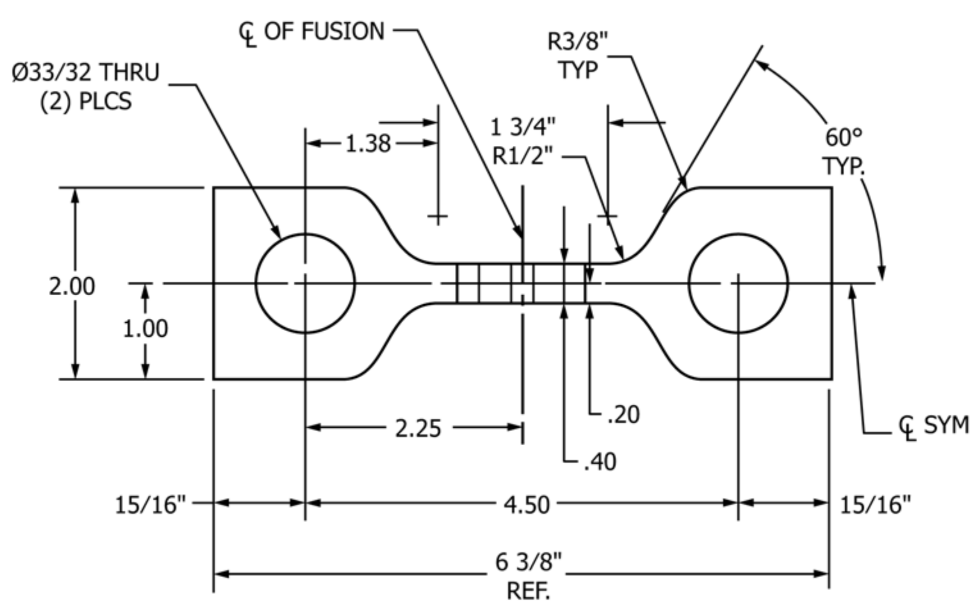
6.3 *Marking*—When marking the specimens, use a permanent marker of a color that will be easily read or engrave the specimen number in the area outside the hole. Do not engrave in the gage portion of the coupon.

7. Number of Test Specimens

7.1 Test at least four specimens from butt fused or plain pipe sections 90° apart for pipe sizes 4 in. and larger. Test two specimens from butt fused or plain pipe sections 180° apart (top center and bottom center) for pipe sizes 2 in. to 4 in. It is advisable to take as many samples from a fused pipe section as is practicable.

8. Speed of Testing

8.1 Speed of the tensile impact testing shall be relative to the modulus of elasticity and wall thickness of the plastic pipe materials.



All machined surfaces 125 RMS or better
Tolerances: Fraction or whole number -- ± .032", 0.xx dimensions –± .010, 0.xxx dimensions –± .005
Dimensions are in inches

FIG. 4 Test Specimen (Not to Scale)

8.2 Choose the speed of testing from Table 1. Determine this chosen speed of testing by the specification for the material being tested, or by agreement between those concerned.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) for not less than 1 h prior to test.

9.2 *Test Conditions*—Conduct the tests at 73.4 ± 3.6°F (23 ± 2°C) unless otherwise specified by contract or the relevant ASTM material specification.

10. Calculations

10.1 *Definitions:*

P_n = Indicated position of movable member at any given $time_n$
P_0 = Indicated initial position of movable member
P_{n-1} = Indicated position of movable member at time n-1 (previous indicated value)
F_n = Indicated Force at any given $time_n$
D_n = Displacement from initial position P_0
V_n = Instantaneous velocity at any given time n
V_{avg} = Average test velocity
E_n = Cumulative Energy applied to the test specimen from beginning of test to any given time n
E_y = Cumulative Energy at yield point
E_r = Cumulative Energy at rupture point
σ_n = Tensile stress at any given time n
t = Test specimen minimum gage section thickness
w = Test specimen minimum wall thickness
A = Test specimen cross sectional area
y = Time at yield point
r = Time at rupture
SR = Sampling rate on data acquisition system

