SEMI F62-0701 (Reapproved 1111)
TEST METHOD FOR DETERMINING MASS FLOW CONTROLLER PERFORMANCE CHARACTERISITICS FROM AMBIENT AND GAS TEMPERATURE EFFECTS

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NOTICE: This Document was reapproved with minor editorial changes.

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1 Purpose

1.1 The purpose of this Document is to define a method for testing mass flow controllers (MFCs) being considered for installation into a gas distribution system and to quantify ambient and gas temperature effects on the MFC's indicated and actual flow.

2 Scope

2.1 This Test Method applies to metal and polymer sealed MFCs with flow rates up to 30 slpm. The tests include those listed below and are to be performed in the following order:

1. Ambient Temperature Effects (Steady State and Transient)
2. Gas Temperature Effects (Steady State and Transient)

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 This method evaluates mass flow controllers in typically encountered, realistic operating conditions.

3.2 This Test Method does not address operational influences outside of the manufacturer's published limitations.

4 Referenced Standards and Documents

4.1 None.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *DUT* — device under test

5.1.2 *g* — gravity

5.1.3 *kPa* — kiloPascal

5.1.4 *MFC* — mass flow controller

5.1.5 *NIST* — National Institute of Standard Technologies

5.1.6 *sccm* — standard cubic centimeters per minute

5.1.7 *slpm* — standard liters per minute

5.2 *Definitions*

5.2.1 *stability, long term* — reading ±2% for over one hour.

5.2.2 *stability, short term* — reading ±2% within five minutes.

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5.2.3 *zero setpoint* — manufacturer's setpoint for no flow from the MFC.

5.3 *Symbols*

5.3.1 MFC_1 — inlet mass flow controller.

5.3.2 T_a — the temperature in the environmental control chamber.

5.3.3 T_g — gas temperature at the inlet to the DUT.

5.3.4 T_{max} — maximum manufacturer-rated temperature for an MFC.

5.3.5 T_{min} — 20°C or manufacturer rated minimum temperature, whichever is greater.

5.3.6 TC_g — temperature coefficient due to changing gas temperature of DUT.

5.3.7 TC_e — temperature coefficient due to changing environmental temperature of DUT.

5.3.8 Q_a — for the purpose of this method, the output value of the flow standard in units of mass flow.

5.3.9 Q_{ind} — for the purpose of this method, the output value of the device under test in units of mass flow.

5.3.10 Q_{sp} — for the purpose of this method, the intended output in mass flow units for a particular setpoint.

5.3.11 V_a — valve A.

5.3.12 V_b — valve B.

5.3.13 V_{1i} — inlet isolation valve.

5.3.14 V_{io} — outlet isolation valve.

6 Significance and Use

6.1 This Test Method defines a procedure for testing components being considered for installation in a gas distribution system. Application of this method is expected to yield data allowing an end user to choose among components tested for the purpose of qualification for this installation.

7 Apparatus

7.1 See Figures 1 and 2 for schematics of the set-ups.

7.2 *Flow Measurement Device* — National Institute of Standard Technologies (NIST) traceable and capable of measuring steady-state and transient flow characteristics, preferably with differential pressure sensors across a flow restriction. This device should have a relative accuracy of at least 2 to 1 with respect to the device under test (DUT).

7.3 *Temperature Measurement Device* — To measure test gas temperature, NIST traceable and capable of real-time measurement, with a low mass (<0.05 g) sensor and with low thermal losses through the leads (<0.3 mW/°C).

7.4 *Pressure Measurement Device* — To measure test gas pressure, NIST traceable, and capable of real-time measurement to measure test gas pressure.

7.5 *Gas Pressure Control Regulators* — To maintain test gas pressure at 275 ± 5 kPa.

7.6 *Gas Temperature Control* — Heat exchangers and heaters to maintain the gas temperature equal to the test temperature within ±1°C at the test flow rates.

7.7 *Environmental Chamber* — Capable of stable temperature control (±1°C) from at least T_{min} to a point exceeding the maximum rated MFC temperature by 10°C.

8 Reagents and Materials

8.1 *Test Gas* — Clean, dry nitrogen.

8.2 *Tubing* — Cleaned and maintained to have no adverse effects on the test.

8.3 *Valves* — Capable of unimpaired operation at 100°C.

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9 Safety Precautions

9.1 All manufacturers' recommendations should be followed and noted when testing the unit. Any safety precautions should always be followed.

10 Technical Precautions

10.1 The flow standard may read a non-zero value due to heating of the gas in the test to determine transient effects on the zero. These readings should be noted.

11 Preparation of Apparatus

11.1 *Setup and Schematic — Ambient Temperature Effects (see Figure 1)*

11.1.1 Install an ambient temperature sensing device within 5 to 10 centimeters horizontally adjacent to the MFC body. The probe should not be in contact with the MFC body or the environmental chamber walls.

11.1.2 Position the gas temperature sensor in the center of the gas stream no more than 10 cm upstream from the inlet surface of the MFC body.

11.1.3 After installation of the MFC, flow nitrogen at a 100% setpoint to purge the system for a sufficient time to remove atmospheric contamination.

11.1.4 If the MFC has a selectable auto zero function, note this on all data presentation documents before proceeding with the test.

11.1.5 Minimize the length of tubing between the heater and the device under test to reduce gas temperature changes.

11.2 *Setup and Schematic — Gas Temperature Effects (see Figure 2)*

11.2.1 Install a base temperature sensing device, T_e adjacent to the MFC body. The probe should be in contact with the MFC body.

11.2.2 Install an ambient temperature sensing device within 5 to 10 centimeters horizontally adjacent to the MFC body. The probe should not be in contact with the MFC body or the environmental chamber walls.

11.2.3 Position the gas temperature sensor in the center of the gas stream no more than 10 cm upstream from the inlet surface of the MFC body.

11.2.4 After installation of the MFC, flow nitrogen at a 100% setpoint to purge the system for a sufficient time to remove atmospheric contamination.

11.2.5 If the MFC has a selectable auto zero function, note this on all data presentation documents before proceeding with the test.

12 Calibration and Standardization

12.1 The flow standard, temperature standards, and pressure standards used are to be NIST traceable.

12.2 All ancillary equipment must be calibrated and maintained to the manufacturer's recommendations. Current calibration records must be maintained.

13 Conditioning

13.1 Reference conditions as listed in Appendix 1 are to be maintained unless otherwise noted.

14 Procedure

14.1 *Environmental Temperature Effect*

14.1.1 Install the test specimen in the test set-up according to the manufacturer's recommendations (see Figure 1).

14.1.2 Set the environmental chamber temperature (T_e) to T_{min} and allow it to stabilize for one hour. Ensure that gas temperature (T_g) and ambient temperature (T_e) are within 2°C of each other before beginning data collection.

14.1.3 Close V_{ii} and V_{io}, and record the MFC Q_{ind} at a zero setpoint.

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14.1.4 Open V_{ii} and V_{io}. Change the MFC flow setpoints to 25%, 50%, 75%, and 100% of full rated scale.

NOTE 1: T_g and T_e must be within 2°C of each other.

14.1.5 At each setpoint, record T_g, Q_{ind} once, and a minimum of 10 values at a maximum of five second intervals of T_e and Q_a for at least 60 seconds. Record the average of the 10 values as shown in Table 3.

14.1.6 Repeat ¶ 14.1.3.

14.1.7 Maintain the setpoint at zero and change the environmental chamber temperature T_{em} to the next level indicated in Figure 3.

14.1.8 Record the Q_{ind} at the zero setpoint in real time (max 30-second intervals) as the temperature T_e is changing. See example of data collection shown in Table 4.

14.1.9 Allow temperature T_e to stabilize for a minimum of one hour.

NOTE 2: The time for the T_e to stabilize at each level should be increased to two hours if the indicated flow at T_e level 1 and 9, or 2 and 8, or 3 and 7, or 4 and 6 are not within 5% of each other. See Figure 3.

14.1.10 Open the isolation valves V_{ii} and V_{io}.

14.1.11 Repeat ¶¶ 14.1.3 through 14.1.9 for each T_e level, as shown in Figure 3.

14.2 *Gas Temperature Effect*

14.2.1 Install the test specimen in the test set-up according to the manufacturer's recommendations (see Figure 2).

14.2.2 Allow the system to stabilize for one hour (see Figure 1). Refer to Figure 5 for flow chart.

14.2.3 Set the heater temperature to raise the gas temperature, T_g, such that T_g is elevated 10°C above ambient.

14.2.4 Simultaneously open V_{ii} and close V_{io}. Continue to monitor T_g, T_e, indicated flow, and actual flow for one hour. If after one hour, the actual flow or T_g has not achieved long-term stability, or if T_g is not equal to T_e + 10 (±2°C), continue until these conditions are met or until an additional one hour period has elapsed. If long-term stability is not achieved, note this occurrence and record the average value of 10 samples minimum taken at maximum five-second intervals for each of T_g, T_e, indicated flow, and actual flow as shown in Table 5, for at least 60 seconds.

NOTE 3: If T_g is not 10°C above ambient return to ¶ 14.2.3 and adjust the temperature.

14.2.5 Repeat ¶¶ 14.2.3 and 14.2.4 until all required setpoints have been run.

15 Calculations or Interpretation of Results

15.1 *Calculations*

15.1.1 The measured values for Q_{ind}, Q_a, and T_g are determined by an arithmetic average of samples taken at time intervals after stability has been achieved at each temperature and flow condition.

15.1.2 The ambient temperature coefficient of flow shall be calculated as follows:

$$TC_e(\%/°C) = \frac{Q_a 2 - Q_a 1}{Q_{sp}\, x\, (T_e 2 - T_e 1)}\, x\, 100 \qquad (1)$$

where Q_{a1} and Q_{a2} are the actual flow rates measured at ambient temperatures T_{e1} and T_{e2} respectively. For zero setpoint use the following.

$$TC_{zero} = \frac{Q_a 2 - Q_a 1}{Q_{fullscale}\, x\, (T_g 2 - T_g 1)}\, x\, 100 \qquad (2)$$

This yields a result expressed as a percent of reading per °C. See example of data collection and analysis shown in Table 3. Final TC_e is to be presented in Table 2 format.

15.1.3 The gas temperature coefficient of flow is to be calculated as follows:

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$$TC_g(\%/°C) = \frac{Q_a2 - Q_a1}{Q_{sp}\, x\, (T_g2 - T_g1)}\, x\, 100 \tag{3}$$

where Q_{a1} and Q_{a2} are the actual flow rates measured at gas temperatures T_{g1} and T_{g2} respectively. For zero setpoint use the following.

$$TC_{zero} = \frac{Q_a2 - Q_a1}{Q_{fullscale}\, x\, (T_g2 - T_g1)}\, x\, 100 \tag{4}$$

This yields a result expressed as a percent of reading per °C. Refer to Table 5 for an example of data collection and analysis. Final *TCg* is to be presented in Table 1 format.

16 Reporting Results

NOTE 4: All special features (remote electronics, auto zero, etc.) should be noted on the testing results for comparative analysis.

16.1 The gas temperature coefficient at each flow rate is to be displayed as shown in Table 1.

16.2 The gas temperature coefficient data from Table 1 is to be displayed as shown in Figure 6. The gas temperature, actual flow, and indicated flow are to be displayed versus time as shown in Figure 7.

16.3 The ambient temperature coefficient is to be presented in tabular form as shown in Table 2.

16.4 The data for the steady-state effect from Table 2 should be presented as shown in Figure 8. The data for the transient effect from Table 4 should be presented as shown in Figure 9.

17 Illustrations

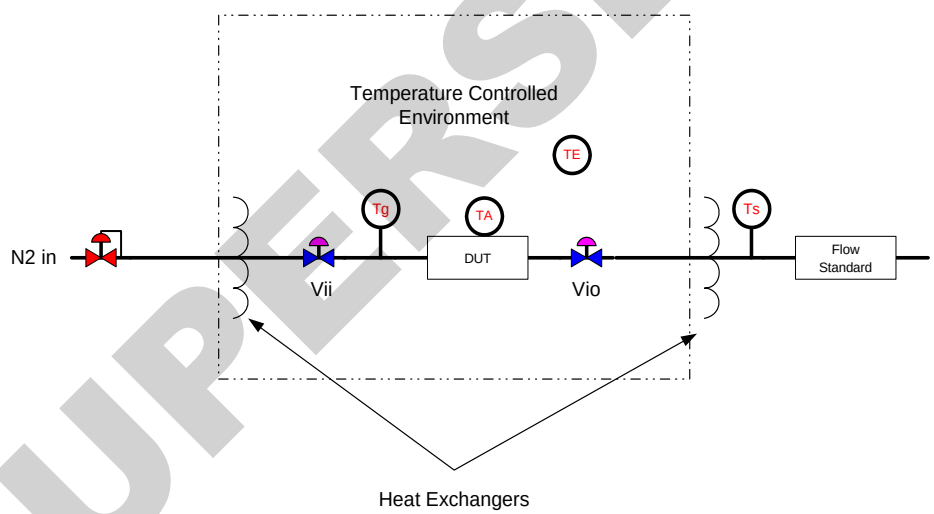

Figure 1
Ambient Temperature Effect Test Apparatus

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