

SEMI E56-0309

TEST METHOD FOR DETERMINING ACCURACY, LINEARITY, REPEATABILITY, SHORT-TERM REPRODUCIBILITY, HYSTERESIS, AND DEADBAND OF THERMAL MASS FLOW CONTROLLERS

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1 Purpose

1.1 The purpose of this Document is to provide a standardized method to quantify the accuracy, linearity, repeatability, short-term reproducibility, hysteresis, and deadband of a thermal mass flow controller.

1.2 The intent of this Document is not to suggest any specific testing program but to specify the test method to be used when testing for parameters that are covered by this method. The user might use this Document to check significant performance characteristics such as accuracy, precision, bias, repeatability, linearity, short-term reproducibility, and deadband under a set of closely controlled test conditions.

1.3 The significance of the accuracy calculations in this method is to allow an MFC user to transfer a process from one manufacturing tool to another and to exchange MFCs within a single manufacturing tool while maintaining process control.

2 Scope

2.1 This Document describes the conditions and procedures for testing the accuracy, linearity, repeatability, hysteresis, and deadband of thermal mass flow controllers (MFCs). Because of the generic nature of this Document, not all test procedures apply to all types of MFCs.

2.2 This Document provided a common basis for communication between manufacturers and users.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 It is not practical to evaluate performance under all possible combinations of operating conditions. This test procedure should be applied under laboratory conditions; its intent is to collect sufficient data to form a judgement of the field performance of the MFC being tested.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI E17 — Guideline for Mass Flow Controller Transient Characteristics Tests

4.2 ASME Standard¹

ASME MFC-10M — Method for Establishing Installation Effects on Flowmeters

4.3 ISA Standard²

ISA S51.1 — Process Instrumentation Terminology

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

¹ American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5900, USA; Telephone: +1.973.882.1170, Fax: +1.973.882.1717, <https://www.asme.org>

² Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709, USA; Telephone: +1.919.549.8411, <https://www.isa.org>

5 Terminology

5.1 Abbreviations and Acronyms

- 5.1.1 A — Measured Value
- 5.1.2 A_a — average measured value
- 5.1.3 A_a — average measured value at 100% setpoint
- 5.1.4 AD — accuracy of the DUT
- 5.1.5 AD_f — accuracy of the flow standard
- 5.1.6 AS — accuracy of setpoint
- 5.1.7 A_l — measured value, down cycle
- 5.1.8 A_u — measured value, up cycle
- 5.1.9 B — bias
- 5.1.10 D — deadband value
- 5.1.11 DBD — deadband of device
- 5.1.12 DBS — deadband of setpoint
- 5.1.13 D_l — lower deadband value
- 5.1.14 D_u — upper deadband value
- 5.1.15 DUT — device under test
- 5.1.16 FS — full scale flow rate
- 5.1.17 HD — hysteresis of device
- 5.1.18 $HDBS$ — hysteresis plus deadband at a setpoint
- 5.1.19 HS — hysteresis at a setpoint
- 5.1.20 i — reading number in a cycle for a given set-point
- 5.1.21 I — intermediate value
- 5.1.22 j — cycle for a given setpoint
- 5.1.23 k — up cycle number for a given setpoint
- 5.1.24 kPa — kilopascal
- 5.1.25 LD — linearity of DUT
- 5.1.26 LS — linearity of setpoint
- 5.1.27 m — slope
- 5.1.28 m — down cycle number for a setpoint
- 5.1.29 n — number of upscale readings
- 5.1.30 NC — normally closed
- 5.1.31 n_j — number of readings at a setpoint at a given cycle
- 5.1.32 NO — normally open
- 5.1.33 P — precision
- 5.1.34 $psia$ — pounds per square inch absolute
- 5.1.35 RPD — repeatability of the DUT

- 5.1.36 *RPS* — repeatability at a setpoint
- 5.1.37 *S* — setpoint
- 5.1.38 S_a — average of setpoint
- 5.1.39 *sccm* — standard cubic centimeters per minute
- 5.1.40 S_l — setpoint, down cycle
- 5.1.41 S_u — setpoint, up cycle
- 5.1.42 *slm* — standard liters per minute
- 5.1.43 *SRD* — short-term reproducibility of the device
- 5.1.44 *SRS* — short-term reproducibility at a setpoint
- 5.1.45 v_i — the *i*th measured value at a setpoint for a given cycle
- 5.1.46 *Y* — ideal linearity value
- 5.1.47 *Z* — zero offset of DUT
- 5.1.48 Z_a — indicated flow at zero actual flow

5.2 Definitions

- 5.2.1 *accuracy* — the closeness of agreement between an observed value and the true value; the total uncertainty of an observed value, including both precision and bias.
- 5.2.2 *accuracy curve* — the curve fitted through the average measured values over the specified range of the device under test.
- 5.2.3 *accuracy device* — the total uncertainty over a specified range of the device. Device accuracy over a range is stated as the worst case accuracy taken over all tested setpoints in this range.
- 5.2.4 *actual flow* — the gas flow as measured by an external standard, not the electrical output of a mass flow meter.
- 5.2.5 *bias* — the difference, at a setpoint, between the measured value and the sum of the setpoint value and the zero offset. The measured values of a flow standard include its total uncertainty.
- 5.2.6 *cardinal setpoint* — a specific setpoint to assess the accuracy of the device under test (DUT). For this test method, the cardinal setpoints are 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% of full scale.
- 5.2.7 *deadband* — the range through which a setpoint may be varied, upon reversal of direction, without initiating an observable change in output signal.
- 5.2.8 *device under test* — mass flow device is being tested by this method.
- 5.2.9 *downscale reading* — a reading approached from a setpoint greater than the current setpoint and beyond the deadband.
- 5.2.10 *downscale value, average* — the sum of all downscale readings, in one cycle, at a single setpoint, divided by the number of these values.
- 5.2.11 *drift* — the change in output over a specified time period for a constant input under specified reference operating conditions.
- 5.2.12 *drift, long-term* — the drift between a series of tests over a specified time interval. This specified time interval is generally much greater than the time necessary to run an individual test.
- 5.2.13 *drift, short-term* — the drift between sets of measurements over the duration of the test.

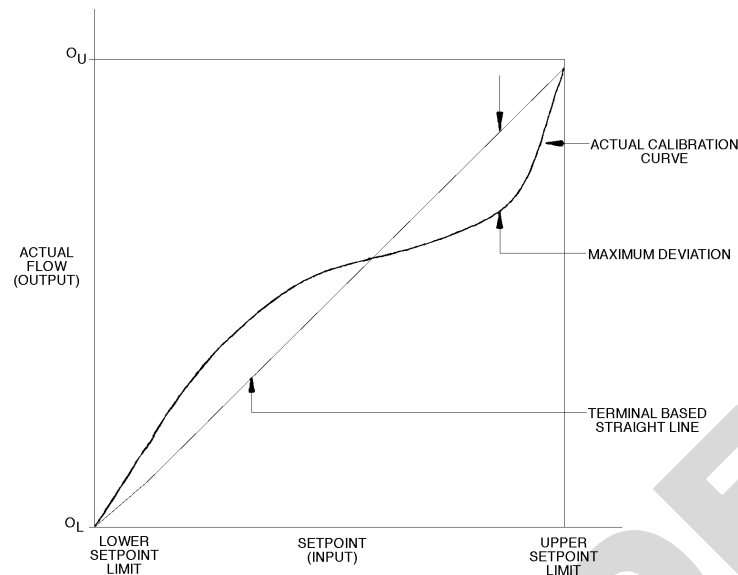


Figure 1
Terminal-Based Linearity for Mass Flow Controller

5.2.14 *hysteresis* — that property of an element evidenced by the dependence of the value of the output, for a given excursion of the input, upon the history of the prior excursions and the direction of the current traverse.

5.2.15 *indicated flow* — flow indicated by MFC under test. Electrical output of the DUT.

5.2.16 *linearity* — the closeness to which a curve approximates a straight line.

5.2.17 *linearity, terminal-based* — the maximum absolute value of the deviation of the accuracy curve (average of upscale and downscale values) from a straight line through the upper and lower setpoint limits of the accuracy curve (see Figure 1).

5.2.18 *measured value* — the actual flow through a device under test, expressed in sccm or slm, as measured by a standard, preferably primary.

5.2.19 *measured value, average* — the sum of all readings (both upscale and downscale) for all cycles, at a single setpoint, divided by the number of these readings.

5.2.20 *operating conditions, normal* — the range of operating conditions within which a device is designed to operate and for which operating influences are stated. [ISA S51.1]

5.2.21 *operating conditions, reference* — the range of operating conditions of a device within which operating influences are negligible. [ISA S51.1]

5.2.22 *operating influence* — the change in a performance characteristic caused by a change in a specified operating condition from reference operating conditions, all other conditions being held within the limits of reference operating conditions. [ISA S51.1]

5.2.23 *pneumatic noise* — localized, random variations in pressure and flow.

5.2.24 *precision* — the closeness of agreement among the measured values at a setpoint. It is often expressed as a standard deviation.

5.2.25 *repeatability* — the closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory, and short intervals of time. It is usually measured as a nonrepeatability and expressed as a repeatability in percent of reading.

5.2.26 *reproducibility* — the closeness of agreement among repeated measured values at a setpoint, within the specified reference operating conditions, made over a specified period of time, approached from both directions. Reproducibility includes hysteresis, deadband, long-term drift, and short-term reproducibility.

