

SEMI F53-0600

TEST METHOD FOR EVALUATING THE ELECTROMAGNETIC SUSCEPTIBILITY OF THERMAL MASS FLOW CONTROLLERS

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1 Purpose

1.1 The purpose of this document is to define a structured method for testing and evaluating the electromagnetic susceptibility of thermal mass flow controllers.

2 Scope

2.1 This document contains the requirements and test method that can be used to evaluate whether a thermal mass flow controller will maintain its functional characteristics when subjected to EMI levels typical of the industry. The test method covers both the radiated susceptibility (RS) and conducted susceptibility (CS) of the controller when exposed to EMI. The electromagnetic susceptibility requirements are extracted from MIL-STD-461C and SAMA PMC-33.1, and the test method is a composite of the RS03, CS01, CS02, and CS06 test methods defined in MIL-STD 462.

2.2 This test method does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This test method is not designed for AC-powered MFCs. The test method addresses electromagnetic susceptibility of MFCs through DC power leads and control signals.

4 Referenced Standards

4.1 Military Standards¹

MIL-STD-461C — Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference

MIL-STD-462 — Measurement of Electromagnetic Interference Characteristics

MIL-STD-463A — Electromagnetic Interference and Electromagnetic Compatibility Technology Definitions and Systems of Units

4.2 Scientific Apparatus Makers Associations²

SAMA PMC — 33.1 Electromagnetic Susceptibility of Process Control Instrumentation, Scientific Apparatus Makers Associations

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 CS — conducted susceptibility

5.1.2 dB — decibels

5.1.3 DC — direct current

5.1.4 EMC — electromagnetic compatibility

5.1.5 EMI — electromagnetic interference

5.1.6 GHz — gigahertz

5.1.7 kHz — kilohertz

5.1.8 MFC — mass flow controller

5.1.9 MHz — megahertz

5.1.10 MIL-STD — Military Standard

5.1.11 psia — pounds per square inch absolute

5.1.12 psig — pounds per square inch gauge

5.1.13 RF — radio frequency

5.1.14 RG-58 — a specification for a particular type of coaxial cable

5.1.15 rms — root mean square

5.1.16 RS — radiated susceptibility

5.1.17 T — teslas

¹ Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120

² Portions of this method are excerpted from SAMA Standard PMC 31.1-1980 with permission of the publisher, Process Measurements & Control Section, SAMA, 1101 16th St., N. W. Washington, DC 20036

5.1.18 V — volt

5.1.19 V/m — volts/meter

5.2 Definitions

5.2.1 *conducted susceptibility* — equipment vulnerability to conducted emissions.

5.2.2 *electromagnetic* — all energy of electrical or magnetic nature; i.e., electric current flow or magnetic field.

5.2.3 *electromagnetic compatibility* — the capability of electronic equipment or systems to be operated in the intended operational electromagnetic environment at designed levels of efficiency.

5.2.4 *electromagnetic interference* — impairment of a wanted electromagnetic signal by an electromagnetic disturbance.

5.2.5 *ground* — a conducting connection, whether intentional or accidental, by which an electric circuit or piece of equipment is connected to the earth, or to some conducting body of relatively large extent.

5.2.6 *limit* — the level of susceptibility that a stated standard allows.

5.2.7 *noise (electrical)* — unwanted electrical signals that produce undesirable effects in the circuits of control systems in which they occur.

5.2.8 *radiated susceptibility* — equipment vulnerable to radiated emissions.

5.2.9 *stable* — the state a signal level obtains when its magnitude varies by less than or equal to $\pm 2.0\%$ of full scale over a one minute period.

6 Summary of Method

6.1 This test method describes the test equipment and procedures for determining if the thermal mass flow controller is susceptible to both radiated and conducted interference. Initially, the controller is exposed to radiated electric fields over a frequency range from 14 kHz to 1 GHz at field strength levels less than 10 volts/meter (V/m). Furthermore, the controller's power leads will be tested for susceptibility to voltage transients with 10 μ s rise times. See flow chart of the test method, Figure 1.

7 Interferences

7.1 MFCs are located in areas where electromagnetic (EM) fields are present. If an MFC is susceptible to the fields, then the delivered flow by the MFC could be adversely effected. The magnitude of the EM field's effect on the MFC performance shall be quantified by this test method.

