THE EFFECT OF EXTENSION TUBING VOLUME AND VACUUM ON SAMPLE FLOW FOR RAE SYSTEMS INSTRUMENTS

INTRODUCTION

Tables 1 - 3 show the wait times that need to be considered when using extension tubing, to allow for the gas sample to reach the instrument. The times assume that the sample line has not been pre-filled with the air sample of interest.

Results

Only the smallest diameter tubing (1/8" O.D., which is 1/16" I.D.) causes a substantial pressure drop and reduced flow rate. Wider 4 mm O.D. (1/9" I.D.) or 3/16" O.D. (1/8" I.D.) can cause some pressure drop at longer lengths or if it has many bends (see Table 4 at end of next page). For the UltraRAE, we recommend using the wider 4 mm Teflon tubing (p/n 411-0005) to reduce strain on the pump and to give better consistency. The times should be added to the standard measurement times for the UltraRAE compound of interest. For the MiniRAE, the delay time data are minimum measurement times that may be exceeded; for the UltraRAE, it is important to have exact timing.

Tubing Materials

Never use Tygon or rubber tubing as extension probes when measuring VOCs, because these materials strongly absorb VOCs. The higher the boiling point of the compound, the greater the effect. Short Tygon connections are acceptable. For benzene, connections less than 6" have little effect at the flow rates typical for MiniRAE and UltraRAE, although it is preferable to keep them less than a few inches. Teflon or metal tubing absorbs the least VOCs; stiff polyurethane is a good second choice if the formers are not available.

Pump Flow Curves

Figure 1 below shows curves of flow vs. inlet vacuum for RAEGuard and ppbRAE. The MiniRAE 2000 has the same flow characteristics as the ppbRAE. Although the pumps can draw down to about 100" of H_2O (74 mm Hg) without leaks, this creates a significantly reduced flow rate. We recommend not applying greater than 40" of H_2O (30 mm Hg) vacuum to avoid excessive strain on the pump and reduce the chance of leaks developing when parts are worn.

Table 1.

UltraRAE/MultiRAE @ 300 cc/min	Nominal					Volume			Delay Time @ 300 cc/min				
Tubing Type	in OD	in		cm		CCs per			Seconds per				
		OD	ID	OD	ID	cm	m	ft	1′	10′	30′	100′	300′
Teflon Extension Probe	1/8	0.125	0.063	0.318	0.159	0.020	2.0	0.60	0.1	1	5*	29*	–
Teflon Mini/UltraRAE	4 mm	0.157	0.110	0.400	0.280	0.062	6.2	1.88	0.4	4	11	38	113
Metal or Teflon	3/16	0.188	0.127	0.476	0.323	0.082	8.2	2.49	0.5	5	15	50	149
Metal or Teflon	1/4	0.250	0.190	0.635	0.483	0.183	18.3	5.58	1.1	11	33	112	335
Metal or Teflon	5/16	0.313	0.248	0.794	0.630	0.312	31.2	9.50	1.9	19	57	190	570
Metal or Teflon	3/8	0.375	0.311	0.953	0.790	0.490	49.0	14.94	3.0	30	90	299	896
Metal or Teflon	1/2	0.500	0.436	1.270	1.107	0.963	96.3	29.36	5.9	59	176	587	1762

* Corrected for decrease in flow rate due to pressure drop in tubing

Table 2.

MiniRAE @ 500 cc/min	Nominal					Volume			Delay Time @ 500 cc/min				
Tubing Type	in OD	in		cm		CCs per			Seconds per				
		OD	ID	OD	ID	cm	m	ft	1′	10′	30′	100′	300′
Teflon Extension Probe	1/8	0.125	0.063	0.318	0.159	0.020	2.0	0.60	0.1	1	4*	20*	–
Teflon Mini/UltraRAE	4 mm	0.157	0.110	0.400	0.280	0.062	6.2	1.88	0.2	2	7	23	68
Metal or Teflon	3/16	0.188	0.127	0.476	0.323	0.082	8.2	2.49	0.3	3	9	30	90
Metal or Teflon	1/4	0.250	0.190	0.635	0.483	0.183	18.3	5.58	0.7	7	20	67	201
Metal or Teflon	5/16	0.313	0.248	0.794	0.630	0.312	31.2	9.50	1.1	11	34	114	342
Metal or Teflon	3/8	0.375	0.311	0.953	0.790	0.490	49.0	14.94	1.8	18	54	179	538
Metal or Teflon	1/2	0.500	0.436	1.270	1.107	0.963	96.3	29.36	3.5	35	106	352	1057

* Corrected for decrease in flow rate due to pressure drop in tubing

Table 3.

