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Service Note

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M700 FLOW MEASUREMENT

SCOPE:

MFC's will change over time however with the API software you can correct for this by doing the MFC calibration that is described in this service note. This service note discusses differences in flow measurements and suggests a way of accurately measuring flow in the Model 700 calibrator.

NOTE: This procedure should be followed prior to sending in any MFC's to API. Most problems with MFC's will be fixed by following this procedure.

TOOLS:

Flow meter:

Hastings or other "Bubble" type flow-meter. This must use NIST traceable calibrated volumes (calibrated to 1% or better).
NIST traceable thermometer (calibrated to 1% or better).
NIST traceable barometer (calibrated to 1% or better).
Digital Stopwatch.

OR:

Bios (or other type Digital) mass flow meter with temp and pressure compensation (temp: 0°C and 29.92 in-hg).

Calculator.
Wrenches: 7/16", ½", 9/16"
Phillips head screwdriver
Flat tip screwdriver

DEFINITIONS:

Volumetric flow: The uncorrected flow measured with a flow-meter. This is a Measure of the total volume of the flow being measured. The volume of a given number of molecules will vary with pressure and temperature due to changes in density. Volumetric flows must be compensated for pressure and density in order to be comparable with mass flows.

Mass flow: The actual number of molecules, (mass) in the flow being measured. The Number of molecules in a given volume of gas will vary with pressure and temperature due to changes in density.

Mass Flow Controller: The device which controls flow in the Model M700 Calibrator. Because this is a Mass Flow device, correction must be applied to volumetric flow measurements taken from the M700 output. The MFC in the M700 is corrected to Standard Temperature and Pressure.

Standard Temperature and Pressure, (STP): This is flow taken with a Volumetric flow-meter and compensated for 0°C and 29.92"-Hg, (760 mm/Hg).

EPA Specification: (Normal Temperature and Pressure) This is flow taken with a volumetric flow-meter and compensated for 25°C and 29.92"-Hg.

Other Specs: Different countries use different specifications. The most common specification besides the above listed compensates to 20°C and 29.92"-Hg.

Background:

There has been some confusion regarding calibration and flow verification of the mass flow controllers, (MFC's) in the model 700 calibrator. This confusion stems from differences in the way flow measurements are made. These differences result from making measurements of volumetric flow vs. Mass flow. When the pressure or temperature changes, the volume of a given number of molecules, (mass), will change as the result of increased or reduced density.

Thus, when measuring flows, a mass flow of 1 LPM from the MFC could result in a volumetric flow which is much smaller or larger than 1 LPM.

Since the MFC is a mass flow device, if you are using a volumetric measuring device, you must correct the volumetric flow for temperature and pressure in order for the measured flow to accurately represent the flow that the calibrator's MFC is putting out.

If you are trying to verify calibrator flows, and you do not correct to STP, the flows will not match the expected values from the calibrator. If you try to adjust the MFC tables based on volumetric, (uncorrected) flows, the calibrator may not give a correct mixture.

PROCEDURE:

1. Remove the calibrator from operation & move it to a desk so that you can work on it. remove the cover from the calibrator.

NOTE: THERE IS HIGH VOLTAGE AND MOVING PARTS IN THE CALIBRATOR USE CAUTION WHEN WORKING IN THE CALIBRATOR. IF YOU ARE NOT SURE IF SOMETHING HAS POWER ON IT. CHECK IT WITH A METER ON BOTH AC AND DC VOLTS BEFORE YOU TOUCH IT.

2. Leak check the calibrator.
3. If your calibrator has a photometer in it you are going to have to bypass the pump & the flow meter in the calibrator. To bypass the pump & the flow meter, remove the fitting that comes straight up out of the pump & take it to the rear of the calibrator. At the output of the bench you are going to see a T fitting. The branch of the T is the pneumatic output of the bench the straight through part has two yellow wires coming out, this is the sample temp thermistor. Remove the output fitting from the branch of the T on the output of the bench. See diagram on Page 7.
4. Connect the fitting that you removed from the pump & connect it to the output fitting on the bench that you removed.
5. Now push "SETUP_MORE_DIAG_NEXT" to "AUTO LEAK CHECK" push "ENTER & ENTER".

6. If the leak check passes then proceed to the next step. If the leak check fails, then you MUST find the leak. Do not continue with this procedure until you find the leak.
7. when you have completed the leak check put the tubes back to their original location. That is to say put the pump back into the circuit so that it will work when you turn it on.
8. Calibrate the DAC's in the calibrator.
9. Put a digital meter onto the recorder output on the back of the calibrator. Use the best meter that you have. If you don't have a meter & you do have a data logger that can display raw voltage then use the data logger, and configure it to "display raw voltage. Most data loggers have good resolution & you can use that for the calibration.
10. Push "SETUP_MORE_DIAG_ENTER_NEXT" to "DAC CALIBRATION_ENTER_ADC_ENTER".
11. Read the voltage that your meter is displaying (or data logger). Adjust R27 on the v/f card to make the number on the front of the calibrator match the number on the meter. Note, that the number on the meter is not going to change, the number on the analyzer is the one that is going to change. Push "ENTER".
12. Read the voltage that your meter is displaying. Adjust R31 on the v/f card to make the number on the front of the calibrator match the number on the meter. Note, that the number on the meter is not going to change. Push "ENTER".
13. The DAC's are now calibrated.
14. Setting up for measuring MFC flows.
15. If you have not yet removed the cover from the calibrator do so now.
16. We recommend that you measure the flows through the mass flow meters and the write down your results onto the table that is provided in this service note (table 2). What we would suggest what you do is to make several copies of table 2 & have some for spares for later use. Once you have measured all the flows, you can now look at the data and decide if you need to make any corrections to the look up table or not.
17. Look at the MFC's and see what range the MFC are that you have in your calibrator. The standard MFC's are 10 LPM Dilution and 100 cc/min Cal gas MFC's. Write down on the tables what the MFC ranges are.
18. Put the calibrator into STANDBY, by pushing the STANDBY button on the front panel. You should have STANDBY in the upper left-hand corner of display.
19. Goto the rear panel of the calibrator and use a T and a reducer to jumper dilution air to the port 1 calibration gas input. This air is going to be used for the gas flow through both the dilution MFC and the CAL gas MFC for the Measurementation of the flow through the MFC's. See diagram page 8.
20. Place your flow meter onto the cal gas output of the calibrator. You should not measure any flow. If you measure any flow you have a valve leaking in the calibrator. To figure out what valve is leaking remove the tube that is going to the cal gas input port 1 and cap the tube so that the air stops leaking. Now measure the flow at the rear panel again. If the flow stopped then you have a leaking valve at the cal gas manifold. If the air did not stop then put the air back to the port 1 input an remove the dilution air input from the rear panel. If the flow stops then you have a leaking dilution air input valve.
21. Fix this problem before you continue on with your MFC calibration.
22. Press "SETUP_MORE_DIAG_ENTER_NEXT" to "MFC CALIBRATION_ENTER"
23. Now you can select either MFC 1 or MFC 2. MFC 1 is the larger dilution MFC and MFC 2 is the smaller CAL gas MFC. Select MFC 1.

24. You should now see the following on the front panel of the calibrator

    DIAG MFC 0) DIL DRV=0; FLW=0.000
    PREV DRIVE FLOW ON PRNT EXIT

25. You are now at the 0 drive voltage point on the MFC.
26. Push the button under OFF & turn the MFC ON.
27. Even though the MFC is ON there is no drive voltage to the MFC. This means that you should have very little flow through the MFC. All MFC's "leak" when they are at zero. The spec from the manufacture is <2% of the full scale of the MFC. Measure the flow at the CAL gas output port of the calibrator. Look at the table 2 that you made for this MFC and calculate what 2% of full scale is and see if this MFC is leaking an acceptable amount.
28. Press EXIT and now turn on MFC 2.
29. Again the leakage on MFC 2 should be <2% of full scale. Write this number down onto your calibration table 2.
30. Once you have established that the MFC's are not leaking too much you can now do the MFC Measurementation.

31. Measuring MFC flows.

32. Now push the NEXT button until you get to a drive voltage of 5000 MV and the look up table on the front panel of the calibrator is @ the full scale of the MFC. You should see:

    DIAG MFC 20) CAL DRV=5000; FLW=0.1000
    PREV DRIVE FLOW ON PRNT EXIT

33. When you look at this menu you can see that the MFC is ON, that the drive voltage is at 5000 MV (full scale) and that the MFC is at 100 cc/min (full scale).
34. Read the flow at the rear panel of the calibrator (test gas output) and write your readings down in your table 2 on the 5000 MV drive voltage line under the Measured flow (LPM) column. If your flow meter only takes one reading then you are going to want to measure the flow at least 3 times (preferably 5 times) and take the average of the number of readings. We use a BIOS mass flow meter and it takes the average of 10 readings of the flow and displays that reading. This way you are eliminating the possible error of only one reading.
35. Now press the previous button and goto the 4750 MV drive voltage and measure the flow at the rear panel. Again write this flow onto your table 2 on the 4750 MV drive line.
36. Press the previous button and again measure the flow at the rear panel.
37. Continue doing this until you have measured all 20 flows at all 20 drive voltage points.
38. When you are done with this MFC press the ON button and turn the MFC off. Now push EXIT_MFC 1. Now turn on MFC 1 and again measure all the flows at the rear panel for all 20 of the drive voltages.
39. When you are done with measuring all the flows turn the MFC off and goto the next step.

40. Doing temp and pressure compensation.

41. If you are using a flow meter that does not have pressure & temperature compensation to 0°C & 29.92 in-hg then goto the next step. If you are using a flow meter that is using temperature & pressure compensation then goto step 46, "Calculating % Error".
42. Measure the room temperature, using an NIST traceable thermometer.

43. Measure the Pressure in the room. As with temperature, it is important to use an NIST traceable barometer.
44. If you are using a bubble-type flow-meter, best results are obtained when the correct volume for the bubbles is selected. The volume should allow you to measure the bubble for at least 30 seconds per measurement. This minimum time helps reduce errors in measurement. At least three measurements should be made at each flow, and the times averaged in order to further reduce error.
45. Use the following formula for correction to STP, (0°C and 29.92"-Hg.):

$$\text{Mass Flow} = \frac{\text{Vol. (cc)}}{\text{Time (Min)}} \times \frac{(P-P_v)}{29.92} \times \frac{273}{(273+T)}$$

Where P = Atmospheric Pressure, (in. of Hg)
Pv = Vapor Pressure of Water, (in. of Hg)
T = Temperature of gas, (°C).

The vapor pressure of water can be found in table 1.

Table 1. Vapor pressure of water

°C	In. of Hg.		°C	In. of Hg.
15	.52		24	.88
16	.54		25	.94
17	.57		26	.99
18	.61		27	1.06
19	.65		28	1.12
20	.69		29	1.18
21	.73		30	1.25
22	.78		31	1.33
23	.83		32	1.40

46. Once you have made your pressure & temperature compensation to the flow readings enter them onto your table 2 under corrected flows (LPM).
47. Calculating % Error.
48. Using the formula below calculate the % error that each flow point is off and see how much error that the MFC's have at each point.

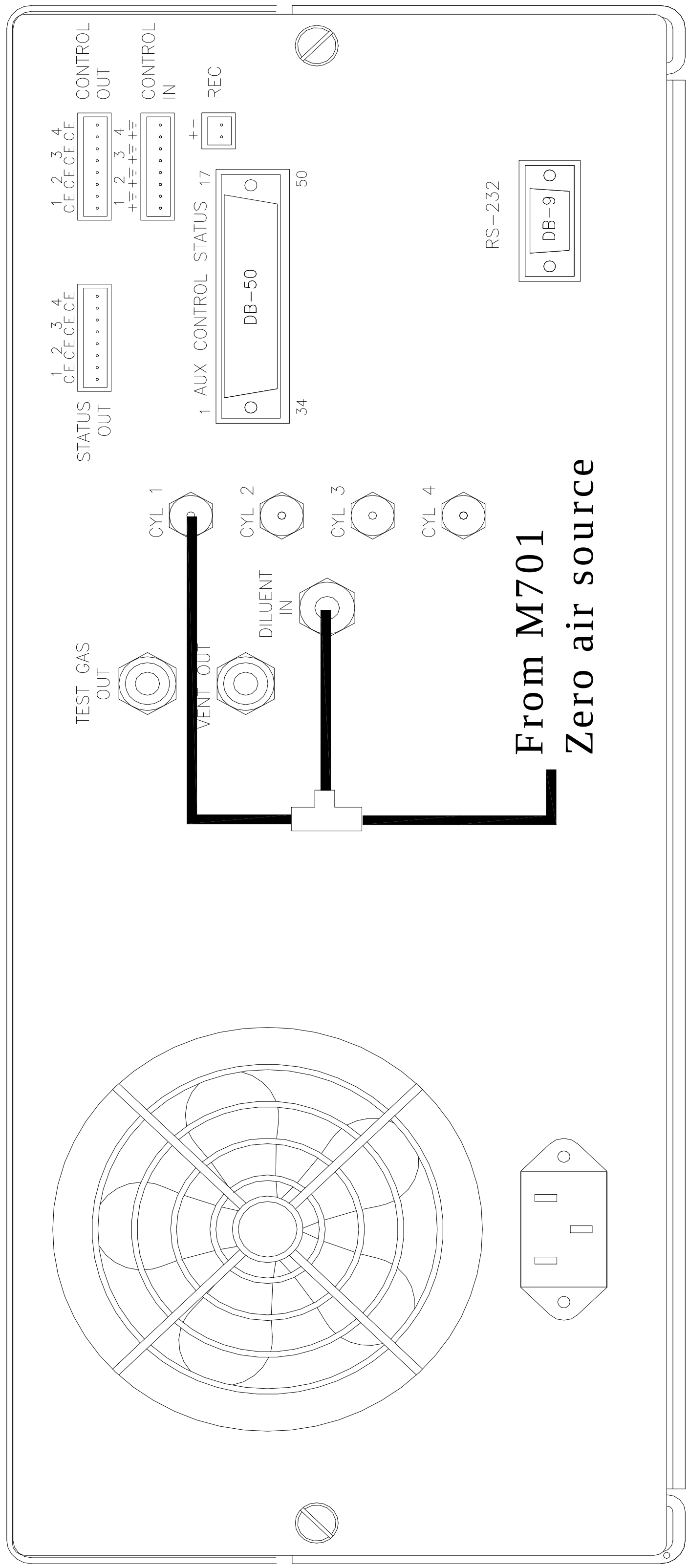
$$\frac{(\text{Measured flow (LPM)}) - (\text{Target flow (LPM)}) \times 100}{\text{Full scale Flow}} = \%\ \text{full scale}$$

49. Compare the % Error that the dilution MFC has compared to the Cal gas MFC has. If the % Error for both the Cal gas MFC is the same % Error as the Dilution MFC then check to ensure that your pressure and temperature compensation is the right compensation factor.
50. If you find that the % Error is not enough that you need to make any changes then you are finished.

51. If you find that the % Error is enough that you are going to have to make changes then goto the next step
52. Adjusting Flows.
53. Go back into the DIAG function & go into the MFC 1 look up table. Push the NEXT button until you come to the flow that you need to change. Press the FLOW button & enter in the flow that you measured & press ENTER. Enter in all the flows that you are going to change & then exit back out to the sample menu.

Table 2. MFC drive voltage to flow table.

