Designation: E2658 – 15

Standard Practices for
Verification of Speed for Material Testing Machines[1]

This standard is issued under the fixed designation E2658; 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 These practices cover procedures and requirements for the calibration and verification of testing machine speed by means of standard calibration devices. This practice is not intended to be complete purchase specifications for testing machines.

1.2 These practices apply to the verification of the speed application and measuring systems associated with the testing machine, such as a scale, dial, marked or unmarked recorder chart, digital display, setting, etc. *In all cases the buyer/owner/user must designate the speed-measuring system(s) to be verified.*

1.3 These practices give guidance, recommendations, and examples, specific to electro-mechanical testing machines. The practice may also be used to verify actuator speed for hydraulic testing machines.

1.4 This standard cannot be used to verify cycle counting or frequency related to cyclic fatigue testing applications.

1.5 Since conversion factors are not required in this practice, either SI units (mm/min), or English [in/min], can be used as the standard.

1.6 Speed measurement values and or settings on displays/printouts of testing machine data systems-be they instantaneous, delayed, stored, or retransmitted-which are within the Classification criteria listed in Table 1, comply with Practices E2658.

1.7 *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.*

[1] These practices are under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.01 on Calibration of Mechanical Testing Machines and Apparatus.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2309 Practices for Verification of Displacement Measuring Systems and Devices Used in Material Testing Machines

3. Terminology

3.1 *Definitions:*

3.1.1 *percent error, n*—in the case of a speed measuring system, the ratio, expressed as a percent, of the error to the reference value of the applied speed.

3.1.1.1 *Discussion*—The speed, as measured by the testing machine, and the speed, as computed from the readings of the calibration devices, shall be recorded at each verified speed. The percent error, shall be calculated from this data as follows:

$$Percent\ Error = \left[\left(TMsp - Refsp \right) / Refsp \right] \times 100 \quad (1)$$

where:

TMsp = speed measured by the machine being verified, mm/min [in/min], and
Refsp = reference value of the measured speed, mm/min [in/min], as determined by the calibration device.

Not all testing machines have available indicated speed values. In such cases, the verification of the testing machine's speed setting is applicable. The percent error for the testing machine speed settings, shall be calculated as follows:

$$Percent\ Error = \left[\left(TMsps - Refsp \right) / Refsp \right] \times 100 \quad (2)$$

where:

TMsps = testing machine speed setting, mm/min (in/min), and
Refsp = reference value of the measured speed, mm/min (in/min), as determined by the calibration device.

3.1.2 *ramp-to-speed condition, n*—during a speed verification run, it is the time and or change in displacement required to achieve a constant speed condition.

[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.

3.1.3 *reference standards, n*—devices used to verify either the speed of a testing machine or the speed indicated by a testing machine.

3.1.4 *speed measuring system, n*—a device or set of devices comprising of a speed transducer and associated instrumentation or a displacement transducer with associated timer and instrumentation.

3.1.5 *tolerance, n*—the allowable deviation from a reference value.

3.1.6 *speed, n*—displacement divided by time expressed in terms of millimeters/minute, inches/minute, etc.

3.1.7 *verification speed, n*—a speed with traceability derived from national standards of length and time, with a specific uncertainty of measurement, which can be applied to speed measuring systems.

TABLE 1 Classification of Speed Application Measuring Systems

Classification	Resolution % of Reading[A]	Percent Error [B]
Class A	±0.25	±0.5
Class B	±0.5	±1.0
Class C	±1.0	±2.0
Class D	±2.5	±5.0
Class E	±5.0	±10
Class F	±10	±20

[A]Resolution is not criteria for classification when speed application only, is verified.
[B]Percent Error of application or indication of speed.

4. Significance and Use

4.1 Material testing requires repeatable and predictable testing machine speed. The speed measuring devices integral to the testing machines may be used for measurement of crosshead speed over a defined range of operation. The accuracy of the speed value shall be traceable to a National or International Standards Laboratory. Practices E2658 provides procedures to verify testing machines, in order that the indicated speed values may be traceable. A key element to having traceability is that the devices used in the verification produce known speed characteristics, and have been calibrated in accordance with adequate calibration standards.

4.2 Verification of testing machine speed at a minimum consists of either or both of the following options:

4.2.1 Verifying the capability of the testing machine to move the crosshead at the speed selected.

4.2.2 Verifying the capability of the testing machine to adequately indicate the speed of the crosshead.

4.3 Where applicable, determine the testing machine's ramp-to-speed condition. This condition can be significant especially when verifying fast speeds or testing conditions with very short testing durations.