RAEGuard @ 650 cc/min	Nominal					Volume			Delay Time @ 650 cc/min				
Tubing Type	in OD	in		cm		CCs per			Seconds per				
		OD	ID	OD	ID	cm	m	ft	1′	10′	30′	100′	300′
Teflon Extension Probe	1/8	0.125	0.063	0.318	0.159	0.020	2.0	0.60	0.1	1	3*	13*	–
Teflon Mini/UltraRAE	4 mm	0.157	0.110	0.400	0.280	0.062	6.2	1.88	0.17	1.7	5	17	52
Metal or Teflon	3/16	0.188	0.127	0.476	0.323	0.082	8.2	2.49	0.23	2.3	7	23	69
Metal or Teflon	1/4	0.250	0.190	0.635	0.483	0.183	18.3	5.58	0.5	5	15	51	154
Metal or Teflon	5/16	0.313	0.248	0.794	0.630	0.312	31.2	9.50	0.9	9	26	88	263
Metal or Teflon	3/8	0.375	0.311	0.953	0.790	0.490	49.0	14.94	1.4	14	41	138	414
Metal or Teflon	1/2	0.500	0.436	1.270	1.107	0.963	96.3	29.36	2.7	27	81	271	813

* Corrected for decrease in flow rate due to pressure drop in tubing

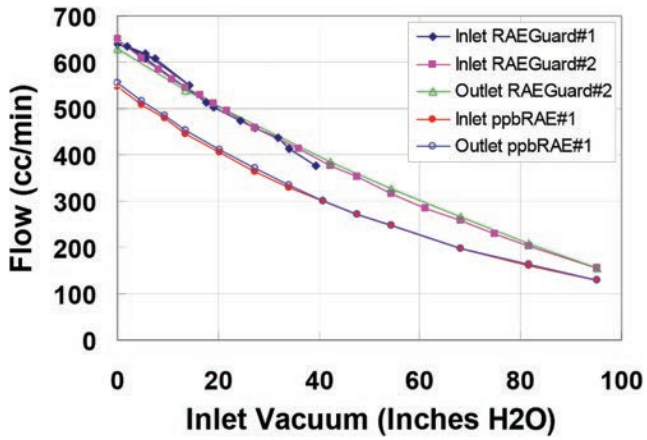

Figure 1. Flow-vacuum curves for ppbRAE (lower curve) and RAEGuard (upper curve).

Pressure Drop in Tubing

Pressure drop in extension tubing depends on the inner diameter, the number and severity of bends, and total flow rate. Typical pressure drop for different types of tubing and flow rates are summarized in Table 4 below. The "Max Flows" in Table 4 are the nominal flows with no tubing or only short sections. To calculate the flowrate with tubing attached, use the value in Table 4 to estimate the vacuum in the tubing and then read the flow drop off of Figure 1. For example, a 10-foot section of 1/16th-inch I.D. tubing will cause a pressure drop of 1.3 x 10 = 13 inches of water in a ppbRAE or MiniRAE with nominal flowrate of 500 cc/min. Figure 1 shows that at a vacuum of 13" H_2O the flowrate drops from 540 to 450 cc/min. For 100 feet of 2.8-mm I.D. tubing a RAEGuard with nominal 650 cc/min flow will result in 0.1 x 100 = 10" H_2O vacuum and thus a flow drop from 650 to about 550 cc/min. These estimates give only a rough idea of the flow rates expected and will vary with the user's exact configuration. Because of the high pressure drop in 1/16th-inch I.D. tubing, we recommend using this tubing only if the length is less than a few meters, and using wider-bore tubing for longer distances.

Table 4. Pressure drop in various sizes of tubing.

Tubing I.D. (inches)	Tubing I.D. (mm)	Max flow 500 cc/min	Max flow 650 cc/min
1/16th	1.6	1.3 "H_2O/ft.	1.6 "H_2O/ft.
1/9th	2.8	0.10 "H_2O/ft.	0.13 "H_2O/ft.
1/8th	3.2	0.083 "H_2O/ft.	0.10 "H_2O/ft.

Maximum Vacuum or Pressure

The maximum vacuum obtained on most RAE instruments with a built-in pump (including MiniRAE 2000, ppbRAE, RAEGuard, VRAE and MultiRAE Plus on high pump speed) is about 280 mm Hg (150 inches of H_2O). On the outlet side, these instruments (except MultiRAE, which has no outlet port) can push against a pressure of up to about 6 psi or 170 inches of H_2O (310mm Hg). Note that the flow is close to zero, or very low, at these maximum values, and RAE Systems does not recommend operating the pump for long periods under such conditions.