SEMASPEC Provisional Test Method for Determining Steady-State Supply Voltage Effects for Mass Flow Controllers

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Technology Transfer 92071230B-STD

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Abstract: This document defines a test method for characterizing mass flow controllers (MFCs) being considered for installation into a high-purity gas distribution system. The procedure applies to thermal MFCs. It is intended to measure the delivered mass flow rate variation as a function of deviation from the reference steady-state supply voltage. The test method is designed for DC-powered MFCs. The supply voltage effects include voltage-depression and over-voltage variations in the DC supply. This test method is not designed for AC-powered MFCs. This test method addresses steady-state effects and does not address any effects caused by transient power supply behavior. This revision of the document incorporates changes made as a result of industry review and from corrections made during working session four of the MFC Test Methods Development Task Force. This test method is provisional until it has been validated. This document is in development as an industry standard by Semiconductor Equipment and Materials International (SEMI). When available, adherence to the SEMI standard is recommended.

Keywords: Testing, Mass Flow Controllers, Gas Distribution Systems

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1. Introduction

This document presents a test method that may be applied for the evaluation of mass flow controllers considered for use in semiconductor equipment.

1.1 *Purpose*—The purpose of this document is to define a method for characterizing mass flow controllers (MFCs) being considered for installation into a high-purity gas distribution system. This method will quantify the steady-state supply voltage effects on the MFC's ability to accurately deliver setpoint flow values.

1.2 *Scope*—This procedure applies to thermal mass flow controllers. It is intended to measure the delivered mass flow rate variation as a function of deviation from the reference steady-state supply voltage. The test method is designed for DC-powered MFCs. The supply voltage effects include voltage depression and over-voltage variations in the DC supply.

1.3 *Limitations*

1.3.1 This test method is not designed for AC-powered MFCs. This test method addresses steady-state effects and does not address any effects caused by transient power supply behavior.

2. Referenced Documents

2.1 SAMA Standard PMC 31.1-1980, Generic Test Methods for the Testing and Evaluation of Process Measurement and Control Instrumentation.[1]

2.2 IEC Publication 546-1976, Methods of Evaluating the Performance of Controller with Analogue Signals for Use in Industrial Process Control.[2]

3. Terminology

3.1 *Acronyms and Abbreviations*

3.1.1 DUT—device under test

3.1.2 MFC—mass flow controller

3.1.3 *NIST*—National Institute of Standards and Technology

3.1.4 *psia*—pounds per square inch absolute

3.1.5 *psig*—pounds per square inch gauge

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[1]Portions of this method are excerpted from SAMA Standard PMC 31.1-1980 with permission of the publisher, Process Measurement and Control Section, SAMA, 1101 16th St., N. W., Washington, DC 20036.

[2]Available from the Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056.

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3.2 *Descriptions of Terms*

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

3.2.2 *reference voltage—manufacturer's recommended power supply voltage.*

3.2.3 *indicated flow*—flow value derived from the MFC.

3.2.4 *actual flow*—flow value measured by the flow standard.

4. Summary Of Test Method

4.1 This test method consists of varying the steady-state supply voltage to an MFC in ±1% (of rated supply) increments from the reference voltage span. Both the positive and negative supply voltages will be varied independently and together in 1% increments. The MFC flow output is monitored at 0% and 100% of its operating range (see Table 1). At each incremental change as well as at the reference supply voltage, the MFC flow and flow standard outputs are recorded at 0% and 100% of its operating range. The test shall end when a ±3% of full-scale output flow change is noted between the flow at the reference voltage and at an incremental change point. A flow chart outlines the procedure (see Figure 1).

5. Significance And Use

Because of fluctuations in ambient temperature or a changing load on the power supply, the reference steady-state supply voltages may change. These changes in supply voltages may adversely effect the MFC's ability to deliver setpoint flow. The magnitude of this effect can be measured by this test method, with the worst case effect expected to be on the order of ±2% of full-scale flow.

The user of an MFC can use the data generated by this method to evaluate the impact of steady-state supply voltage variations on the MFC's ability to deliver setpoint flow values. Knowing the magnitude of this effect and the power level variations, allows the user to decide on what measures to take to reduce this effect, if necessary.

