UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711
OFFICE OF AIR QUALITY PLANNING AND STANDARDS

Technical Note- Clarifications and Guidance on Residence Time Determination

June 3, 2019

Some EPA Regional Offices and Air Monitoring Organizations have interpreted language in the QA Handbook for Air Pollution Measurement Systems: "Volume II: Ambient Air Quality Monitoring Program" EPA-454/B-17-001, January 2017, *Section 7.3.1 Design of Probes and Manifolds for Automated Methods, Residence Time Determination* differently. Because of this, a better explanation of how to determine and calculate the residence time of air pollutants within the entire ambient air sampling system is appropriate to ensure this process is performed correctly and consistently. OAQPS and the Regions agree the clarifications and guidance described in this technical memo will provide the necessary information to effectively determine ambient air sampling system residence time. These clarifications and guidance are effective immediately.

Therefore, the section entitled "Residence Time Determination" (currently page 6 of 17 of section 7 of the QA Handbook: https://www3.epa.gov/ttn/amtic/files/ambient/pm25/qa/Final%20Handbook%20Document%201_17.pdf through page 8 of 17, to "7.3.2 Placement of Probes and Manifolds" (of the same referenced section), is replaced with the following:

Residence Time Determination

No matter how nonreactive the sampling probe material may be, after a period of use, reactive particulate matter is deposited on the probe walls. Therefore, the time it takes the gas (sample) to travel from the probe inlet (ambient air) to the sampling device is critical. Ozone, in the presence of nitrogen oxide (NO), will show significant losses even in the most inert probe material when the residence time exceeds 20 seconds. Proper sample system designs indicate that a 10 second or less residence time is easily achievable.

Residence time is defined as the amount of time that it takes for a sample of ambient air to travel from the opening of the inlet probe (or cane), through the manifold, to the inlet of the instrument and is required to be less than 20 seconds for reactive gas monitors. The residence time of pollutants within the entire sampling system is critical. It is recommended that the cumulative residence time of each component of the sampling system, i.e. the probe, the manifold and sample lines from the manifold to the back of the instrument be less than 10 seconds (up to a maximum total allowable 20 seconds). It is important to determine the residence time in each portion of the sampling system. For example, if the volume of the manifold does not allow this residence time to be achieved, a booster pump/blower motor or other device (vacuum pump) can be used to decrease the residence time in that portion of the sampling system. It is also important to ensure the pressure drop be less than 1 inch of water measured in the manifold portion of sampling system to prevent the individual sampler pumps (in the monitors) from being overworked, but also to ensure that ambient air is being sampled.

Residence Time Determination Process

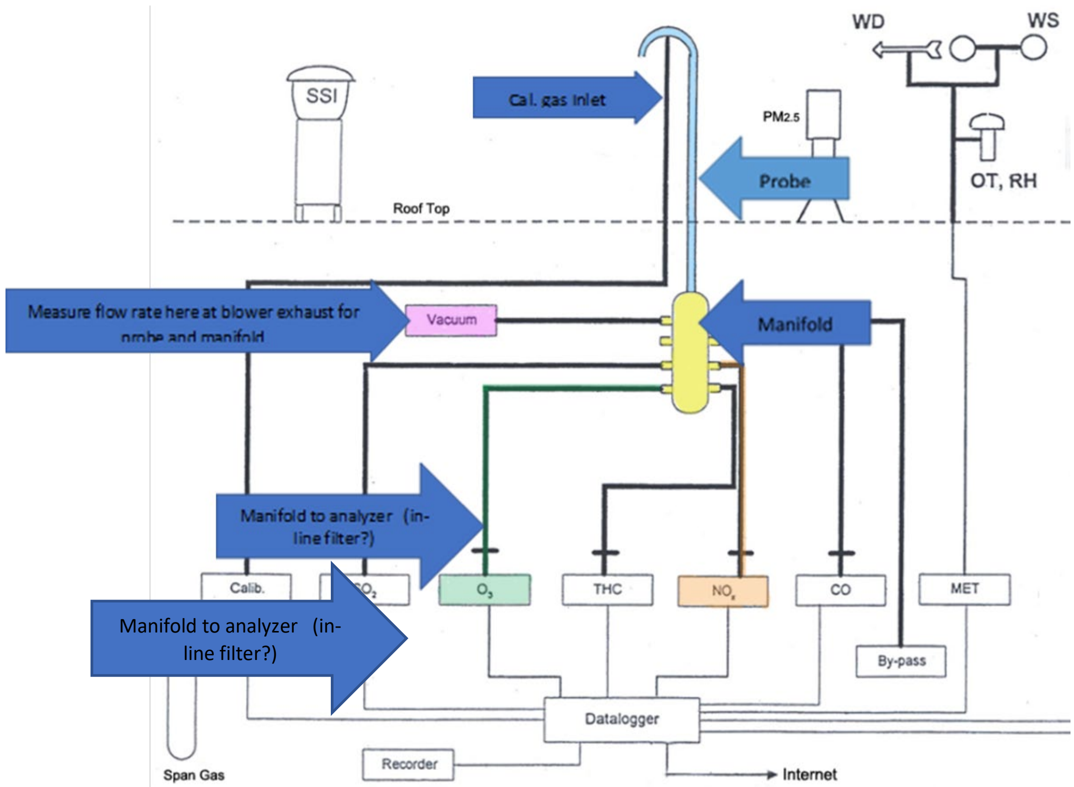
The residence time for a sampling system that contains multiple components (i.e. probe inlet, manifold, and analyzer sampling lines) can be determined utilizing the following spreadsheet:

CARB Res-Time Example.xls

All the components that make-up the sampling system must be measured individually to obtain the residence time including inside diameter of the probe/ manifold/ tubing, and lengths of each component measured. Flow rates in the probe/ manifold and for each instrument must also be separately measured. **When using the spreadsheet above (and attached below), the probe/manifold flow rate must be measured at the outlet of the booster pump/blower motor**. (It is possible to measure the flow rate elsewhere, but care must be taken to ensure the various flowrates and volumes of each component of the system be considered properly. The provided spreadsheet cannot be used if flow of the probe/ manifold is measured elsewhere.)

For the spreadsheet to calculate the sampling system residence time the following steps need to be performed.

- Separately obtain the internal diameter of the probe inlet line and manifold in millimeters (mm) and enter this on the spreadsheet.
- Separately obtain the length of the probe inlet line and manifold in meters (m) and enter this on the spreadsheet.
- Obtain the flow rate from outlet of the manifold blower/booster pump that the probe inlet line and manifold are connected to in liters per minute (lpm).
- For each analyzer connected to the manifold obtain the internal diameter (mm), length (m) of tubing used between the manifold and back of the analyzer. *Note: If there are multiple tubing diameters and lengths used for a given analyzer sampling line these need to be entered on the spreadsheet. Care should also be taken to consider the volume of any in-line filter holders here as well.*
- Obtain flow rate (lpm) for each analyzer and enter this on the spreadsheet.



PROBE RESIDENCE TIME - Multiple Diameters

Site Name: ______________________ Auditors: ______________ Date: __________

Booster pump flow = ____ LPM			Pollutant					
	Probe	Manifold	Manifold to Instrument	Manifold to Instrument	Manifold to Instrument	Manifold to Instrument	Manifold to Instrument	Manifold to Instrument
Material	Teflon	Glass	Teflon	Teflon	Teflon	Teflon	Teflon	Teflon
			T1 T2 T3	T1 T2 T3	T1 T2 T3	T1 T2 T3	T1 T2 T3	T1 T2 T3
ID (mm)			*	*	*	*	*	*
Length (m)			*	*	*	*	*	*
Flow (lpm)								
Time			*	*	*	*	*	*
Total Residence Time =								

Residence Time Calculation = $\frac{3.14(ID^2) \times LENGTH \times 0.015}{FLOW} = \frac{3.14 * radius^2 (mm) * LENGTH (m) * 60 (sec/min)}{FLOW (lpm) * 1000}$

Multiple Tubing Diameters Calculation*
*used for entry into the Audit Information System, where different diameters of tubing are present

= $((tubing\_2\ I.D./tubing\_1\ I.D.)^2 * tubing\_2\ length) + ((tubing\_3\ I.D./tubing\_1\ I.D.)^2 * tubing\_3\ length) + tubing\_1\ length$

Common Sample Line Diameters

Outside Diameter (in.)	1/8"	3/16"	1/4"	1/4"	5/16"	5/16"	3/8"	3/8"	1/2"	1/2"
Wall Thickness (in.) *	.030"	.030"	.030"	.062"	.030"	.062"	.030"	.062"	.030"	.062"
Inside Diameter (mm)	1.6	3.2	4.8	3.2	6.4	4.8	7.9	6.4	11.1	9.5

* "thin wall" is typically = 0.030", while "thick wall" is typically = 0.062"

Manifolds

O.D. (in.)	1.25"	2.0"
W.T. (in.)	.25"	.25"
I.D. (mm)	25.4	44.5
Length (m)	0.25	0.30

Data recorded and verified by: ______________ ______________

After the internal diameters, lengths and flow rates are entered on the spreadsheet for each component, the residence time for that component is calculated and displayed. After the parameters of the probe inlet line, manifold and each analyzer have been entered on the spreadsheet the total residence time will be calculated and displayed. This "total residence time" **should** be less than 10 seconds and **must** be less than 20 seconds.

Residence Time Spreadsheet Formulas/Equations

The spreadsheet uses the following formula/equation to calculate residence time for each component of the sampling system that may be present in any sampling configuration (for example, if a single sampling line is used from the instrument to collect outside ambient air- only consider the 3rd and 4th components below):

1) Residence Time in probe:

(sec) (*RT(probe))* = $\frac{3.14(ID^2) \text{ x Length x } 0.015}{\text{Total Flow}}$

$$= \frac{3.14 * \text{radius (mm)}^2 * \text{Length (m)} * 60 \text{ (sec/min)}}{\text{Total Flow (lpm)} * 1000}$$

Where:
3.14 = pi
ID = inside diameter of inlet probe, mm
Length = length of probe, m
Total Flow = flow rate of manifold blower or booster pump measured at its exhaust, plus total flow of each instrument, lpm:

2) Residence Time in manifold:

(sec) (*RT (manifold))* = $\frac{3.14(ID^2) \text{ x Length x } 0.015}{\text{Total Flow}}$

$$= \frac{3.14 * \text{radius (mm)}^2 * \text{Length (m)} * 60 \text{ (sec/min)}}{\text{Total Flow (lpm)} * 1000}$$

Where:
3.14 = *pi*
ID = inside diameter of manifold, mm
Length = length of manifold, m
Total Flow = flow rate of manifold blower or booster pump measured at its exhaust, plus total flow of each instrument, lpm:

3) Residence Time in sample line (between manifold and instrument:

(sec) *(RT (sample line))* = $\frac{3.14 (ID^2) \text{ x Length x } 0.015}{\text{Sample Flow of instrument/ analyzer}}$

$$= \frac{3.14 * \text{radius (mm)}^2 * \text{Length (m)} * 60 \text{ (sec/min)}}{\text{Sample flow of instrument/ analyzer (lpm)} * 1000}$$

Where:
3.14 = *pi*
ID = inside diameter of tubing used from manifold to instrument, mm
Length = length of tubing used from manifold to instrument, m
Flow = flow rate of analyzer, lpm

- *Note: If there are multiple tubing diameters and lengths used for a given analyzer sampling line these need to be entered on the spreadsheet. Care should also be taken to consider the volume of any in-line filter holders here as well.*

Total residence time (RT) = RT(probe)+ RT (manifold)+ RT (sample line)
(as described above)

Additional Considerations

It has been demonstrated that there are no significant losses of reactive gas (O3) concentrations in conventional 13 mm inside diameter sampling lines of glass or Teflon if the total sample residence time (which also includes the RT in the sample line between the manifold and the instrument) is 10 seconds or less. However, when the sample residence time exceeds 20 seconds, loss is detectable, and at 60 seconds the loss is nearly complete.

The air flow through the manifold must not be so great as to cause the pressure inside the manifold system to be more than one inch of water below ambient. This is important to prevent the analyzer/monitor pump from being over worked to maintain proper flows and the system from leaks that may cause ambient air dilution. The following assessment can be made to make this determination. Construct the sampling system/manifold. Use a pitot tube to measure the flow of the sample inside the manifold as close to the blower as possible. At the same time, attach a water manometer to a sampling port. Turn on the blower and measure the flow rate and the vacuum. (Remember to allow for the air demand of the instrumentation and confirm the instrument(s) have adequate flow). Adjust the blower flow rate to fit between these two parameters. If this is impossible, the diameter of the manifold is too small.

If the manifold that is employed at the station has multiple ports, then placement of the instrument lines can be crucial. If a manifold like the Figure shown above is used, ambient air flows down the center tube and then travels up on both sides of the manifold to the analyzer ports. It is suggested that instruments requiring lower flows be placed towards the bottom of the manifold. The general rule of thumb states that the placement of the calibration line (if used) should be in a location such that the calibration gases flow past the instruments before the gas is evacuated out of the manifold. The Figure above illustrates a potential introduction port for the calibration gas which would enter near the top of the probe.