10.2 Calculate Displacement (D_n) as follows:

$$D_n = (P_n - P_0) \tag{1}$$

10.3 Calculate instantaneous velocity (V_n) as follows:

$$V_n = \frac{(D_n - D_{n-1})}{(SR)^{-1}} \tag{2}$$

TABLE 1 Test Speed—Tolerance= + .5 in./s (+ 12.7 mm/s to – 25.4mm/s)

Pipe Material	Standard	Wall Thickness	Tensile Impact Testing Speed
Polyethylene Pipe	D2513 or D3035	< 1.25 in. (32mm)	6 in./s (152 mm/s)
Polyethylene Pipe	D2513 or D3035	>1.25 in. (32mm)	4 in./s (102 mm/s)

10.4 Calculate average velocity (V_n) as follows:

$$V_{avg} = \frac{1}{r}\sum_{i=1}^{r} V_n \tag{3}$$

10.5 Calculate test specimen engineering area (A) as follows:

$$A = t*w \tag{4}$$

10.6 Calculate tensile stress (σ_n) as follows:

$$\sigma_n = \frac{F_n}{A} \tag{5}$$

10.7 Calculate cumulative energy (E_n) (at any point) as follows:

$$E_n \sum_{i=1}^{n} F_i*(D_i - D_{i-1}) \tag{6}$$

11. Procedure

11.1 Set up the machine and set the speed of testing to the proper rate as required in Section 8.

11.2 Measure the width and wall thickness of each specimen in the gage section to the nearest 0.001 in. (0.025 mm). Each dimension shall be measured in a minimum of three places in the gage section and the smallest measured value shall be recorded in the DAS.

11.3 Pin each specimen in the clevis tooling of the testing machine. This will align the long axis of the specimen and the tooling with the direction of pull of the machine. See Fig. 5.

11.4 Enter all appropriate data.

11.5 Perform the test. For each specimen, the data acquisition system shall record the force curve over time and the position curve over time at the minimum sampling rate given in 5.1.5.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the test specimens including the pipe size and DR, material tested including manufacturer's code numbers, and related applicable standards, date, who performed the test, testing company and any other data that would help evaluate the joints.

12.1.2 Individual test record for each specimen tested with recorded force/time graph, maximum force attained in the test, rupture energy, yield energy, yield stress, average high speed tensile impact test speed and documented type of rupture (brittle or ductile) (see Fig. 1, Fig. 2, and Fig. 3).

FIG. 5 Pin the Specimen in the Testing Machine

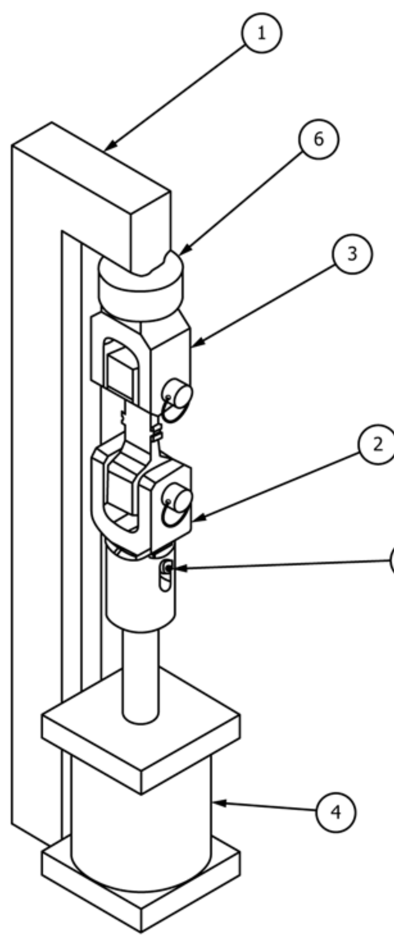


FIG. 6 Testing Apparatus

12.1.3 Project Report that compiles the data recorded on all specimens tested and shown in spreadsheet format for evaluation. See Figures Figs. X1.1-X1.4 in Appendix X1 for help interpreting the results of the test.

