Autodilution AccuSizer® SPOS System

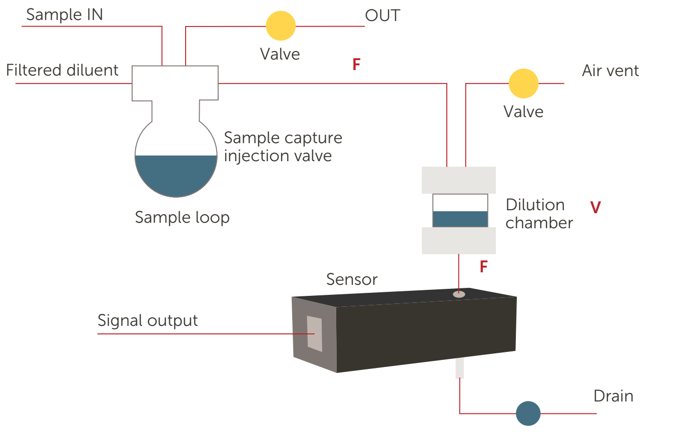

Figure 1. Simplified schematic diagram of a type I autodilution system (single-stage, "continuous-decay" dilution), including an optional sample capture/injection valve.

HOW AUTODILUTION WORKS

The automatic dilution system described in this document includes an input, output, dilution chamber, sample material, and diluent. A known quantity of sample material is injected into the dilution chamber. Filtered diluent flows into the dilution chamber, mixes with the sample material, and continuously dilutes the initial concentration. The diluted sample then flows out of the dilution chamber and through the sensor for particle size and count analysis.

SINGLE-STAGE AUTOMATIC DILUTION

Single-stage automatic dilution uses a small quantity of concentrated sample suspension, which is added to a given volume of clean (filtered) diluent fluid in a "dilution chamber," resulting in a volume, V, of diluted sample suspension. Additional dilution of the latter is achieved by adding clean diluent fluid to the stirred contents of the dilution chamber at a fixed, known flow rate, F. Diluted sample suspension is thereby forced to exit the chamber at the same flow rate, causing it to pass through the SPOS sensor and to be analyzed. The particle concentration in the sample fluid exiting the chamber falls continuously with time. Analysis of the sample suspension commences when the particle concentration falls below an appropriate, preset value.

Filtered diluent first flows through the dilution chamber and is counted to assure an acceptable background count level. The "acceptable" value depends on the specific particle sizing application and the starting threshold diameter, d_0, (i.e., minimum diameter to be measured). The flow rate chosen to determine both the background concentration and the particle size distribution, PSD, for the diluted sample suspension is typically 60 mL/min. The value of F can be increased to 100 – 150 mL/min in the "fast-flush" mode in order to hasten the process of flushing the dilution chamber and the associated fluidics. When the background particle concentration falls below the indicated value, flushing stops and the system is ready for automatic sample dilution.

An appropriate quantity (typically 25 µL to 1 mL) of concentrated sample suspension is injected into the diluent fluid residing in the dilution chamber. In the case of the laboratory version of the AccuSizer® AD system, injection is accomplished by pipetting the desired volume of sample suspension directly into the dilution chamber through a side port. In the case of a modified AccuSizer AD system, containing a sample capture injection valve (seen in Figure 1) the volume of sample suspension captured in the "sample loop" is injected mechanically into the diluent fluid flow path by actuation of the valve. This action causes the captured volume of sample suspension to be injected quickly into the stirred contents of the dilution chamber by the flow of fresh diluent fluid.

Automatic dilution of the particle suspension residing in the dilution chamber is achieved by continuously adding fresh diluent to the chamber at the designated flow rate as shown in Figure 1. The time at which the concentrated sample suspension has been completely injected into the dilution chamber is defined as t = 0. The continuous addition of fresh diluent fluid to the contents of the dilution chamber causes the diluted sample suspension to exit the chamber and enter the SPOS sensor at the same flow rate and the particle concentration in the suspension to decay continuously in time, according to the exponential law,

$C(t) = C_0 \exp(-t/\tau)$ *Equation 1*

where t is the "residence time" of the dilution chamber, given by:

$\tau = V/F$ *Equation 2*

The time behavior of the particle concentration in the sample fluid exiting the chamber and passing through the sensor is shown in Figure 2.