4.4 This procedure will establish the relationship between the actual crosshead speed and the testing machine indicated speed and or selected setting. It is this relationship that will allow confidence in the reported displacement over time data acquired by the testing machine during use.

NOTE 1—Many material tests never reach the desired test speed. Unless the actual data from the material test is examined, it is often impossible to know if the test speed has been reached or is repeatable from test to test.

5. Calibration Devices

5.1 Reference standards used for verification of speed measuring systems shall have estimated measurement uncertainties. The measurement uncertainty of verification results, contain the combination of the uncertainty of the displacement calibration device and time indicating device. The combined estimate of uncertainty for the reference standards shall be equal to or less than ⅓ the allowable error for the measuring system. The estimated measurement uncertainty of the reference standards should have a confidence level of 95% (k=2).

5.2 It is recommended that the testing machine have its displacement measuring systems verified in compliance with Practices E2309 prior to performing this verification. Often the same displacement calibration devices can be used to perform Practices E2309 and this practice. It may be possible to attach the Displacement Calibration Device one time and perform both verification practices.

5.3 *Displacement Calibration Devices:*

5.3.1 *Digital Linear Scales and Displacement Measuring Transducers*—These devices typically have sufficient resolution and accuracy to perform verification of all speed settings. It is important to assess the minimum measurement capability of the device. At very slow speeds it may take considerable time to reach an end displacement value that is adequate for the use of the device.

5.3.1.1 These devices may also have the capability to be automated.

5.4 *Time Indicating Devices*—

5.4.1 Time pieces such as quartz wrist and stop watches can be used for slower speed settings. The time piece shall have a calibration traceable to a national metrology institute. For most purposes, a time piece with an accuracy of ±0.02% (approximately 2 second in 3 hours) is sufficient. The uncertainty of the calibration of the time piece shall be at most ⅓ the accuracy of the time piece and shall not significantly contribute to the uncertainty of the speed measurement. See NIST Special Publication 960-12.[3] With automated computer software, accuracies of ±0.01 seconds may be achieved. However, care must be taken in designing such systems to avoid errors due to things such as timer resolution, programming language limitations, competing interrupts and processes, etc. Third party software is available to track and adjust the computer clock referenced to NIST.

6. System Verification

6.1 Speed measuring systems shall be verified as a system with the speed sensing and measuring devices in place and operating as in actual use.

6.2 System verification is invalid if the speed sensing devices are removed and checked independently of the testing machine.

[3] Gust, J.C., Graham, R.M., Lombardi, M.A. Special Publication 960-12 Stopwatch and Timer Calibrations National Institute of Standards and Technology 2004

6.3 The verification shall consist of at least two verification runs of speed derived data per selected testing machine speed setting.

6.3.1 If the initial verification run produces any percent error values outside applicable specifications, the "as found" data may be reported and may be used in accordance with applicable quality control programs.

6.3.2 Adjustments may be made to improve the accuracy of the system. They shall be followed by one additional verification run, and issuance of a new verification report. Typically, making adjustments to improve testing machine speed will influence all speed settings. If an adjustment is made, all tested speeds must be re-verified unless it can be demonstrated that the adjustment did not affect other speed settings.

6.3.3 Quality control programs may require evidence of repeatability, reproducibility and reversibility. In such cases it is recommended that a minimum of one speed be verified for repeatability, reproducibility, and reversibility.

6.4 The testing machine is verified with the crosshead configured to free run with no specimen installed.

NOTE 2—Testing machine compliance under loading conditions may introduce small errors in the displacement measurement data during actual materials testing. This error is considered insignificant relative to this verification. There are also testing machines where the crosshead speed slows when force is applied. In such cases where it is necessary to verify speed of the testing machine under loaded conditions, higher accuracy displacement calibration devices such as laser interferometer measuring systems, or extensometer type displacement reference standards must be used due to the very small displacements being verified.

7. Methods of Verification

7.1 *Start and Stop Method:*

7.1.1 This method requires that a set of starting and stopping displacement and time readings be recorded from the displacement and time calibration devices.

7.1.2 In order to obtain data within expected tolerances an assessment of the ramp-to-speed condition may be necessary so the test run can be started after the crosshead has reached a constant speed condition.

7.1.3 It is best to have testing machine software that can easily acquire and report displacement and time data during the verification run for each selected speed.

7.1.4 The comparison of the reference start and stop values and the data reported by the testing system provides the basis for verification of speed using this method.

7.2 *Continuous Acquisition Method:*

7.2.1 This is the preferred method of verifying testing machine speed.

7.2.2 This method requires automated computer software to acquire data from the displacement calibration device.

7.2.3 This method can be used to adequately assess the ramp-to-speed condition for each speed setting verified.

7.2.4 This method can show variability in the testing machine speed throughout the verification run.

8. Selection of Verification Speed Values

8.1 Many testing machines have a selection of preset crosshead speeds, typically ranging from .025mm/min to 10,000mm/minute (.001in/min to 400 in/minute). It is difficult and very time consuming to verify every selectable setting available with testing machines. Additionally, it is often impossible to adequately verify the fastest speed selections because displacement calibration devices are typically not long enough to accommodate the displacement necessary. For these reasons, at a minimum, speeds most commonly used should be selected for verification. A minimum of two runs of verification data for each speed is required.

8.1.1 In some cases a testing machine might only be used at one speed with one clutch selected. In such a case only one speed with two runs of data are all that is required to meet this standard.

8.2 Many testing machines have multiple clutch selections. If the testing machine is used with multiple clutch settings, speeds for each clutch setting shall be verified even if the selected speed is the same as a selected speed verified with a different clutch setting.

8.3 In selecting speeds to be verified, consideration of the total displacement and time must be considered. The total displacement must be great enough to allow for the displacement calibration device's measurement uncertainty. If the calibration devices are automated, time is not as critical to the overall measurement uncertainty. But, if a manual Start and Stop method is employed, the duration of the verification run must be long enough to minimize error due to human action. The manual Start and Stop method also requires that the total displacement and duration of the verification run be long enough to start beyond the ramp to speed condition. See Appendix X1.

8.4 It is not normal to experience a difference in the speed indication of the testing machine when the crosshead moves in the opposite direction. However, gravity may contribute to a difference in the ramp to speed condition when the crosshead is operated in the descending mode. The testing machine should be verified in the mode of operation normally used during testing.

9. Preliminary Procedure

9.1 *Alignment:*

9.1.1 When attaching the displacement calibration device, it is important to minimize any misalignment. Significant errors can be induced due to misalignment. Gauge blocks or a square may be used to ensure that the displacement calibration device operates perpendicular to the crosshead in electro-mechanical testing machines, or in-line or parallel, to the actuator in hydraulic testing machines.

9.2 *Temperature Considerations:*

9.2.1 Turn on power and allow the components to warm up for a period of time recommended by the manufacturer. In the absence of any recommendations, allow at least 15 minutes for the components to stabilize.

9.2.2 Position a temperature measuring device in close proximity to the machine being verified. Allow the speed measuring device and all relevant parts of the verification equipment to reach thermal stability.

9.2.3 Include any bias due to temperature effects in the expanded uncertainty statement associated with the verification speed values if required.

10. Procedure

10.1 *General:*

10.1.1 After completing the preliminary procedure given in Section 9 and before commencing with the verification procedure, adjust the testing machine to the maximum displacement to ensure that displacement can be achieved, and the machine has adequate space for the calibration device.

10.1.2 During the verification, measure the ambient temperature by placing a calibrated temperature measuring device as close to the calibration device as possible. The calibrated temperature measuring device should have an accuracy of ±1°C or better.

10.1.3 Place the displacement calibration device in the testing machine so that its center line coincides as closely as feasible with the center line of the testing machine's application of force. Ensure that there is sufficient clearance to avoid accidental damage to the displacement calibration device throughout the crosshead movement.

10.1.4 There are two methods for using speed calibration devices:

10.2 *Stop and Start Method*—Select the speed to be verified.

10.2.1 Determine the displacement at which the verification run will start. For example: Due to the ramp to speed condition, you may have determined or estimated that the crosshead must move 10 mm before it reaches a relatively constant speed. Therefore you should select to start the verification run at any displacement value greater than 10 mm.

10.2.2 Configure the testing machine software to start acquiring displacement and time data at the start of the crosshead movement.

10.2.3 3 Start the crosshead moving and carefully watch the displacement calibration device readout. At the point in time when the displacement calibration device readout reaches the Start displacement, start the Time calibration device. Let the crosshead travel for a sufficient distance. See Table X1.1, and Appendix X1 for recommended total displacement and duration values.

10.2.4 Once the crosshead has reached the predetermined Stop displacement as indicated by the displacement calibration device, stop the time calibration device, then stop the crosshead from moving.

10.2.5 Calculate the Crosshead speed :

$$Refsp = (Rd2 - Rd1)/(Rt2 - Rt1) \quad (3)$$

Where:

Rd1 = Reference displacement calibration device start value.
Rd2 = Reference displacement calibration device stop value.
Rt1 = Reference time start value
Rt2 = Reference time stop value

10.2.6 Obtain the testing machine data acquired during the verification run. Examine the data and select a Start set of data and a Stop set of data as close to the Reference values as possible. Calculate the indicated Crosshead speed:

$$TMsp = (Md2 - Md1)/(Mt2 - Mt1) \quad (4)$$

Where:

Md1 = Testing machine indicated displacement start value.
Md2 = Testing machine indicated displacement stop value.
Mt1 = Testing machine time start value
Mt2 = Testing machine time stop value

10.2.7 Compute the Indicated Speed Error in %.

$$Percent\ Error = [(TMsp - Refsp)/Refsp] \times 100 \quad (5)$$

10.2.8 For systems that do not have indicated speed data available, calculate the Speed Error relative to the testing machine setting.

$$Percent\ Error = [(TMsps - Refsp)/Refsp] \times 100 \quad (6)$$

where:

TMsps = Testing machine speed setting.

10.2.9 Repeat the verification run to acquire the second run for Repeatability and report the Percent Error values on the verification report for all selected speed verification settings. It is recommended that the start time and displacement values be retained for each selected speed in order to reproduce the verification in the future if necessary.

10.2.10 Repeat steps 10.2.1 through 10.2.9 for each selected speed to be verified.

10.2.11 It is possible to automate the Stop and Start method if a data connection is made between the displacement calibration device and a computer and adequate software is developed. If the method is automated, faster speeds can be verified. See Appendix X1.

10.3 *Continuous Acquisition Method*—Select the speed to be verified.

10.3.1 Determine the start displacement from which the verification run will start. For example: Due to the ramp to speed condition, the crosshead may have to move 10 mm before it reaches a relatively constant speed. Therefore, for this example, the verification run should be started at any displacement value greater than 10 mm. Automated software may provide for a selectable trigger value for the Start of the verification run.

10.3.2 Configure the testing machine software to start acquiring displacement and time data at the start of the crosshead movement.

10.3.3 If the reference device's automation program does not provide for a trigger value, start the crosshead moving and carefully watch the displacement calibration device readout. At the point in time when the displacement calibration device readout reaches the Start displacement, start the software acquisition. Let the crosshead travel for a sufficient distance. See Table X1.1, and Appendix X1 for recommended total displacement and duration values.

10.3.4 The automation software should be designed to automatically stop acquiring displacement and time data from the calibration devices when a predetermined displacement value is reached. If not, once the crosshead has reached the predetermined end displacement, as indicated by the displacement calibration device, stop the automated acquisition software, and stop the crosshead from moving.

10.3.5 The resulting complete data sets from the Reference software program and the testing machine software may be extracted and graphed for comparison throughout the entire verification run.

10.3.6 The automated reference software may be designed to report the calculated speed at each acquisition sample and or the average speed during the verification run. Great care must be taken when evaluating calculated speed over single sample or very short time durations as the resolution and accuracy of the displacement measuring devices and time functions, may cause erroneous values. If a testing system has a real time speed indicator, correlation between the indicator and acquired speed data may be assessed. As a minimum, select a corresponding set of data for calculation of the percent error as described in 10.2.5 – 10.2.8.

10.3.7 Repeat the verification run to acquire the second run for Repeatability and report the Percent Error values on the verification report for all selected speed verification settings. It is recommended that the start time and displacement values be retained for each selected speed in order to reproduce the verification in the future if necessary.

10.3.8 Repeat steps 10.3.1 – 10.3.7 for each selected speed to be verified.

11. Basis of Verification

11.1 The percent error for the speed indication or setting shall not exceed the required classification criteria listed in Table 1. It should be noted that the errors for the verification of speed indication versus the errors for verification of speed setting will not necessarily result in the same classification. The algebraic difference between errors of two applications of the same speed (repeatability) shall not exceed the required classification criteria listed in Table 1.