NOTE 1: Between repeated measurements, the input may vary over the range, and operating conditions may vary within normal operating conditions.

5.2.27 *reproducibility, short-term* — the closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory and short intervals of time, approached from both directions. The approach must be from beyond the deadband. Short-term reproducibility includes repeatability, hysteresis, deadband, and short-term drift.

5.2.28 *setpoint* — the input signal provided to achieve a desired flow, reported as sccm, slm, or percent-full scale.

5.2.29 *setpoint limit, lower* — the lowest setpoint at which the instrument is specified to operate.

5.2.30 *setpoint limit, upper* — the highest setpoint at which the instrument is specified to operate, usually full scale.

5.2.31 *settling time* — the time between the set point step change and when the actual flow remains within the specified band (see SEMI E17).

5.2.32 *span* — the full-scale range of the DUT.

5.2.33 *stability* — the ability of a condition to exhibit only natural, random variation in the absence of unnatural, assignable-cause variation.

5.2.34 *standard conditions* — 101.32 kPa, 0.0°C (14.7 psia, 32°F).

5.2.35 *uncertainty, total* — the range within which the true value of the measured quantity can be expected to fit; an indication of the variability associated with a measured value that takes into account the two major components of error, bias and the random error attributed to the imprecision of the measurement process.

5.2.36 *upscale reading* — a reading approached from a setpoint less than the current setpoint and beyond the deadband.

5.2.37 *upscale value, average* — the sum of all upscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.38 *zero drift* — the undesired change in electrical output, at a no-flow condition, over a specified time period, reported in sccm or slm.

5.2.39 *zero offset* — the deviation from zero, at a no-flow condition, reported in sccm or slm.

6 Summary of Test Method

6.1 Specific procedures are given for characterizing MFCs discharging to atmospheric pressure or into a vacuum using accepted reference standards to determine accuracy, linearity, repeatability, short-term reproducibility, hysteresis, and deadband (see Figure 2).

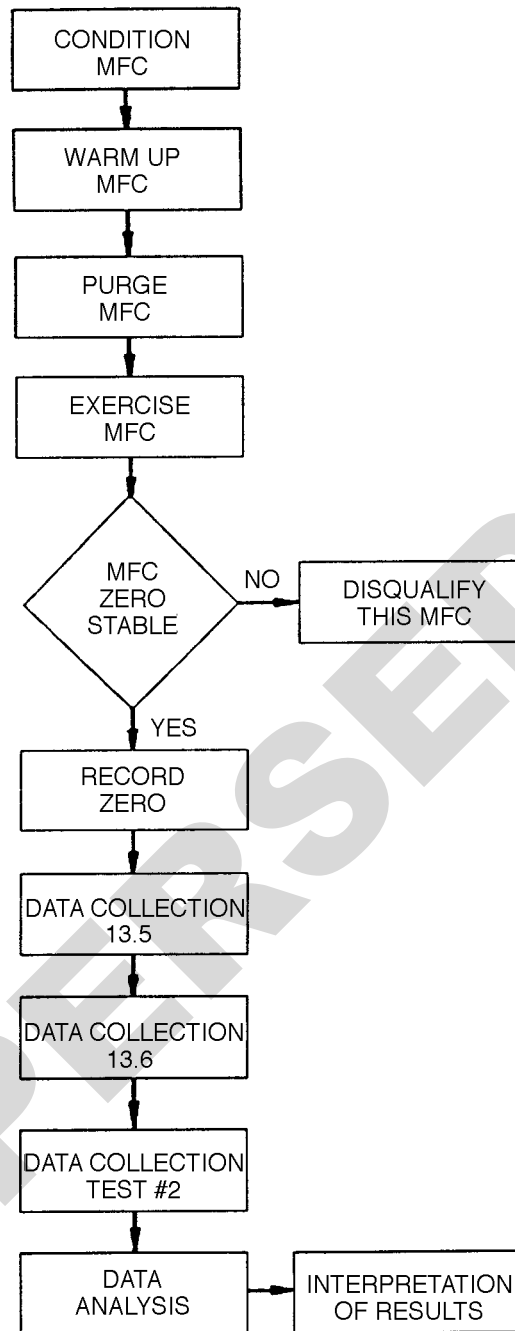


Figure 2
Test Flowchart

7 Interferences

7.1 The accuracy rating of the measuring equipment must include superior measurement capability compared with that of the DUT. In no instance should the accuracy rating of the measuring equipment be less than twice that of the DUT (e.g., if the accuracy of the DUT is ± 1 sccm, then the accuracy of the measuring device must be better than or equal to $\pm 1/2$ sccm). The traceability of all the pertinent measuring instruments and devices should be realistically established and quantified.