6. Apparatus

The equipment and instrumentation required to complete this test method are shown in Figure 2.

6.1 *DC Power Supply*, to provide the required voltage to the MFC under test, with the capability to vary its output over the range of ±25 VDC at 500 mA, and with ripple less than 0.1% rms.

6.2 *DC Power Supply Monitor/Recorder*, placed in parallel with the DC power supply, and capable of measuring the DC voltage to within ±20 mV over the entire operating range of the supply.

6.3 *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.

6.4 *Flow Standard*, installed downstream and in series with the flow through the MFC. The flow standard shall be capable of measuring flow changes within ±0.3% of full scale.

6.5 *Current Meter*, connected in series in the power common line of the DC power supply, capable of measuring over a range of 0–200 mA to within ±1 mA.

7. Materials

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

8. Precautions

8.1 *Safety Precautions*

8.1.1 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before using this method.

8.1.2 The user must know the respective instrumentation, practice proper handling of test components, and understand good laboratory practices.

8.1.3 The user should not exceed the ratings (such as pressure, temperature, flow, and voltage) of the components.

9. Preparation Of Apparatus

9.1 *Setup and Schematic*—See Figures 2 and 3.

10. Calibration And Reference Standards

10.1 All instrumentation shall be calibrated with NIST traceable standards and shall be under current calibration.

11. Conditioning

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 ±2 C for the duration of each analysis. The ambient temperature shall be held to 22 ±1 C.

12. Procedure

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

12.2 Apply power to all devices shown in Figure 2 per manufacturer's specifications. Allow the devices to warm up for the duration specified by the equipment manufacturer.

12.3 Set the DC power supply to the recommended reference voltage, nominally ±15 VDC. Verify the voltage magnitude using the power supply monitor.

12.4 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 with the test MFC at its full-scale rated flow rate.

12.5 Close the inlet shut-off valve and then the outlet shut-off valve located adjacent to the MFC (see Figure 3). Adjust the MFC setpoint to zero flow. Follow the manufacturer's recommendations for adjusting the MFC zero. If the MFC has an auto-zero function, leave it active and note this fact on the data sheet in Table 1. Wait for the signals to become stable. Record on the data sheet (see Table 1) three separate readings of the MFC flow output, the power supply voltages, and the current of the power supply common.

12.6 Vary the positive DC power supply voltage in +1% steps from the reference value while holding the negative supply at its reference value.

[Note: If reference voltage is +15 V, the first step is a change in voltage of +0.15 V].

After the monitored signals become stable, record the MFC zero value, the current value, and the power supply voltage magnitudes. Record three measurements at each step-change of power level on the data sheet. Continue to increase the positive supply voltage span until the MFC zero point changes by ±3% of full scale flow, the MFC zero output point remains unstable for five minutes, or the power level changes to +110% of original value (+16.5 V).

12.7 Return the power supply level to the original reference value and repeat step 12.5.

12.8 Repeat the procedure described in step 12.6, with the following exception: Decrease the power supply span in 1% decrements until either the MFC zero changes by ±3% of full scale, the zero output point remains unstable for five minutes, or 85% of the original value is reached (+12.75 V).

12.9 Return the power supply level to the original reference value, repeat step 12.5, and go to step 12.10.

12.10 Repeat steps 12.6 through 12.9, with the following exception: Vary the negative DC power supply while holding the positive power supply at its reference value.

12.11 Vary both DC power supply voltages together in +1% steps from the reference value.

[Note: If the reference voltages are ±15 V (30 V span), the first step is a change in voltage of ±0.15 V increasing the span to ±15.15 V (30.3 V span)].

After the monitored signals become stable, record the MFC zero value, the current value, and the power supply voltage magnitudes. Record three measurements at each step change of power level on the data sheet. Continue to increase the supply voltage span until the MFC zero point changes by ±3% of full scale flow, the MFC zero output point remains unstable for five minutes, or the power level changes to +110% of span (±16.5 V).

12.12 Return the power supply level to the original reference value, repeat step 12.5, and go to step 12.13.

12.13 Repeat step 12.11, with the following exception: Decrement the power supply voltages by 1% and go to step 12.14.

12.14 Return the power supply level to the original reference value, repeat step 12.5, and go to step 12.15.

12.15 Open the inlet and outlet shut-off valves that are adjacent to the MFC (see Figure 3) and adjust the MFC setpoint to 100%. Ensure that all reference conditions are within the specified tolerances. Once the output signals become stable, record the MFC output signal, the power supply voltage, the flow standard output, and the current value. Repeat these measurements three times and record the results on the data sheet.

12.16 Vary the positive DC power supply voltage in +1% increments from the reference while holding the negative power supply at its reference value as described in step 12.6. Record, on the data sheet, three separate measurements of the MFC flow output, the power supply voltage, the flow standard output, and the current meter signal after the values become stable. Continue to increase the voltage span in 1% increments until either the MFC or flow standard signal changes by ±3% of full scale, the MFC output signal remains unstable for five minutes, or until a 10% increase in the power supply original level voltage (16.5 V) is reached.

12.17 Return the power supply level to the original reference value, repeat step 12.5, and go to step 12.18.

12.18 Open the inlet and outlet shut-off valves that are adjacent to the MFC and adjust the MFC setpoint to 100%. Repeat the procedure described in 12.16, but decrease the positive supply voltage in 1% decrements until either the flow signal changes by ±3% of full scale, the MFC output signal remains unstable for five minutes, or until the original supply level voltage has changed -15% (12.75 V).

12.19 Return the power supply level to the original reference value, repeat step 12.5, and go to step 12.20.

12.20 Repeat steps 12.15 through 12.19, with the following exception: Vary the negative DC supply voltage level while holding the positive power supply at its reference value and go to step 12.21.

12.21 Repeat step 12.15 and then go to step 12.22.

12.22 Vary both DC power supply voltages together in +1% steps from the reference value.

[Note: If the reference voltages are ±15 V (30 V span), then the first step is a change in voltage of ±0.15 V increasing the span to ±15.15 V.]

After the monitored signals become stable, record the MFC flow and flow standard values, the current value, and the power supply voltage magnitudes. Record three measurements at each step-change of power level on the data sheet. Continue to increase the supply voltage span until either the flow changes by ±3% of full scale flow, the MFC zero output point remains unstable for five minutes, or the power level has been changed to +110% of span (±16.5 V).

12.23 Return the power supply level to the original reference value, repeat step 12.5, and go to step 12.24.

12.24 Open the inlet and outlet shut-off valves that are adjacent to the MFC and adjust the MFC setpoint to 100%. Repeat the procedure described in 12.22, with the following exception: Decrease the supply voltages together in 1% decrements until either the flow signal changes by ±3% of full scale, the MFC output signal remains unstable for five minutes, or until the supply voltage span has changed ±15% (±12.75 V). Then go to step 12.25.

12.25 Return the power supply level to the original reference value, repeat step 12.5, and go to Section 13.

13. Data Analysis

13.1 *Calculations*

13.1.1 Convert the MFC indicated flow output data and the flow standard output data to percent of full scale flow as follows:

MFC Indicated Flow:

$$\text{Percent of full scale flow} = \frac{\text{output data (v)}}{\text{full scale output (v)}} \times 100$$

where the output data is in Column B in data sheet. Record this result in Column G on the data sheet.

Flow Standard (actual flow):

Follow the manufacturer's recommendation for the flow standard output (Column C in data sheet) conversion to percent of full-scale flow. Record this result in Column H of the data sheet.

13.1.2 Calculate the average value of the three data-flow points at each power level setting for the MFC indicated flow (Column G) and the flow standard (Column H) in the data sheet. Record the averages in Columns I and J of the data sheet, respectively.

13.1.3 Determine the span by subtracting the zero value (Column G or H) at a particular power supply variation setting from the 100% flow value (Column G or H) at the same power variation setting. These span values for the MFC and the flow standard are to be recorded in Table 2.

Span = 100% avg. (Column G or H) - 0% avg. (Column G or H)

@ the same power variation setting

13.1.4 Calculate the change in flow at a power supply level by subtracting the MFC indicated value (Column I) from the flow standard value (Column J). Record these results in Column K of the data sheet. Calculate the voltage variation from the reference voltage value as a percent change as follows:

$$\text{voltage change (VC)} = \frac{\text{voltage value - reference voltage}}{\text{reference voltage}} \times 100$$

Record this result in Column L and M of the data sheet for the positive and negative power supplies, respectively.

14. Data Presentation

14.1 Present the data as shown in Table 2 for both zero and span.

14.2 Present the data plots for the values in Table 2 as illustrated in Figure 4.

15. Precision And Bias

15.1 The precision and bias of this test method will be determined during validation.

16. Illustrations

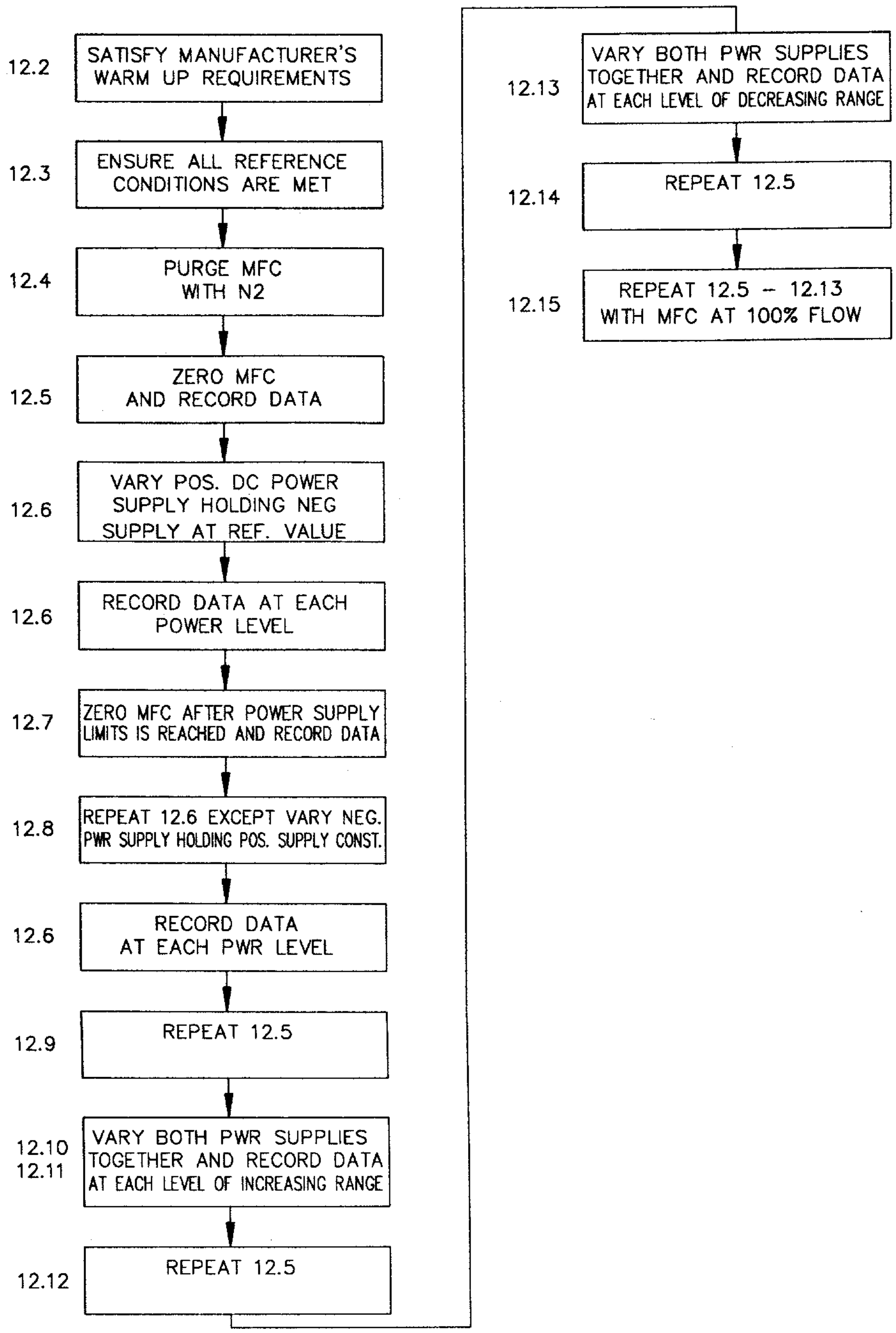

Figure 1 Flow Chart

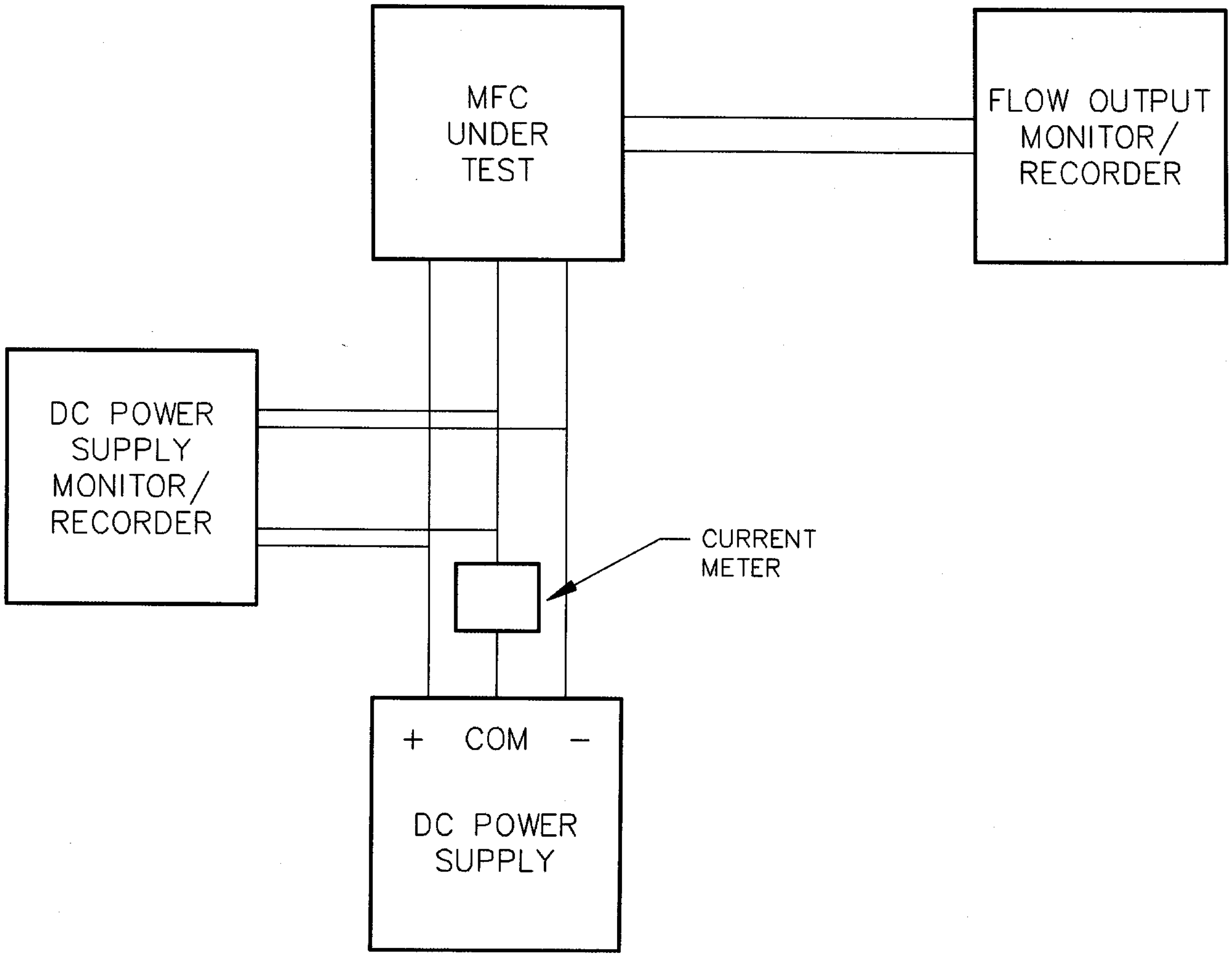

Figure 2 Test Setup for DC Supply Voltage Effects

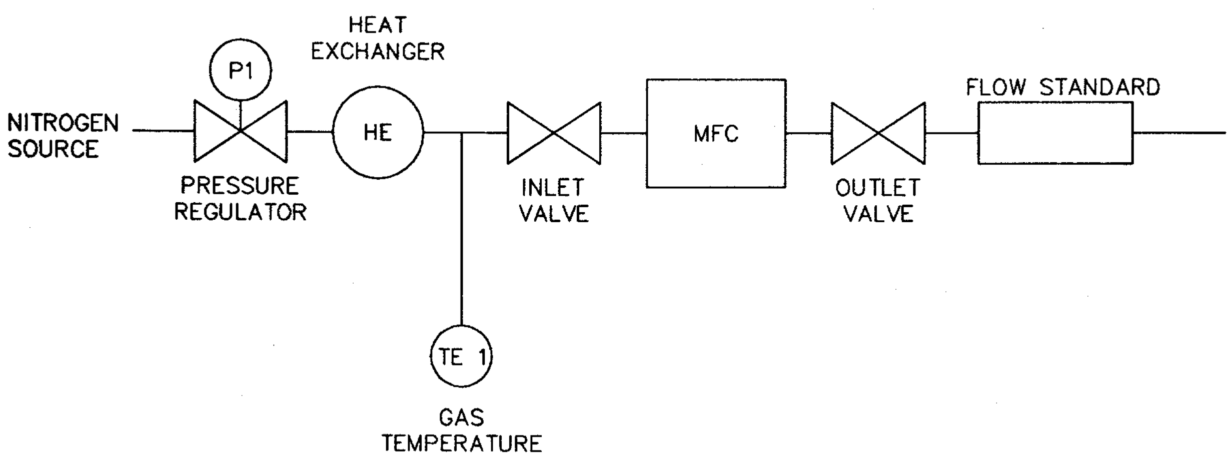

Figure 3 Flow Setup

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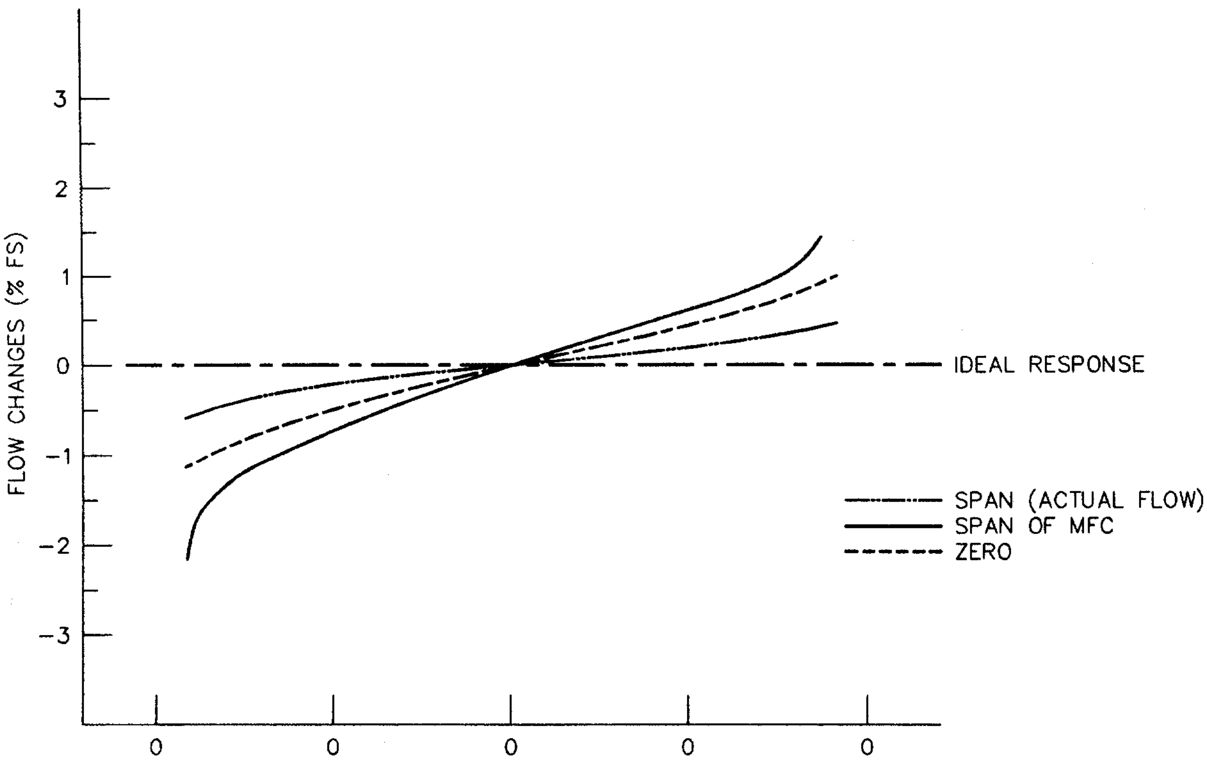
ZERO AND SPAN EFFECTS AS A RESULT OF
VARYING THE POSITIVE POWER SUPPLY