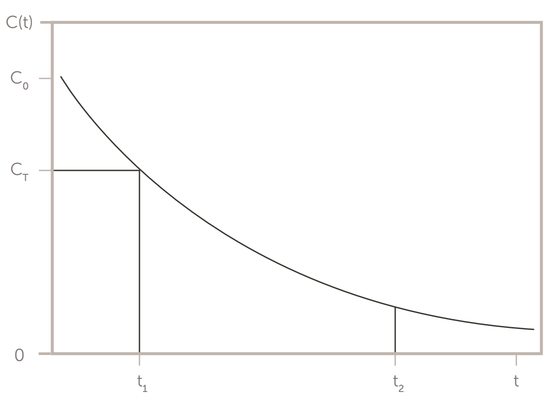

Figure 2. Particle concentration, C(t), in the diluted sample suspension that exits the dilution chamber plotted versus time (t) for single stage autodilution.

Data collection automatically begins for the designated length of time, T, when the particle concentration falls below the desired target value, C_T. This time is defined as time $t = t_1$. Data collection ends at time $t = t_1 + T$, defined as t_2. The number of particles measured during the data collection time T, from $t = t_1$ to $t = t_2$, is defined as DN_2. This quantity must be multiplied by a computed "dilution factor", DF, in order to obtain an estimate of the total number of sample particles, N_0, which were originally injected into the dilution chamber at the start of dilution. The expression for DF is given by,

$DF = 1/[\exp(-t_1/\tau) - \exp(-t_2/\tau)$ *Equation 3*

or,

$DF = \exp(t_1/\tau) / [1 - \exp(-T/\tau)$ *Equation 4*

For typical applications, where the sample suspension after injection is over-concentrated (i.e., $C_0 > C_T$), Equation 5 can be rewritten by solving for the term $\exp(t_1/t)$ recognizing that $C(t_1) = C_T$

$\exp(t_1/\tau) = C_0/C_T)$ *Equation 5*

Hence,

$DF = (C_0/C_T) / [1 - \exp(-T/\tau)]$ *Equation 6*
$(C_0/C_T > 1)$

The number of particles, DN_2, measured during T is, by definition, given by N_0/DF. From Equation 7, this becomes,

$DN_2 = N_0 [1 - \exp(-T/\tau)] / (C_0/C_T)$ *Equation 7*
$(C_0/C_T > 1)$

In cases where the sample suspension after injection is under-concentrated (i.e., $C_0 \leq C_T$), $t_1 = 0$ The expression for the dilution factor DF is simple:

$DF = 1 / [1 - \exp(-T/\tau)]$ *Equation 8*
$(C_0/C_T < 1)$

The number of particles, DN_2, measured during time T is again given by N_0/DF. In this case, using Equation 9, the expression for DN_2 becomes,

$DN_2 = N_0 [1 - \exp(-T/\tau)]$ *Equation 9*
$(C_0/C_T < 1)$

In cases where the sample suspension after injection is under-concentrated (i.e., $C_0 \leq C_T$), t1 = 0. The expression for the dilution factor DF is simple,

$DF = 1 / [1 - \exp(-T/\tau)]$ *Equation 10*
$(C_0/C_T < 1)$

The number of particles, DN2, measured during time T is again given by N_0/DF. In this case, using equation (9), the expression for DN_2 becomes,

$DN_2 = N_0 [1 - \exp(-T/\tau)]$ *Equation 11*
$(C_0/C_T < 1)$

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Corporate Headquarters
129 Concord Road
Billerica, MA 01821
USA

Customer Service
Tel +1 952 556 4181
Fax +1 952 556 8022
Toll Free 800 394 4083