12.1.4 Project Matrix of test specimen numbers and fusion parameters used in joining,

12.1.5 The Project Matrix must include base material specimens for the purpose of comparison.

12.1.6 A reference to this ASTM standard.

13. Precision and Bias

13.1 The precision of this test method is based on an interlaboratory study of F2634, Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method, conducted in 2014. Three laboratories participated in this study. Each of the labs reported eight replicate test results for two different PE butt fusion joints. Every "test result" reported represents an individual determination. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:F17-1053. [4]

13.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

NOTE 2—All testing resulted in rupture of the test specimens outside of the joining interface. Therefore, the tables provided below illustrate the performance of the pipe material in the test specimen rather than directly reflecting the performance of the unfailed joint.

13.1.1.1 Repeatability can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

13.1.1.2 Repeatability limits are listed in Tables 2-9 below.

13.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

13.1.2.1 Reproducibility can be interpreted as the maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

13.1.2.2 Repeatability limits are listed in Tables 2-9 below.

13.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

13.1.4 Any judgment in accordance with statements 13.1.1 and 13.1.2 would normally have an approximate 95% probability of being correct, however the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and laboratories reporting results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95% probability limit would imply. The repeatability limit and the reproducibility limit should be considered as general guides, and the associated probability of 95% as only a rough indicator of what can be expected.

13.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

13.3 The precision statement was determined through statistical examination of 384 test results, from three laboratories, on two different butt fusion joints. These joints were described as:

Material A: Yellow MDPE Joint Test Specimen
Material B: Black HDPE Joint Test Specimen

To judge the reliability of two test results, it is recommended to choose the material type closest in characteristics to the test material.

14. Keywords

14.1 butt fusion; butt fusion joint test; tensile-impact; rupture energy; yield energy

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F17-1053.

TABLE 2 Minimum Width Measured (inches)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	0.399	0.001	0.002	0.002	0.004
Material B	0.401	0.002	0.004	0.005	0.010

[A] The average of the laboratories' calculated averages

TABLE 3 Average Velocity (inches per second)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	5.862	0.031	0.117	0.086	0.329
Material B	5.843	0.005	0.212	0.013	0.593

[A] The average of the laboratories' calculated averages

TABLE 4 Yield Stress (psi)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	4148	28	249	80	697
Material B	4534	35	47	99	133

[A] The average of the laboratories' calculated averages

TABLE 5 Yield Energy (lbs)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	271.3	10.5	45.7	29.3	127.8
Material B	339.9	19.8	39.4	55.4	110.5

[A] The average of the laboratories' calculated averages

TABLE 6 Rupture Energy (lbs)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	1029	31	81	143	227
Material B	1137	315	315	881	881

[A] The average of the laboratories' calculated averages

TABLE 7 Maximum Force (lb-f)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	1185	11	241	30	673
Material B	1509	18	22	49	61

[A] The average of the laboratories' calculated averages

TABLE 8 Area Calculated (in²)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	0.284	0.002	0.040	0.006	0.111
Material B	0.333	0.003	0.006	0.009	0.018

[A] The average of the laboratories' calculated averages

TABLE 9 Depth Measured (inches)