11.2 The testing machines may be more or less accurate than the allowable classification criteria listed in Table 1, which is the Practices E2658 verification basis. Buyers/owners/users or product specification groups might require or allow larger or smaller errors for systems. Systems with accuracy and repeatability errors greater than the allowable criteria for Class F as listed in Table 1 do not comply with Practices E2658.

12. Time Interval Between Verifications

12.1 Verification intervals should be discussed and agreed upon with the client/customer. It is recommended that speed measuring systems be verified annually. In no case shall the time interval between verifications exceed 18 months (except for machines in which a long-time test runs beyond the 18-month period). In such cases, the machine shall be verified after completion of the test.

12.2 Speed measuring systems shall be verified immediately after repairs (this includes new or replacement parts, or mechanical or electrical adjustments) that may in any way affect the operation of the speed measuring systems, or the values displayed.

12.2.1 Examples of new or replacement parts, that do not affect the proper operation of a speed measuring systems are: printers, computer monitors, keyboards, and modems.

12.3 Verification is required whenever there is a reason to doubt the accuracy of the speed measuring system, regardless of the time interval since the last verification.

13. Report

13.1 Prepare a clear and complete report of each verification of a speed measuring system including the following:

13.1.1 Name of the calibrating agency or individual,

13.1.2 Date of verification,

13.1.3 Testing machine description, serial number, and location,

13.1.4 Serial number and manufacturer of the speed measuring system being verified if different from the testing machine,

13.1.5 Serial, asset, or control number for all devices used for verification,

13.1.6 Temperature during the verification,

13.1.7 The speed measuring system percent error and algebraic error difference (repeatability) for each speed value,

13.1.8 Class of the speed indication and or setting,

13.1.9 The uncertainty of the verified speed values, if required,

13.1.10 Statement that verification has been performed in accordance with Practices E2658. It is recommended that verification be performed in accordance with the latest published issue of Practices E2658, and

13.1.11 Names of verification personnel.

14. Keywords

14.1 accuracy; classification; crosshead speed; ramp-to-speed condition; speed measuring system

APPENDIXES

(Nonmandatory Information)

X1. SELECTING VERIFICATION SPEED AND DURATION

TABLE X1.1 Speed Verification-Length Gage Measurement Uncertainty Analysis (Metric)

Speed Setting mm/Min	Displacement (mm)	Duration (Sec)	Displacement Error mm	Time Error Seconds	Displacement Error%	Time Error %	Uncertainty 95% CL	TUR[A]
2500	250	6	0.0501	0.01	0.02004	0.100	0.204	4.9
1000	250	15	0.0501	0.01	0.02004	0.067	0.135	7.4
500	250	30	0.0501	0.01	0.02004	0.022	0.070	14.3
200	200	60	0.0401	0.01	0.02005	0.017	0.039	25.6
100	100	60	0.0201	0.01	0.0201	0.017	0.039	25.6
50	50	60	0.0101	0.01	0.0202	0.017	0.039	25.6
20	20	60	0.0041	0.01	0.0205	0.017	0.039	25.6
10	20	120	0.0041	0.01	0.0205	0.008	0.026	38.5
5	10	120	0.0021	0.01	0.021	0.008	0.027	37.0
2	8	240	0.0017	0.01	0.02125	0.004	0.023	43.5
1	4	240	0.0009	0.01	0.0225	0.004	0.024	41.7
0.5	2.5	300	0.0006	0.01	0.024	0.003	0.025	40.0
0.2	2	600	0.0005	0.01	0.025	0.002	0.025	40.0
0.1	2	1200	0.0005	0.01	0.025	0.001	0.025	40.0
0.05	2	2400	0.0005	0.01	0.025	0.000	0.025	40.0

[A]Test Uncertainty Ratio Based on a ±1.0% Class B, Classification. This table is not intended to be used as an indication of the total expanded uncertainty of the verification

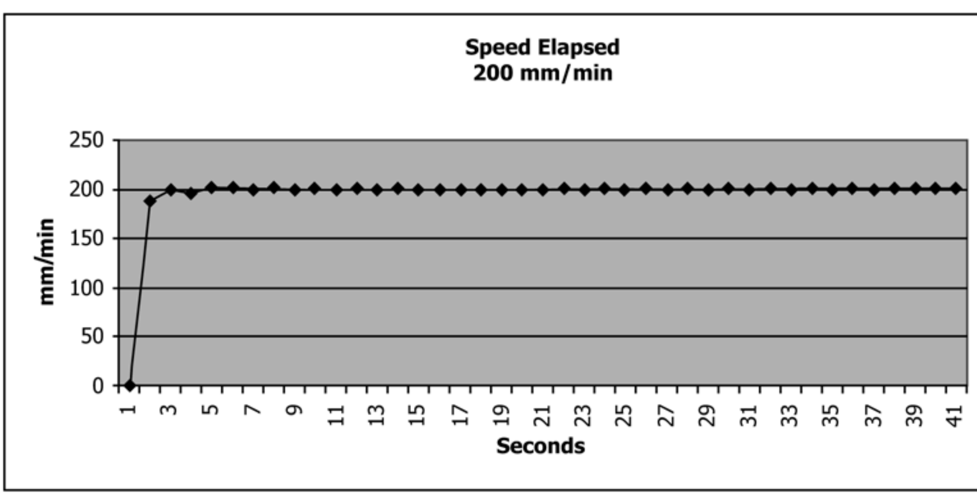

FIG. X1.1 Example of a Ramp to Constant Speed Chart, Derived form Testing Machine Data

Testing Machine Speed Verification Report

Name: **XYZ Corporation**
Calibration Agency: **XYZ Cal Lab**

System ID:
System:
Location:

Equipment

Device Type: XYZ Testing Machine Model: X: XYZ Type Serial No: 1234

Procedure

Verification has been performed in accordance with: ASTM E2658

Calibration Equipment Serial No.

Length Standard: SN 1000
Temperature Probe: SN 1001
Time reference traceability is maintained through the use of laptop clock sync software Traceable to NIST.

Conditions

Ambient Temperature: 25C Ascending: [X] Descending: [ ]

In Tolerance: [X] Out of Tolerance: [ ]

As Found: [X]
As Adjusted: [ ]

Report Units: mm/minute

Classification Indication: [A] Tolerance ± 0.5%
Classification Setting: [B] Tolerance: ± 1.0%

Verification of Machine Indication Speed

	Speed Setting mm/min	Run 1 Actual Speed	Run 1 Indicated	Run 2 Actual Speed	Run 2 Indicated	Run 1 % Error	Run 2 % Error	Repeatability % Error
Clutch 1:	1	1.005	1.002	1.006	1.004	–0.299	–0.199	0.100
	5	4.995	5.001	4.998	5.005	0.120	0.140	0.020
	20	20.115	20.108	20.105	20.095	–0.035	–0.050	0.015
Clutch 2:	1	0.994	0.998	1.001	1.005	0.402	0.400	0.002
	5	4.997	4.984	5.002	4.998	–0.260	–0.080	0.180
	20	19.987	19.951	19.998	20.002	–0.180	0.020	0.200

Verification of Machine Setting

	Speed Setting mm/min	Run 1 Actual Speed	Run 2 Actual Speed	Run 1 % Error	Run 2 % Error	Repeatability % Error
Clutch 1:	1	1.005	1.006	0.498	0.596	0.098
	5	4.995	4.998	–0.100	–0.040	0.060
	20	20.115	20.105	0.572	0.522	0.050
Clutch 2:	1	0.994	1.001	–0.604	0.100	0.704
	5	4.997	5.002	–0.060	0.040	0.100
	20	19.987	19.998	–0.065	–0.010	0.055

Verification are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology

Performed By: Joe Calibration Date: day-month-year

FIG. X1.2 Sample Verification Report of Speed Indication and Setting

Testing Machine Speed Verification Report

Page 1 of 1

Name: **XYZ Corporation**
Calibration Agency: **XYZ Cal Lab**

System ID:
System:
Location:

Equipment

Device Type: XYZ Testing Machine Model: X: XYZ Type Serial No: 1234

Procedure

Verification has been performed in accordance with: ASTM E2658

Calibration Equipment Serial No.

Length Standard: SN 1000
Temperature Probe: SN 1001
Time reference traceability is maintained through the use of laptop clock sync software Traceable to NIST.

Conditions

Ambient Temperature: 25C Ascending: [X] Descending: [ ]

In Tolerance: [X] Out of Tolerance: [ ]

As Found: [X]
As Adjusted: [ ]

Report Units: mm/minute

Classification Indication: [ ] Tolerance ± 0.5%
Classification Setting: [B] Tolerance: ± 1.0%

Verification of Machine Setting

	Speed Setting mm/min	Run 1 Actual Speed	Run 2 Actual Speed	Run 1 % Error	Run 2 % Error	Repeatability % Error
	1	1.005	1.006	0.498	0.596	0.098
Clutch 1:	5	4.995	4.998	–0.100	–0.040	0.060
	20	20.115	20.105	0.572	0.522	0.050
	1	0.994	1.001	–0.604	0.100	0.704
Clutch 2:	5	4.997	5.002	–0.060	0.040	0.100
	20	19.987	19.998	–0.065	–0.010	0.055

Verifications are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology

Performed By: Joe Calibration Date: day-month-year

FIG. X1.3 Sample Verification Report of Speed Setting

X2. IDENTIFYING AND DETERMINING MEASUREMENT UNCERTAINTY COMPONENTS DURING AN ASTM E2658 VERIFICATION

X2.1 The measurement uncertainty determined using this appendix is the measurement uncertainty of the errors reported during verification of speed of a testing machine. It is not the measurement uncertainty of the testing machine speed or the measurement uncertainty of test results determined using the testing machine.

X2.2 Under normal conditions, the measurement uncertainty of the reported errors of the speed of a testing machine determined during a verification using Practices E2658 is a combination of three major components: the measurement uncertainty of the calibration laboratory performing the verification, the uncertainty due to the non-repeatability of the testing machine during calibration, and possibly the uncertainty component of the resolution of the speed indicator of the testing machine at the start displacement for the speed to be verified and at the stop displacement of the speed to be verified. Some testing machines do not have a speed indicator. Resolution may be determined from the time and displacement data from the testing machine during verification, if available.

X2.2.1 The measurement uncertainty of the calibration laboratory performing the verification is a combination of factors such as, but not limited to:

X2.2.1.1 The measurement uncertainty of the laboratory's speed standards,

X2.2.1.2 Environmental effects such as temperature variations,

TABLE X2.1 Verification Data

Machine Speed 1 (mm/min)	Verification Apparatus Speed 1 (mm/min)	% Error 1	Machine Speed 2 (mm/min)	Verification Apparatus Speed 2 (mm/min)	% Error 2	% Repeatability
0.1005	0.1004	0.100%	0.1006	0.1007	-0.099%	0.199%
0.4995	0.5001	-0.120%	0.4998	0.5005	-0.140%	0.020%
0.994	0.998	-0.402%	1.001	1.004	-0.300%	0.102%
4.998	4.997	0.020%	5.002	4.998	0.080%	0.060%
19.997	19.995	0.010%	19.998	20.002	-0.020%	0.030%

X2.2.1.3 Uncertainty in the value used for time,

X2.2.1.4 Drift in the speed standard,

X2.2.1.5 Measurement uncertainty of the verification of the speed standard, and

X2.2.1.6 Repeatability and reproducibility of the speed standard in actual use.

NOTE X2.1—A laboratory's measurement uncertainty should be based on the maximum uncertainty of the speed standards used and the worst environmental conditions allowed. It may be advantageous to evaluate the measurement uncertainty of the actual speed standard used at the actual speed for which the measurement uncertainty of the error of the testing machine speeds being determined.

NOTE X2.2—If there are circumstances in which verification is performed under conditions outside of the laboratory's normal operating parameters, additional components may need to be considered. For example, a laboratory may permit a 5°C temperature variation to occur during verification and has factored this into their measurement uncertainty. When greater temperature variations occur, the uncertainty due to this increased temperature variation should be included in the determination of measurement uncertainty.

NOTE X2.3—A calibration laboratory's measurement uncertainty is usually expressed as an expanded uncertainty using a coverage factor of two. If this is the case, prior to combining it with the other uncertainty components, divide it by two.

X2.2.2 A way of assessing the uncertainty due to repeatability during the verification process is to evaluate the differences between the two runs of data (the repeatability).

X2.2.2.1 For each displacement verification point, find the sum of the squares of the differences in error between the first run and the second run of that verification point and the four verification points closest to that verification point. Divide that sum by ten and take the square root of the result to obtain an estimate of the uncertainty due to repeatability during the verification process.

