TOTAL LAG TIME

Single line Application

By Glenn Sheffield

Total lag time for a sample loop is the total internal volume of the transport tubing and conditioning devices divided by the flow rate in consistent units as follows:

t = V÷f
where t = time lag (minutes)
V = volume of components (cm^3)
f = sample flow (cm^3/min)

This equation should be modified to allow for first order lag and a compressibility factor for a gas sample. First order lag is the amount of time required to displace enough volume through a sample-conditioning device to ensure the sample is representative of a process change i.e., mixing time. This is generally a factor of 3 times the volume.

The compressibility factor for gas reflects the relative density of molecules in a given volume, which is proportional to the pressure of the sample. Taking the absolute pressure of the sample gas and dividing by 14.7 PSIA calculate the compressibility factor. Thus the higher the pressure of a gas sample the greater the time required to transport it to the analyzer or to evacuate the sample from a conditioning device.

The temperature factor is not included for simplicity and because it has a negligible effect in the temperature range of most field applications.

The lag time equation for a liquid conditioning device is:
t = V x 3÷f
where **3 =** factor for first order lag

The equation for a gas-conditioning device is:
t = (V x 3÷f) x Z
where **Z** = compressibility factor of gas
= (System pressure psig + 15 psia) / 15 psia

Example: Compressibility factor for 15psig sample pressure would be:

15 psig + 15 psia ÷ 15 psia = 2

VOLUME CALCUATIONS

TRANSPORT LINE
Calculating the volume of transport tubing is simplified by using the known volumes of common tubing. The volumes of standard size tubes are as follows:

0.125 inch (⅛") OD tube:	**1cc/ft**
0.25 inch (¼") OD tube:	**5cc/ft**
0.50 inch (½") OD tube:	**30cc/ft**

The calculation for the lag time of tubing is:

t = (V x L) ÷ f x Z
where t = time lag of transport tube (minutes)
vol = volume of sample (cc/ft)
L = length of supply tubing (feet)
f = sample flow (cc/min)
Z = compressibility factor for gas

SAMPLE CONDITIONING DEVICE
The calculation for the volume of a sample-conditioning device is as follows:
$V = \pi r^2 h$
where **π =** 3.14
r^2 = radius of the device squared
h = the length of the device

WORKING EXAMPLE

An analyzer has a single line sample transport system with 100ft. of ¼" tubing from a regulator set at 15psig. Due to the relatively clean sample the only sample-conditioning device is a 3inch high x 2.5inch wide filter. The flow to the analyzer and bypass rotometer is a total of 1000 cc/min.
What is the lag time of the transport system? What is the lag time of the filter housing? What is the total lag time? Is this considered excessive?

TRANSPORT LAG TIME
t **= (vol x L) ÷ f x Z**
= 5cc/ft x 100ft.= 500cc ÷ 1000cc/min = 0.5 minutes (30 seconds) for a liquid sample.

For gas sample, **Z** = (System pressure psig + 15 psia) / 15 psia.
= (15psig + 15psia) / 15psia = 2 (14.7 psi ≈ 15 psi)
so **t =** (5cc/min x 100 ft) ÷ 1000cc/min x 2 = 1.0 minute (60 seconds for gas)
The transport lag time is 30 seconds for liquid and 1 minute for gas.

CONDITIONING DEVICE LAG TIME
Dimension for filter: 3 inch high by 2.5 inch wide.

Area = $\pi r^2 h$

$\pi = 3.14 \approx 3$

Converting to consistent volume units (cm),

r = D/2 = 2.5 inch ÷ 2 = 1.25 inch x 2.5cm/inch = 3.1 cm ≈ 3

h = 3 inch x 2.5 cm/inch = 7.5 cm

Area - $\pi r^2 h$ = 3 x 9 x 7.5 = 202.5 ≈ 200 cm^3

200 cm^3 x 3 (mixing factor) = 600 cm^3

t = V x 3 / f x Z

= 200 cm^3 x 3 / 1200 cc/min = .50 minutes = 30 seconds for liquid

= 200 cm^3 x 3 / 1200 cc/min x 2 (compressibility for gas) = 60 seconds

T (total) = sample transport + conditioning lag
= 30 seconds + 30 seconds for liquid or
= 60 seconds + 60 seconds for gas

The rule of thumb is a maximum of 1 minute for transport and 30 second conditioning time.

The following is a comparison of the common filter used for the example above and the Sheffield kinetic separator. The same flow rates and pressures are assumed and thus only the dimensions are changed.

Dimension for Sheffield Separator:

First Chamber: = 35 cm^3

Polishing Chamber: =31cm^3

No mixing lag is necessary because the narrow dimensions of the chambers allows the separator to displace sample at a rate similar to tubing which requires not mixing lag.

66cm / 1200 cc/min.= .055 min. = 3.3 seconds for liquid
Compressibility factor for gas = 2 x 3.3 seconds = 6.6 seconds