A similar plot would be obtained for:

- Zero and span effects as a result of varying the negative power supply
- Zero and span effects as a result of varying both power supplies together

Figure 4   Data Plots

Table 1 Data Sheet

DATA SHEET 1 Data From Steady-State Power Supply Effects													
	Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G	Col. H	Col. I	Col. J	Col. K	Col. L	Col. M
Data Pnts	MFC Setpoint	MFC Indicated Flow (V)	Flow Standard Output (V)	Positive Power Supply Level (V)	Negative Power Supply Level (V)	Power Supply Current Level (V)	MFC Indicated Flow %FS	Flow Standard %FS	Average of MFC Indicated Flow %FS	Average of Flow Standard %FS	Average Flow Change %FS	Positive Power Supply Var. (%)	Negative Power Supply Var. (%)
1	0	0	0	15	-15	30	0	0	0	0	0	0	0
2	0	0	0	15	-15	30	0	0					
3	0	0	0	15	-15	30	0	0					
. . .													
4	0	0.015	0	15.15	-15	30	0.3	0	0.233	0	0.25	1.0	0
5	0	0.010	0	15.15	-15	30	0.2	0					
6	0	0.010	0	15.15	-15	30	0.3	0					
. . .													
7	0	0.015	0	14.85	-15	30	0.3	0	0.267	0	0.27	-1.0	0
8	0	0.010	0	14.85	-15	30	0.2	0					
9	0	0.015	0	14.85	-15	30	0.3	0					
. . .													
10	0	0.010	0	15	-15.15	30	0.3	0	0.3	0	0.3	0	1.0
11	0	0.010	0	15	-15.15	30	0.3	0					
12	0	0.010	0	15	-15.15	30	0.3	0					
. . .													
13	0	0.005	0	15	-14.85	30	0.1	0	0.133	0	0.13	0	-1.0

Table 2 Zero and Span Effects as a Function of Steady-State Power Supply

Power Supply Voltage Change (% of reference)		Change in Zero of MFC (% FS)	Span of MFC (%FS)	Span - Actual Flow (%FS)
Positive	Negative			
0	0	0	0	0
-1	0	0.25	99.8	100.0
. . .	. . .	. . .	. . .	. . .
0	0	0	0	0
-1	0			
. . .	. . .			
0	0			
0	+1			
. . .	. . .			
0	0			
1	-1			
. . .	. . .			
0	0			
1	1			

Current value for power supply common @ nominal voltage level _____ mA.

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