NOTE X2.4—The sum is divided by ten because there are five pairs of readings used, and the variance of each pair is equal to the difference divided by two.

X2.2.2.2 Usually this type of assessment of uncertainty due to repeatability will include the uncertainty due to the resolution of the testing machine speed; however, it is possible to repeat runs without seeing the effects of the resolution. At each speed, test to see that the uncertainty due to repeatability is greater than the uncertainty due to the resolution of the testing machine speed. If, at a given verification speed, the uncertainty due to repeatability is not greater than or nominally equal to the uncertainty due to the resolution of the testing machine speed, for that verification speed, include the components of uncertainty due to the resolution of the testing machine speed at the start displacement and at the stop displacement.

X2.2.2.3 The uncertainty due to the resolution of the testing machine speed at each verification speed is the square root of the sum-of-the-squares of the following two components.

(1) The uncertainty component due to the *resolution of the speed indicator* of the testing machine speed at the Stop displacement can be determined by dividing the *resolution of the speed indicator* at the Stop displacement by the quantity of two times the square root of three.

(2) The uncertainty component due to the *resolution of the speed indicator* of the testing machine speed at the Start displacement can be determined by dividing the *resolution of the speed indicator* at the Start displacement by the quantity of two times the square root of three.

X2.3 The two major components (or three if necessary) can be combined by squaring each component, adding them together, and then taking the square root of the sum to determine the combined measurement uncertainty of the error determined for the testing machine speed.

X2.4 The expanded measurement uncertainty may then be determined by multiplying the combined uncertainty by two, for a confidence level of approximately 95%.

NOTE X2.5— Example: The measurement uncertainty of the reported error of a testing machine speed is to be determined at 1 mm/min. The calibration laboratory's measurement uncertainty expanded using a factor of 2 is 0.024% of applied speed. The testing machine's speed measuring system or device's resolution at the Stop displacement is 0.001 mm/min. The testing machine's speed measuring system or device's resolution at the Start displacement is 0.001 mm/min.

X2.4.1 The following are the calculations of measurement uncertainty for the 1 mm/min data point and two calibration runs:

X2.4.1.1 The uncertainty component due to the calibration laboratory's measurement uncertainty, u_{CL} is:

$$u_{CL} = \frac{0.00024 \times 1}{2} = 0.00012 \text{mm/min} \quad \text{(X2.1)}$$

X2.4.2 The uncertainty component due to repeatability at 1.0 mm/min, u_r is calculated as follows:

X2.4.2.1 The repeatability at 1 mm/min and the four closest speeds to 1 mm/min are 0.199% of 0.1 mm/min, 0.020% of 0.5 mm/min, 0.102% of 1 mm/min, 0.060% of 5 mm/min, and 0.030% of 20 mm/min which respectively are 0.0002, 0.0001, 0.001, 0.003, and 0.006 mm/min. Therefore:

$$u_r = \sqrt{\frac{0.0002^2 + 0.0001^2 + 0.001^2 + 0.003^2 + 0.006^2}{10}} = 0.002 \text{mm/min} \quad \text{(X2.2)}$$

X2.4.3 The component due to the testing machine's speed measuring systems or device's resolution at the Stop displacement, u_{Rstop} is:

$$u_{Rstop}\frac{0.001}{2\sqrt{3}} = 0.0002\text{mm/min} \quad (X2.3)$$

X2.4.4 The component due to the testing machine's speed measuring systems or device's resolution at the Start displacement, u_{Rstart} is:

$$u_{Rstart}\frac{0.001}{2\sqrt{3}} = 0.0002\text{mm/min} \quad (X2.4)$$

X2.4.5 The total component due to resolution for the 1 mm/min speed verification is:

$$\sqrt{0.0002^2 + 0.0002^2} = 0.0003\text{mm/min} \quad (X2.5)$$

X2.4.6 Since the uncertainty due to non-repeatability is greater than that due to resolution, the component due to resolution is not included. The combined measurement uncertainty of the error determined at 1 mm/min, u is:

$$u = \sqrt{0.00012^2 + 0.0002^2} = 0.002\text{mm/min} \quad (X2.6)$$

X2.4.7 The expanded measurement uncertainty of the error determined at 1 mm/min, U using a coverage factor of two is:

$$U = 2 \times 0.0002 = 0.004\text{mm/min} \quad (X2.7)$$

0.004 mm/min is 0.4% of 1 mm/min.