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Standard Guide for Evaluating Computerized Data Acquisition Systems Used to Acquire Data from Universal Testing Machines[1]

This standard is issued under the fixed designation E 1856; 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 guide is intended to assist the user in the evaluation and documentation of computerized data acquisition systems used to acquire data from quasi-static tests, performed on universal testing machines. The report produced will aid in the correct use and calibration of the computerized universal testing machine.

1.2 *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:*

E 4 Practices for Force Verification of Testing Machines[2]

E 8 Test Methods for Tension Testing of Metallic Materials[2]

E 74 Practice for Calibration of Force Measuring Instruments for Verifying the Force Indication of Testing Machines[2]

E 83 Practice for Verification and Classification of Extensometers Systems[2]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

E 1012 Practice for Verification of Specimen Alignment Under Tensile Loading[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *basic data*—basic data are the digital equivalents of analog counterparts, such as force and displacement measurements, which under static conditions are traceable to national standards (see Fig. 1).

3.1.2 *derived data*—derived data are additional numbers derived from the basic data through computation using software algorithms, such as a peak force or a modulus value.

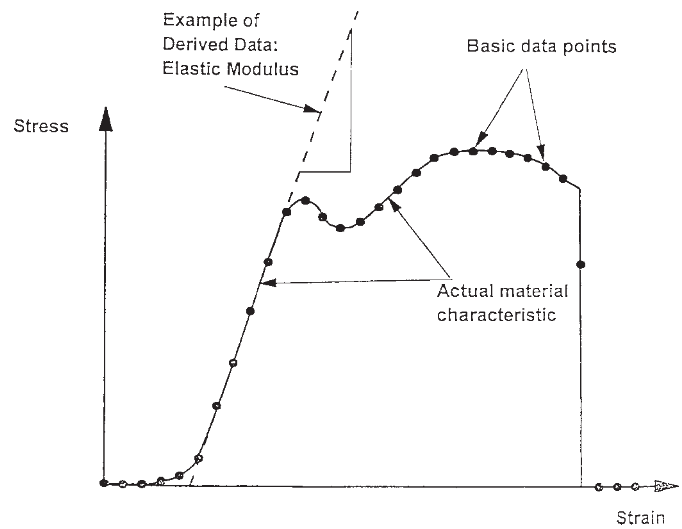

FIG. 1 Basic Data and Derived Data

3.1.3 *data acquisition rate*—data acquisition rate is defined as the rate at which digital samples of each wave-form (that is, force, strain, displacement, and so forth) are acquired, expressed in samples/second.

3.1.4 *resolution*—the resolution is the smallest change in force, strain, or displacement, or both, that can be displayed or obtained, or both, from the computerized testing system at any applied force, strain, or position, or both (for force resolution see Practice E 4).

3.1.5 *transducer-channel bandwidth*—the bandwidth of a transducer-measurement channel which is measuring a force, strain, or displacement in a testing machine is the frequency at which the amplitude response of the measurement system has fallen by 3 dB, that is, the measured signal is in error by about 30 % and the phase shift has become 45° or greater. The precise amplitude and phase responses vary with the electrical design of the system, but the 3 dB bandwidth (expressed in Hertz) is a simple single measure of responsiveness (see Fig. 2).

3.1.6 *computerized data acquisition system—for the purpose of this guide*, a computerized data acquisition system is a device which collects basic data from a universal testing machine during a test and calculates and presents derived data based on the basic data collected.

[1] This guide is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.15 on Automated Testing.

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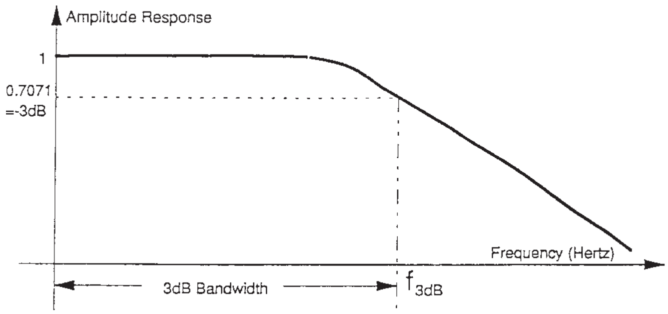
[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.



3dB BANDWIDTH OF A SENSOR CHANNEL

FIG. 2 Bandwidth

4. Summary of Guide

4.1 Comparative tests are performed to determine if the derived data acquired with a computerized universal testing machine agree with results acquired on the same machine from graphical records or with results acquired on other testing machines to ensure that the materials being tested are correctly characterized.

5. Significance and Use

5.1 This guide is recommended to be used by anyone acquiring data from a universal testing machine using a computerized data acquisition system.

6. Procedure

6.1 Choose at least five different test specimen types which are representative of the specimens commonly tested on the testing machine.

NOTE 1—If the testing machine is used to test less than five different specimen types, choose all those tested.

NOTE 2—Specimen types can be differentiated by material (strength level), size, shape, or test performed, or both.

6.2 Use one of the following procedures to evaluate and document the conformity of the computerized test results.

6.2.1 *Round Robin Procedure*:

6.2.1.1 Perform a round robin involving at least two other testing machines. The other testing machines need not necessarily be computerized.

NOTE 3—It is preferable to use testing machines of varying types so that systemic problems are not masked.

6.2.1.2 If possible, configure the testing machines in such a way as to be able to obtain a graphic record of the tests. The graphic record may be generated by analog signal sources, the computer system, or may be generated manually from digital data recorded by the data system.

6.2.1.3 Ascertain that all readout and recording devices have been calibrated in accordance with Practices E 4, E 83, or other applicable standards.

6.2.1.4 Test at least five specimens of each specimen type on each machine in conformance with the applicable test methods or established procedures.

NOTE 4—It may be desirable to test many more specimens after an initial screening, particularly if high standard deviations are observed on all machines.

6.2.1.5 Obtain the results from the computer system or graphic records of the tests from each machine, or both.

6.2.1.6 From the graphic records obtained, manually calculate the same test results obtained by the computer system.

6.2.1.7 Calculate the average and standard deviation of both the manually calculated results and the results obtained by the computer system(s) (derived data) within each group of five or more specimens.

6.2.1.8 Investigate, identify, and correct, if necessary, the cause of any average results obtained by the computer which differ from the manually obtained average results, or the average results obtained by other testing machines, by more than 2.0 % of the average or more than one standard deviation, whichever is greater.

NOTE 5—In all cases, use the smallest non-zero standard deviation for evaluations.

6.2.1.9 Investigate, identify, and correct, if necessary, the cause of any standard deviations of the results obtained by the computer which are more than two times the standard deviation obtained manually or by the other machines.

NOTE 6—Differences in averages and standard deviations of these magnitudes are quite often due to variations in the material being tested, and a complete statistical evaluation of the data using methods such as Practice E 691 may be necessary.

6.2.2 *Single Machine Procedure*:

6.2.2.1 This procedure may be used for testing machines with the capability of producing graphic records from which test results (derived data) can be manually calculated.

6.2.2.2 Configure the testing machine in such a way as to be able to obtain a graphic record of the tests. The graphic record may be generated by analog signal sources, the computer system, or may be generated manually from digital data recorded by the data system.

6.2.2.3 Ascertain that all readout and recording devices used (analog or digital, or both) have been calibrated in accordance with Practices E 4, E 83, or other applicable standards.

6.2.2.4 Ascertain that all transducers with their readout or recording devices, or both, including the devices producing the graphic record, have the required bandwidth for the tests performed with the machine (see Appendix X2).

6.2.2.5 Test at least five specimens of each specimen type in conformance with the applicable test methods or established procedures, obtaining both a graphic record and results from the computer system at the same time.

6.2.2.6 From the graphic record, determine the same test results as are calculated by the computer system.

6.2.2.7 Calculate the average and standard deviation of both the manually calculated results and the results obtained by the computer system (derived data) within each group of five specimens.

6.2.2.8 Investigate, identify, and correct, if necessary, the cause of any average results obtained by the computer which differ from the manually obtained average results by more than 2.0 % of the average or more than one standard deviation, whichever is greater.

NOTE 7—In all cases, use the smallest non-zero standard deviation for evaluations.

6.2.2.9 Investigate, identify, and correct, if necessary, the cause of any standard deviations of the results obtained by the computer which are more than two times the standard deviation of results obtained manually.

7. Test Result Evaluation

7.1 A bias in average results between machines or readouts may be due to one or more of the following:

7.1.1 *Calibration Differences*—A bias in all of the force results observed is usually indicative of a difference in calibration. If maximum forces disagree between the manual and computerized results, it may be due to differences in calibration between parts of the machine (see Appendix X1). If force results are in agreement and stress results vary, the difference may be due to cross-sectional area or other measurements such as span in a flexure test. If maximum force results agree and other force results differ, the difference is probably not due to differences in force calibration.

7.1.2 *Differences in the Speed of Testing*—Depending on the strain rate sensitivity of the material being tested, a difference in derived data may or may not be observed if there is a difference in the speed of testing. A simple way to check the speed of testing is to measure the elapsed time between two points during the tests.

7.1.3 *Incorrect Inputs to the Computer Algorithms*—If the results calculated by manual methods from the graphic record agree with the other machines but the results from the computer disagree, the difference may be due to incorrect inputs to the computer algorithms.

7.1.4 *Algorithms Used*—If the results calculated by manual methods from the graphic record agree with the other machines but the results from the computer disagree, the difference may be due to algorithms used by the computer system.

7.1.5 *Algorithms That Are Not Working Properly*—If the results calculated by manual methods from the graphic record agree with the other machines but the results from the computer disagree, the difference may be due to algorithms that are not working properly.

7.1.6 *Ambiguity in the Interpretation of the Test Method*—The writer(s) of the algorithms used, or the user, or both, may be interpreting the test method differently or incorrectly.

7.1.7 *Differences in Gripping and Other Apparatus in Contact with the Specimen*—Differences in gripping and other apparatus in contact with the specimen may cause premature failure of the specimen or act as a heat sink and cause differences in elongation related results.

7.1.8 *Alignment of the Test Piece*—Poor alignment can cause lower than normal test results or poorly formed stress-strain curves, or both, in the elastic region of the curve (see Practice E 1012).

7.1.9 Insufficient bandwidth in one or more of the transducer channels (see Appendix X2).

NOTE 8—Differences are just as likely to be due to problems with the manually calculated results as they are to problems with the computer generated results.

NOTE 9—For additional information, see the appendix on Factors Affecting Tension Test Results in Test Methods E 8.

7.2 A difference in the standard deviation between machines may be due to one or more of the following:

7.2.1 *Differences in Resolution*—Poor resolution can show up in two forms. A standard deviation of zero may indicate poor resolution. Alternatively, if two or more discrete numeric results (derived data) occur with a difference between them which is large relative to the result being measured, poor resolution may be the cause. Example: 206, 206, 210, 206, 210 (see Appendix X3).

7.2.2 *Specimen Dimension Precision*—If derived-data force standard deviations agree and derived-data stress standard deviations differ, the difference is probably due to imprecise measurements of cross sectional area.

7.2.3 *Differences in the Speed of Testing*—Testing at speeds that are too fast may give either high or low standard deviations due to one or more of the transducer-channel bandwidths (see Appendix X2).

7.2.4 *Unstable Control of Test Speed*— Unstable control of the testing machine speed may increase the standard deviation of derived data in strain-rate sensitive materials and cause poorly formed stress-strain curves and measurement errors in extreme cases.

7.2.5 *Electrical Noise Being Picked Up By One or More of the Transducer Channels*—Electrical noise can cause computer algorithms to perform poorly. This may be observed in the graphic record or in the basic data. This problem may be detected by capturing data at a fixed force or strain. The standard deviation of this data should be comparable to the resolution.

7.2.6 *Differences in Gripping and Other Apparatus in Contact with the Specimen*—Some devices in contact with the specimen may only cause an occasional premature failure. This will show up as a high standard deviation.

7.2.7 *Alignment of the Test Piece*—Poor alignment is often not repeatable and leads to high standard deviations (see Practice E 1012).

7.2.8 Insufficient band width in one or more of the transducer channels (see Appendix X2).

8. Report

8.1 For each testing machine evaluated, report the following information:

8.1.1 Name of reporting agency,

8.1.2 Date of report,

8.1.3 Complete testing machine description(s) including the serial number(s) of the machine(s), and all instrumentation, and the location(s),

8.1.4 Software version(s) identification,

8.1.5 Graphic data and manually calculated test results, if available,

8.1.5.1 Computer test report(s),

8.1.5.2 Averages and standard deviations for each test result,

8.1.5.3 Tabulation of the differences observed, and

8.1.6 Name(s) of reporting personnel.

8.2 This report need only be performed once and need not be repeated unless changes are made to the system which would significantly affect the report.

8.2.1 Changes which can significantly affect the results of this report include, but are not limited to:

8.2.1.1 Replacement of the indicating system with a different type of system,

8.2.1.2 Software changes or modifications, and

8.2.1.3 Changes to the computer(s) in the system which affect the processor's speed.

9. Precision and Bias

9.1 The precision and bias of this guide for evaluating computerized data acquisition systems on universal testing machines is dependent upon the derived data being determined. Refer to the test method for the derived data being determined such as Test Method E 8 for the precision and bias of the derived data.

10. Keywords

10.1 algorithm; bandwidth; basic data; computer; data acquisition; data acquisition rate; derived data; resolution; universal testing machine

APPENDIXES

(Nonmandatory Information)

X1. CALIBRATION CONSIDERATIONS

X1.1 It is important to understand the way(s) in which information is transmitted within the testing system, so that the system is properly calibrated and verified. Information is transmitted either digitally or in an analog fashion between components within a testing system.

X1.1.1 An example of a digital transmission of data within a testing system is the transmission of test results from a computer to a printer. In some cases, a testing machine will digitally transmit force and other data to a computer.

X1.1.2 An example of an analog transmission of data is the electrical signal developed by a force cell that is transmitted to amplifiers in the testing machine, where the signal is converted into engineering units. Another example is a testing machine which transmits a dc voltage proportional to the applied force to an analog X-Y recorder.

X1.2 An analog to digital converter (A/D) converts analog signals to digital signals, and a digital to analog converter (DAC) converts digital signals to analog signals. In modern testing machines, one or more of these devices are used. Calibration may be required at each point in a system where an A/D or a DAC is used in the transmission of data. The calibration may be on the analog, digital, or on both sides of the converter.

X1.3 In most cases, if devices receive digital signals from a calibrated digital device with no A/Ds or DACs in between (such as printers and monitors) the receiving devices will not require routine calibration and may be replaced without calibration.

X1.4 Determine from electrical schematics or obtain from the manufacturer a block diagram of the testing system which shows, as a minimum, all transducers used and all data output devices. Mark on the diagram all necessary calibration points. During routine verification of the testing machine, use this as a guide to ensure that the system has been verified at all of the necessary places.

X2. DETERMINING SYSTEM SPEED OF RESPONSE[4]

X2.1 Bandwidth[4] and data acquisition rate are two elements which can affect accuracy due to the response of the system to dynamically changing inputs. This procedure requires determination of the minimum bandwidth, and from this, determination of the minimum data acquisition rate.

X2.2 There are two bandwidth values that should be considered when the system response and the requirements for the test conditions are being defined. These are the required bandwidth, derived from the test conditions, and the transducer-channel bandwidth, which is a function of the testing machine.

X2.3 The transducer-channel bandwidth should equal or exceed the required bandwidth. To obtain high accuracy, it is important that the measured signal (excluding noise) has no frequency content approaching the transducer-channel bandwidth.

X2.4 *Required Bandwidth*—It is difficult to give an exact number for the minimum required bandwidth of a quasi-static testing machine, but it is important to ensure that the response being observed during a test is not limited by the bandwidth of the testing machine. On the other hand, an excessively high bandwidth can be detrimental to the system's performance as

[4] Nicolson, A. M., "Event Criteria to Determine Bandwidth and Data Rate in Tensile Testing," *Automation of Mechanical Testing, ASTM STP 1208*, D. T. Heberling, ed., ASTM, 1993, pp. 91–105.

accuracy may degrade and noise may increase. For testing under conditions similar to those found in Test Methods E 8, a bandwidth of at least 0.2 Hz is usually sufficient. To estimate the required bandwidth, a simple criterion may be derived as follows:

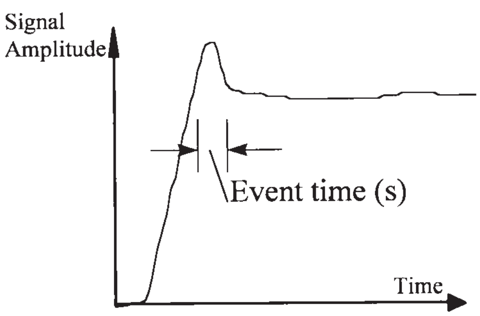
X2.4.1 Estimate the duration (in seconds) of an event in the response of the system over which an accurate (<1 % error) result is required. The result could be a peak value of force or the elastic portion of a stress-strain curve to obtain modulus (see Fig. X2.1).

X2.4.2 The required bandwidth in Hertz for relatively slow changing events is given by the following equation:

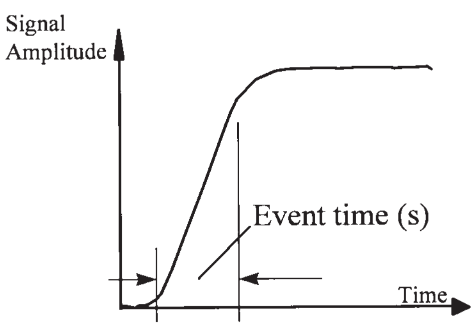
$$\text{Required Bandwidth} = \frac{3}{\text{Duration(s)}}\ \text{Hz} \quad \text{(X2.1)}$$

X2.4.3 *Spike-like* events occur when the force-time curve has a sharp point. The required bandwidth to accurately capture *spike-like* events that occur during a test demand a much higher bandwidth. It could be as high as:

$$\text{Required Bandwidth} = \frac{20}{\text{Duration(s)}}\ \text{Hz} \quad \text{(X2.2)}$$



Duration of an event over which a peak value has to be measured



Duration of an event over which a slope has to be measured

FIG. X2.1 Event Times

X2.5 *Transducer-Channel Bandwidth*—The transducer-channel-bandwidth value should be stated by the manufacturer of the testing machine. If there is further bandwidth reduction as a result of digital filtering of data, the manufacturer must include this in the specification of transducer-channel bandwidth.