8 Apparatus

8.1 Radiated Electric Field Susceptibility (RS-03)

8.2 Signal Generator, 14 kHz to 1 GHz

8.3 Audio Power Amplifier, 14 kHz to 1 MHz

8.4 RF Power Amplifier #1, 1 MHz to 400 MHz

8.5 RF Power Amplifier #2, 500 MHz to 1 GHz

8.6 Field Strength Meter

8.7 Oscilloscope

8.8 Parallel Element Antenna, 14 kHz to 20 MHz

8.9 Biconical Antenna, 30 MHz to 200 MHz

8.10 Conical Log Spiral Antenna, 300 MHz to one GHz

8.11 Tripod

8.12 Coaxial Cable, 50-ft, RG-58, with BNC male plugs at each end.

8.13 X10 Attenuator Scope Probe

8.14 Assorted Coax Cables for Interconnects

8.15 *Flow Standard* — Installed downstream and in series with the flow through the MFC. The flow standard shall be capable of measuring flow to within $\pm 0.3\%$ of full scale.

8.16 *Flow Output Monitor* — Connected to the MFC output and signal common/ground points. The monitor/recorder shall be capable of measuring over a range of 0–10 VDC to within ± 5 mV.

8.17 Transient Susceptibility of Power and Control Leads (CS-06) (Conducted Susceptibility)

8.18 Spike Generator, with series and parallel outputs

8.19 Oscilloscope, dual channel

8.20 X10 Attenuator Probe

8.21 X100 Scope Attenuator Probe, two each

8.22 Test Leads, 12-in long with banana plugs at each end, four each

9 Reagents and Materials

9.1 *Test Gas* — Nitrogen with a dew point of less than or equal to -40°C and at a source delivery pressure of 35 psig.

10 Safety Precautions

10.1 *Safety Precautions* — This test method may involve hazardous materials, operations, and equipment.

10.2 The user must have a working knowledge of the respective instrumentation, must practice proper handling of test components, and must understand good laboratory practices. The user should not operate the components in such a manner as to exceed the ratings (i.e., pressure, temperature, flow, and voltage).

10.3 *Technical Precautions* — These tests are to be performed in a shielded or screened room to prevent possible problems with nearby instrumentation or electrical systems caused by the EM fields. At a minimum, the instrumentation associated with this test series (see Figure 2) must be shielded from the EM fields to ensure their proper operation.

11 Preparation of Apparatus

11.1 The test gas source and delivery system must be capable of satisfying the test volume flow rate at a constant pressure, ± 0.1 psia.

11.2 The test gas source and delivery system must be capable of delivering a gas at ambient temperature $\pm 1^\circ\text{C}$ for the duration of each analysis. The ambient temperature shall be held to $22^\circ\text{C} \pm 1^\circ\text{C}$.

12 Calibration and Standardization

12.1 For each test, verify that calibration of test equipment is up-to-date.

13 Procedure

13.1 Install the MFC into the test setup per manufacturer's recommendations.

13.2 Apply power to all devices shown in Figure 3 per manufacturer's specifications. Allow the devices to warm up for the duration specified by the equipment manufacturer.

13.3 Purge the system with nitrogen for a length of time equal to ten times the amount of time it takes to replace the system volume once, when the test MFC is at its full-scale rated flow rate.

13.4 Close inlet shut-off valve. Then close the outlet shut-off valve located adjacent to the MFC (see Figure 2). Adjust the MFC setpoint to zero flow. Wait for the signals to become stable. Record the following on the data sheet:

- MFC indicated flow,
- Flow standard flow,
- Ambient temperature,
- Gas temperature, and
- Gas pressure.

13.5 Ensure that the inlet and outlet shut-off valves adjacent to the MFC (see Figure 2) are open. Adjust the MFC setpoint to 50%. Ensure that all manufacturer's recommended conditions are met for the MFC. Once the output signals become stable, record the MFC output signal, the flow standard output signal, the ambient and gas temperature, and the gas pressure on the data sheet in Table 1.

13.6 Ensure that the MFC power leads and control signal cables are shielded in the area that will be irradiated by the EM fields. The cable shielding shall be intact up to the connector. The type of shielding and connector shall be recorded on the data sheet in Table 1.