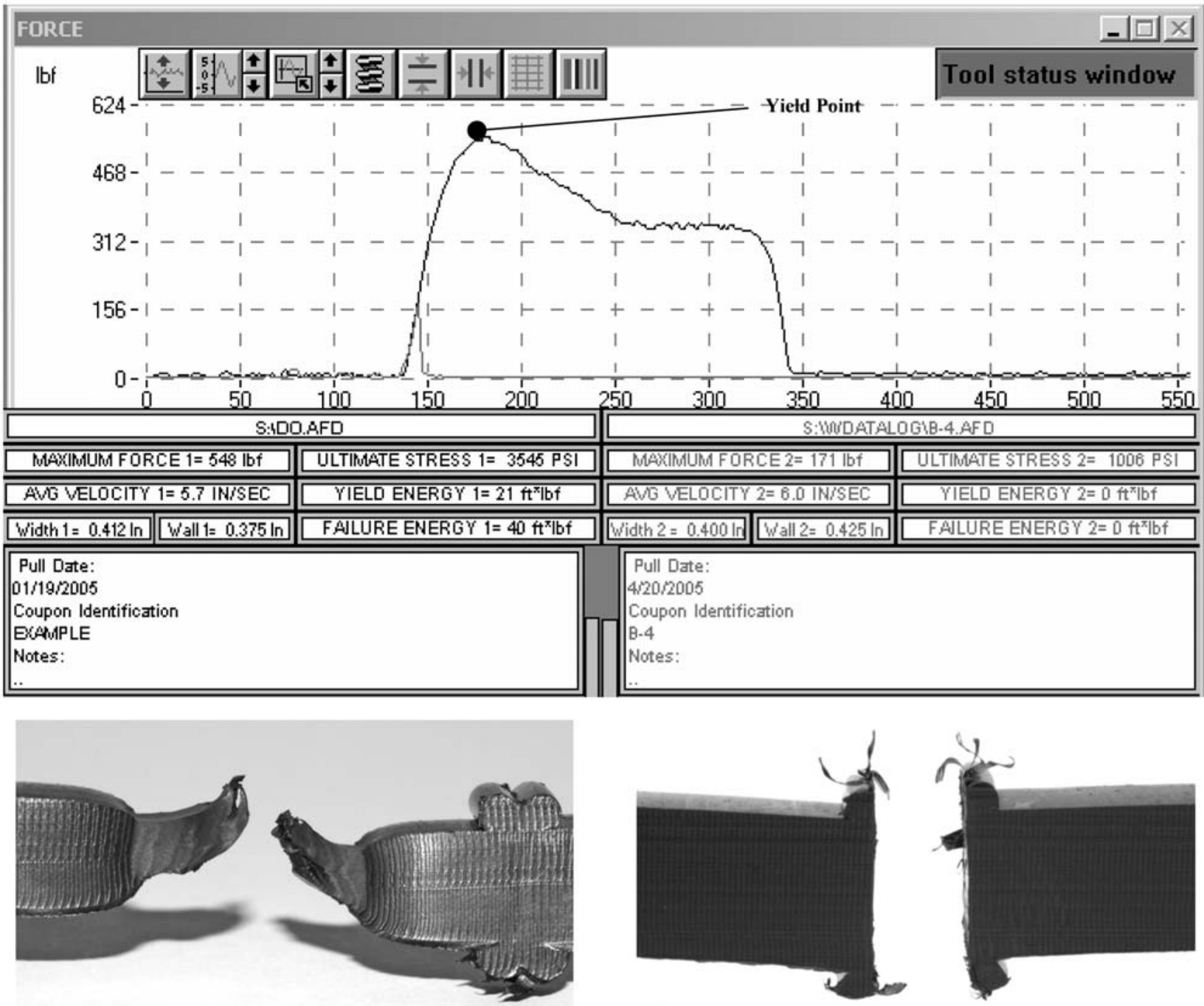
Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	S_R	r	R
Material A	0.712	0.005	0.097	0.014	0.271
Material B	0.830	0.008	0.010	0.023	0.029

[A] The average of the laboratories' calculated averages

APPENDIX

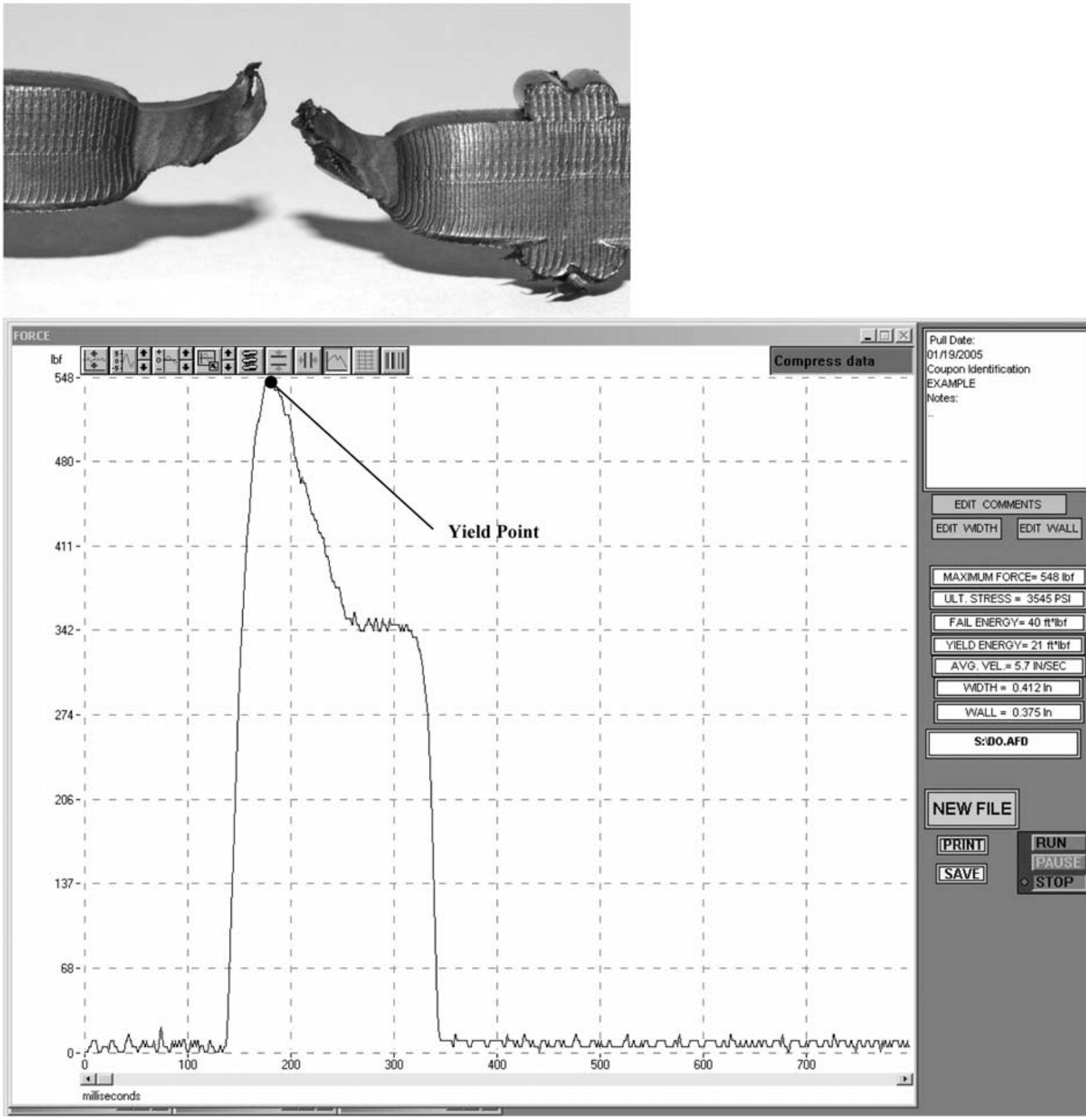
(Nonmandatory Information)

X1. Evaluating Test Results



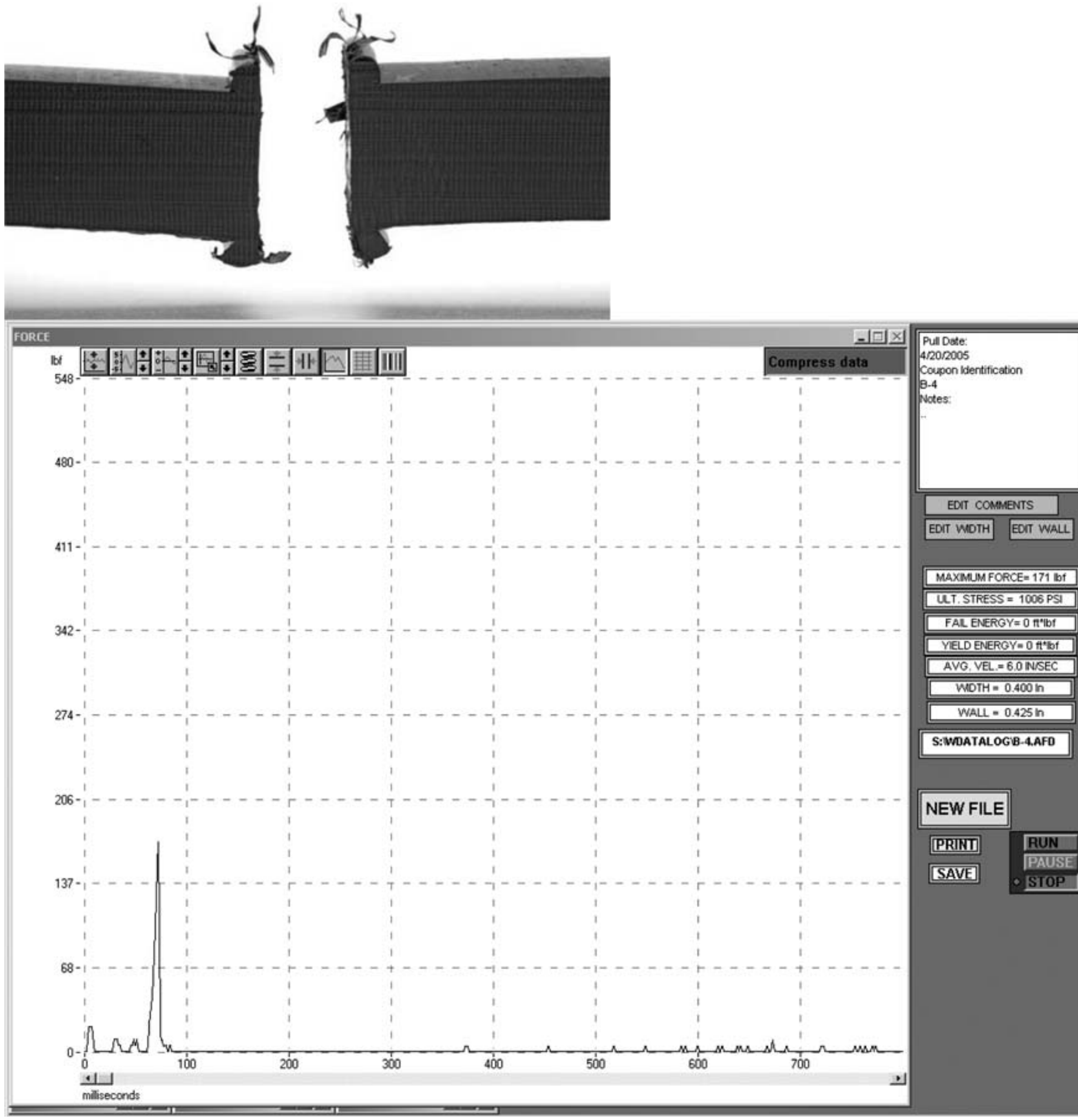
The test on the left is a good quality joint. The specimen shows a ductile rupture. The test on the right is a poor quality joint. The specimen shows insufficient ductility and is considered a brittle rupture.

FIG. X1.1 Force/Time Graph of High Speed Tensile Impact Test Comparison of Two Specimens



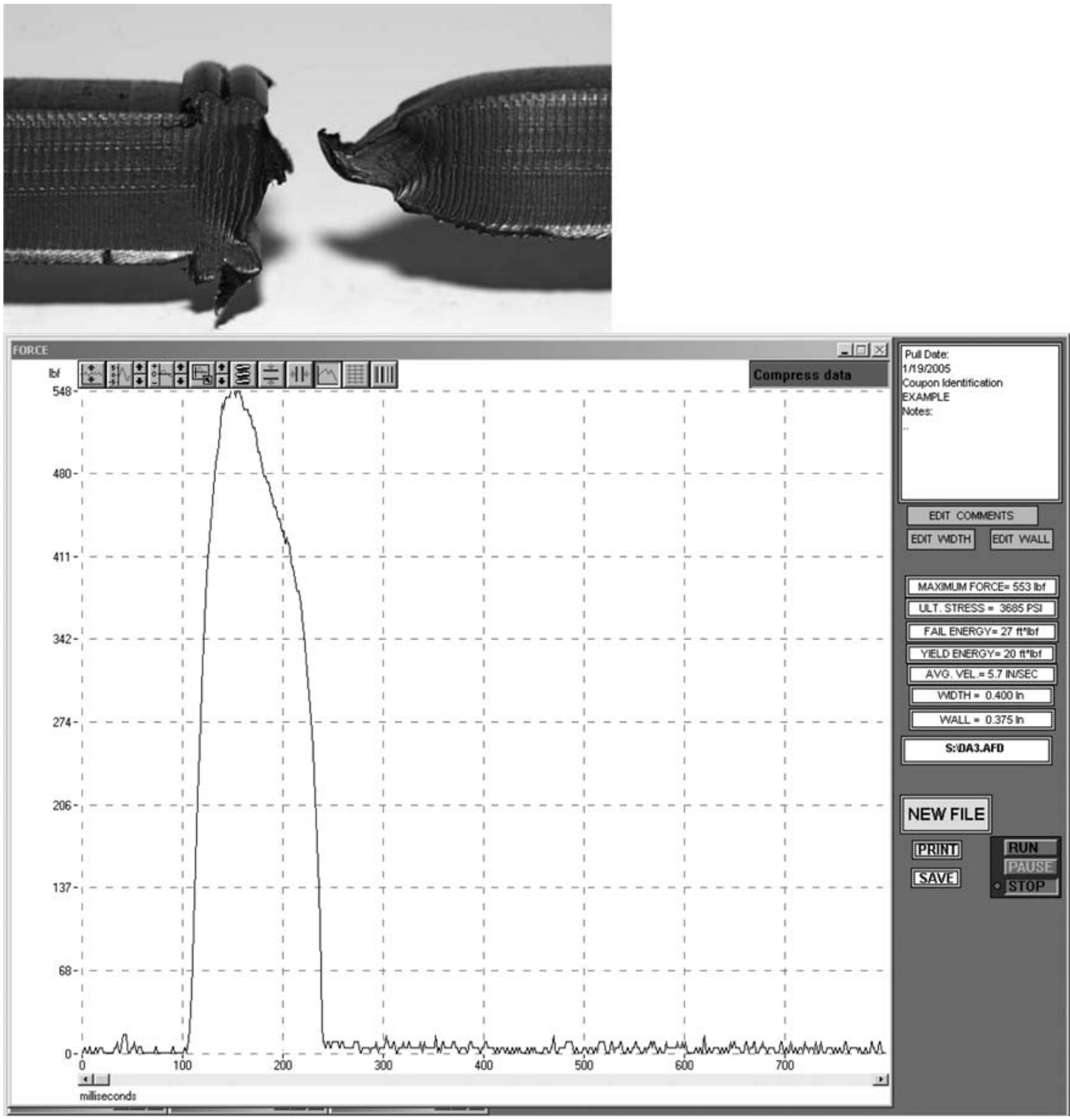
Any test that exceeds the yield point of the pipe and ruptures in a ductile mode is generally considered an acceptable joint.

FIG. X1.2 Ductile Rupture Outside of Joint Interface



This specimen shows insufficient ductility, as the yield point of the material is not exceeded, and the rupture mode is brittle.

FIG. X1.3 Brittle Rupture



Some graphs of ductile ruptures adjacent to fusion interface will show the substantial elongation found in ductile ruptures outside of fusion interface graphs.

FIG. X1.4 Ductile Rupture Adjacent to Joint Interface

SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (F2634–10) that may impact the use of this standard.

(1) Revised Section 13 to introduce a new precision and bias statement.

(2) Revision of Summary of Changes.