X2.6 *Method of Estimation of Transducer-Channel Bandwidth*—It is possible to estimate the bandwidth of the force measuring system by a simple measurement of its step response. Connect a small-diameter, high-tensile-strength wire between the grips of the machine (a single strand guitar string is adequate for this purpose). Slowly apply an increasing force to the wire until it breaks, capturing the transient step-like wave-form for the decrease in force on a high speed digital or analog storage oscilloscope. Measure the difference in time (in seconds) between the 10 % and 90 % points on this step response using linear interpolation, if necessary, as shown in Fig. X2.2 to obtain $t_{10–90}$. If this time is less than the interval between two data points, then use the time between two data points as $t_{10–90}$. The approximate bandwidth of the system is:

$$\text{Transducer}-\text{Channel Bandwidth} = \frac{0.34}{t_{10–90}}\ \text{Hz} \quad \text{(X2.3)}$$

X2.6.1 If the manufacturer provides a sufficiently high data acquisition rate, then the overall system response may be measured directly from the digitally sampled step response.

X2.6.2 The above procedure also gives a simple qualitative method to verify that the bandwidth is adequate. Compare the response curve of the specimen with the curve produced by breaking a high-strength wire as above. If the rate of change of the curve is as fast as the rate observed when breaking a high-tensile wire, then that part of the response curve could be erroneous since the response being measured is a characteristic of the testing machine and not characteristic of the specimen.

X2.7 *Determining Required Data Acquisition Rate*—The minimum required data acquisition rate can be estimated from the required bandwidth. It can be shown that for less than 1 % error, a minimum data acquisition rate of about 31 times the required bandwidth (samples/s) is sufficient.

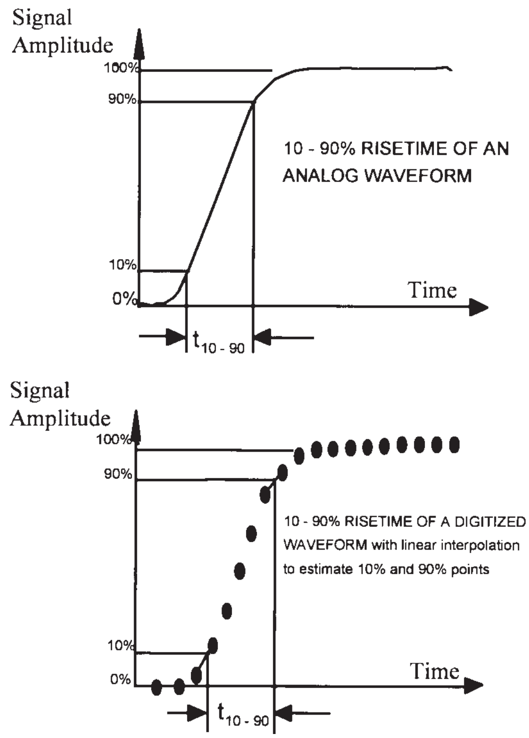


FIG. X2.2 Step Responses

X3. DETERMINING SYSTEM RESOLUTION

X3.1 The resolution of a digital testing system in general is a complex function of many variables including, but not limited to, applied force, force range, electrical and mechanical components, electrical and mechanical noise, and software employed.

X3.2 Determine from electrical schematics or obtain from the manufacturer of the testing system a statement on the resolution of the computer system.

X3.3 Test the system to ensure that the stated resolution is obtainable. A variety of methods may be used to check the resolution of the system. One method is as follows:

X3.4 Use a weight, proving ring, or force cell conforming to Practice E 74 to apply a force to the system while acquiring data. Do this several times, changing the force by approximately one-half of the designed resolution. Monitor the readout devices to observe the change in force. A similar procedure may be used with extensometer calibrators to test strain resolution and dial indicators to test displacement resolution, if applicable.

X3.5 Attach the test results to the statement of resolution.

X3.6 The system shall not be used to report derived data where the resolution is poorer than one part in 200. However, basic data with resolution poorer than one part in 200 may be used to find a derived-data point. As an example, the lower portion of a stress-strain curve may be used to numerically construct the linear portion of the curve for the calculation of an offset stress. The data used for the construction of the line may have a resolution poorer than one part in 200 but the offset stress reported must be in a region where the resolution is better than one part in 200.