13.7 Radiated Electric Field Susceptibility (RS-03)

13.7.1 Testing from 14 kHz to 20 MHz:

13.7.1.1 Mount the parallel element antenna on a tripod at a distance of one meter from the controller and connect the antenna to the audio power amplifier using the 50-ft length of RG-58 coaxial cable (see Figure 3). Set the switch to low frequency range.

13.7.1.2 Connect the amplifier input to the signal generator output.

13.7.1.3 Turn on amplifier and signal generator.

13.7.1.4 Using the X10 probe, connect the scope across the antenna terminals.

NOTE 2: It is important to use the X10 probe rather than a coax that terminates in 50 ohms. The audio amplifier will not drive the required voltage into 50 ohms.

13.7.1.5 Set frequency output of the signal generator to 14 kHz.

13.7.1.6 Turn off signal generator modulation and set voltage across the antenna input connector at 35-V rms.

NOTE 3: With this voltage applied to the antenna at frequencies below one MHz, the required field strength of 10 V/m at a distance of one meter from the antenna should be established.

13.7.1.7 If, at any frequency, the required voltage cannot be developed across the antenna terminals, set to the maximum possible without exceeding equipment ratings.

13.7.1.8 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal one kHz source.

13.7.1.9 Check operation of the controller in the presence of this radiated field. Record the MFC indicated flow, flow standard output, and the frequency on the data sheet in Table 1.

13.7.1.10 Before changing frequency as described in Sections 13.7.1.10–13.7.1.15, reduce the voltage amplitude to zero.

13.7.1.11 Set frequency to 20 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.12 Set frequency to 50 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.13 Set frequency to 100 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.14 Set frequency to 200 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.15 Set frequency to 500 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.16 Set frequency to one MHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.17 Shut down the test equipment. Then remove the audio amplifier and install RF power amplifier #1 in its place.

13.7.1.18 Having exceeded one MHz, turn antenna switch to the high frequency range.

13.7.1.19 Turn on test equipment and resume testing.

13.7.1.20 Set output of the signal generator to two MHz and set field strength to 10 V/m, using field strength meter at the controller location.

NOTE 4: If, at any frequency, the required field cannot be developed, set to the maximum possible without exceeding equipment ratings.

13.7.1.21 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal one kHz source.

13.7.1.22 Check operation of the controller in the presence of this radiated field. Record the MFC indicated flow, the flow standard output, and the frequency on the data sheet.

13.7.1.23 Before changing frequency as described in Sections 13.7.1.23–13.7.1.25 reduce the field amplitude to zero.

13.7.1.24 Set frequency to 5 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.25 Set frequency to 10 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.26 Set frequency to 20 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.27 After testing at fixed frequencies, sweep the signal source from 50 kHz to 20 MHz at an amplitude of about 35 V rms or 10 V/m. If a malfunction occurs during the sweep, stop and go back to that frequency

range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and during the switching can create strong transient noise. Only the results at single frequencies can be trusted; the sweep is only to locate the problems, not to completely define them.

13.7.1.28 Reduce signal source output to zero and de-energize test equipment.

13.7.1.29 Disconnect and remove parallel element antenna.

13.7.1.30 Testing from 30 MHz to 200 MHz:

13.7.1.31 Mount biconical antenna on the tripod. Test in a sequence similar to that in Sections 13.7.1.1–13.7.1.9.

13.7.1.32 Verify that RF power amplifier #1 is still in place.

13.7.1.33 At a minimum, test at the following frequencies: 30 MHz, 40 MHz, 50 MHz, 60 MHz, 70 MHz, 80 MHz, 90 MHz, 100 MHz, 120 MHz, 140 MHz, 160 MHz, 180 MHz, and 200 MHz.

13.7.1.34 At each frequency, set the field strength to 10 V/m using the field strength meter at the controller location with the antenna in both the vertical and the horizontal positions.

13.7.1.35 Check operation of the controller in the presence of the radiated fields generated. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet.

13.7.1.36 After testing at fixed frequencies, sweep the signal source from 30 MHz to 200 MHz. If a malfunction occurs during the sweep, stop and go back to the faulty frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and can create strong transient noise during the switching. Only the results at single frequencies can be trusted; the sweep is only to locate problems, not to completely define them.

13.7.1.37 Reduce signal source output to zero and de-energize test equipment.

13.7.2 Testing from 300 MHz to one GHz: