#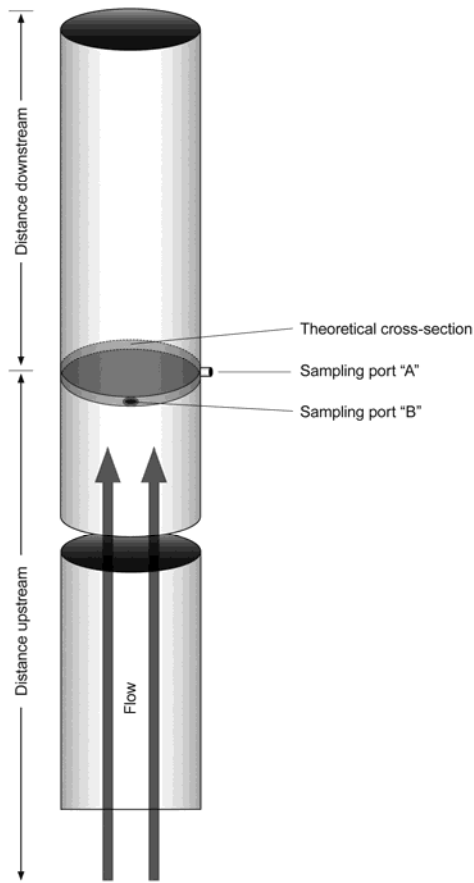 If a VOC (constant rate; no nozzle) method is applied to a condition with water or aerosol droplets there is a significantly low bias to the results