Drive (mV)	Target Flow (LPM)	Measured flows (LPM)	Corrected flows (LPM)	% Error
0				
250				
500				
750				
1000				
1250				
1500				
1750				
2000				
2250				
2500				
2750				
3000				
3250				
3500				
3750				
4000				
4250				
4500				
4750				
5000				



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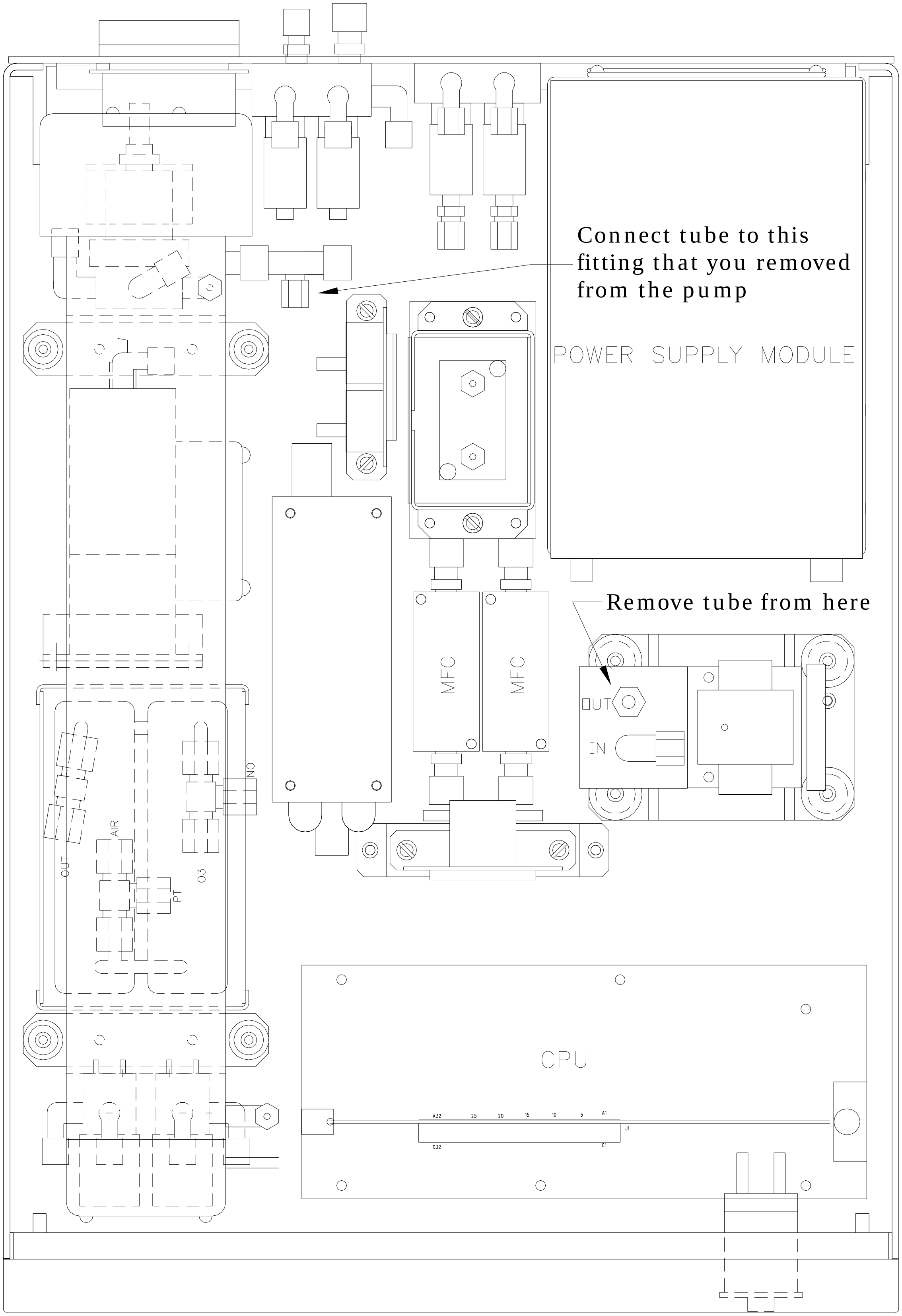

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