Use an isokinetic sampling train to eliminate the bias

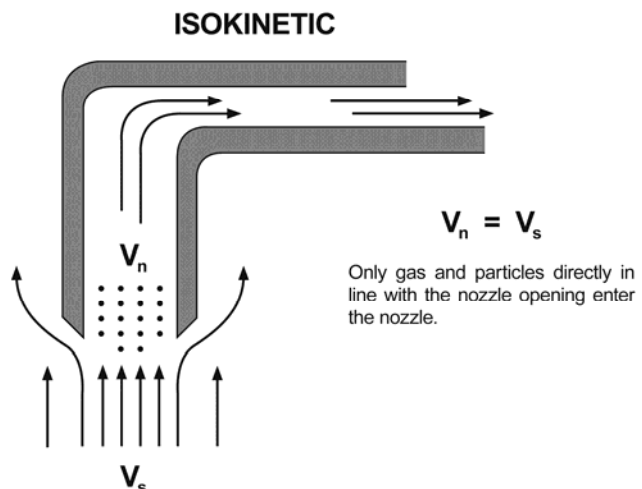### *What is isokinetic sampling?*

Flue gas is removed from a pipe by traversing at least two axes across the pipe. A probe with a nozzle is inserted perpendicular to the flow.   The nozzle is pointed into the gas stream. The nozzle is sized according to the velocity of the flue gas.
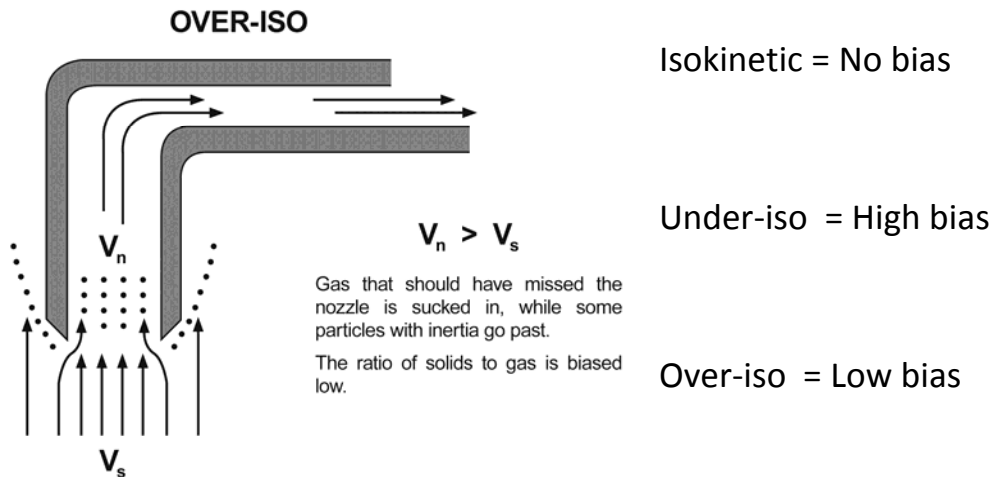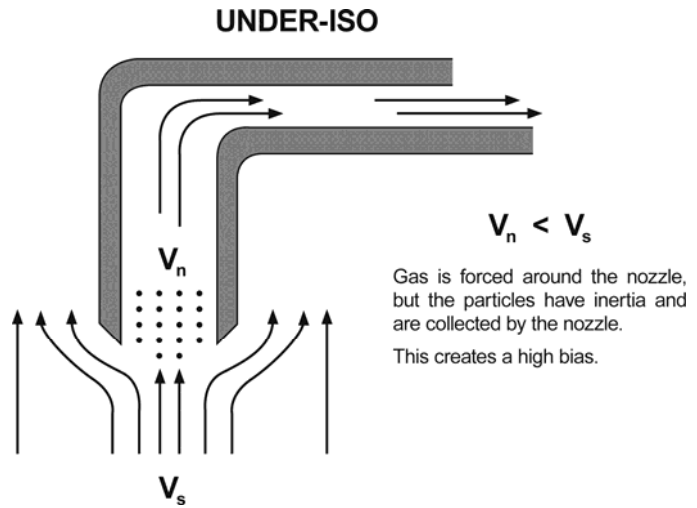
Usually 8 to 24 different locations (points) within the stack are sampled on a plane perpendicular to stack flow. The location and position of the sampling points used during the traverse is determined based on: 1) the size of the pipe, 2) straight run upstream of the sampling point, and 3) straight run downstream of the sampling location. Generally, the greater the upstream undisturbed straight run the fewer traverse points required.   Sampling is most often conducted by keeping the nozzle at each traverse point an equal amount of time equally distributed over the time of the sampling event. For instance, twelve (12) five (5) minute points sampled over 1 hour is a frequent scenario.

Why might there be bias?

At each sampling point, the local velocity of the flue gas (Vs) is measured and the flow rate of the sampling train is adjusted so that the flow within the nozzle (Vn) is the same velocity as the gas in the duct you are sampling. This condition is called isokinetic sampling.   If the velocity of the gas in the nozzle is too slow or

ISOKINETIC

$$V_n = V_s$$

Only gas and particles directly in line with the nozzle opening enter the nozzle.

V_n

V_s

too fast, you cannot collect a representative sample. If the velocity is too slow, this is called under-iso conditions. Some gas in-line with the nozzle has to divert and go around the nozzle because the flow in the nozzle is too slow. This represents a high bias for particles in the stack because the particles have inertia. Therefore, they continue on their previous course and enter the nozzle. So, the mix of particles to gas within the nozzle is higher than in the stack gas – a high bias. Conversely, if the flow in the nozzle is too high, then gas that would have gone past the nozzle is sucked into the nozzle, but the particles associated with that gas hit the outside of the nozzle and don't end up in the sample. Gas that didn't belong in the sample gets pulled in, but the corresponding particles did not. This creates a low bias because the extra gas dilutes the sample.

UNDER-ISO

$V_n < V_s$

Gas is forced around the nozzle, but the particles have inertia and are collected by the nozzle.

This creates a high bias.

V_n

V_s

OVER-ISO

$V_n > V_s$

Gas that should have missed the nozzle is sucked in, while some particles with inertia go past.

The ratio of solids to gas is biased low.

V_n

V_s

Isokinetic = No bias

Under-iso = High bias

Over-iso = Low bias

* V_n = flow rate of sampling train ÷ area of the nozzle (sq. ft.)

How is a test run conducted?

The sampling points are arranged within the stack such that each point is within an area created by theoretically slicing the cross-section both across the stack and in circles. Each section has the same area as every other section. Because the circumference of the outer sections is greater than the inner sections, the outer sections are thinner, and the outer points are closer together. Notice that none of the points are at the center of the duct.

•A6
•A5
•A4

B6 B5 B4   B3 B2 B1

•A3
•A2
•A1
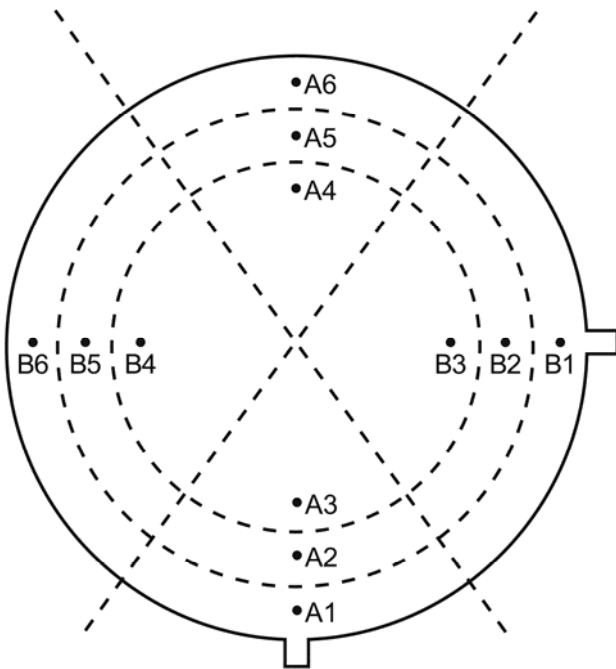
Because the velocity profile of the gas in the duct is not uniform, you must measure the duct velocity (v_s) at each sampling point and then adjust the sample flow rate up or down until the velocity in the nozzle (V_n) matches V_s. The calculations required to determine the nozzle velocity on-the-fly are pretty complicated. Therefore a laptop loaded with a pre-programmed XL sheet is used to do this. An orifice based flow meter is installed in the sampling train at the exit of the pump. This acts kind of like a speedometer. You'd be hard pressed to maintain the speed limit if all you had to look at was your odometer. In an isokinetic sampling train the volume meter is like the odometer and the orifice meter is the speedometer. A traverse usually follows a script similar to this:

1. Leak check sampling train

2. Place probe in stack such that the nozzle is at point A1 – allow things to equilibrate for a minute.

3. Measure impact pressure of the gas using a pitot tube and measure the gas temperature.

4. Input this data to the spreadsheet. The spreadsheet gives you the setting for the orifice meter.

5. Record initial volume meter reading. Turn on the pump. Adjust the sample train flow rate to the setting.

6. Maintain this flow rate for 5 minutes.

7. Move the train until the nozzle is at point A2. Keep the pump running while you do this.

8. Repeat steps 3-6 until you have completed all of the points for axes A.

9. Remove the probe from the stack. Leak check it.

10. Move to Port B. Repeat steps 2-9.

How does this apply to VOCs?

As illustrated in the above discussion inertia creates the potential for bias in the sampling. Therefore, any chemical or physical target for the testing that might exhibit inertia needs to be sampled

isokinetically. Particulate (suspended solids) must be sampled isokinetically. However, water soluble compounds must also be sampled isokinetically if there are water droplets in the stack. Also, aerosols must be sampled isokinetically. Aerosols often form when a VOC is carried in a gas stream that cools as it travels down the duct. At the hot end of the duct, the VOC saturation concentration is high, but saturation concentration decreases with temperature. If the saturation concentration drops below the actual concentration in the duct VOCs condense and form aerosol droplets. Droplets in the stack, unless they are very small, behave much like particulate.   VOC methods usually specify a constant rate sample and they don't use a nozzle. Most sample perpendicular to the flow instead of pointed into the flow. This is equivalent to sampling in an over-iso condition. So, any aerosol droplets or water soluble VOC held within a water droplet are under-represented in the sample. Thus**, if a VOC method is applied to a condition with water or aerosol droplets there is a significantly low bias to the results**. There are necessary modifications to this sampling arrangement that must be made. They will be situation dependent. Please call to get guidance for your particular situation.