NO MORE "STEP BY STEP" DILUTION WITH CAPILLARIES
NOW CONTINUOUS COVERAGE IN THE RANGE 99,5...0,02%.

BACKGROUND:

Necessarily in a capillaries type diluter, a finite number of capillaries , is installed and the dilution is obtained by directing the gas gas to be diluted through a part of them, while the diluent gas is directed to the remaining part: the number of possible dilutions obtainable is therefore limited by the total number of capillaries.

The opportunity that we want to present is made possible by the availability in our diluters of the electronic regulation of the pressures applied to the capillaries: the control function is based on the measurement of the pressures at the entrance and discharge of the capillaries and is managed by two PID controllers.

It's longtime that we use these controls to compensate for any differences in viscosity between the mixture to be diluted and the diluent gas: in laminar flow conditions, the pressures have direct linear effect while the viscosity have a reverted linear effect on the gas flow (the flow increases linearly with increasing pressure and with decreasing viscosity).

As we said, the physics of laminar flows is extremely simple (it is almost the transposition in pneumatics of Ohm's law, where the flow of gas corresponds to the electric current, the pressure applied to the capillaries to the electrical voltage applied to the resistance and the combination Length-Hole Diameter-Viscosity corresponds to the combination Section-Length-Resistivity of the material composing the resistor.

The only notable difference is the elevation to the fourth power of the diameter in the case of capillaries. In the case of capillaries in fact,

1) $Q = \pi D^4 \Delta P / 8 L \eta$

In a diluter with equal capillaries, applying the same pressure at the entrance of the N capillaries affected by the gas to be diluted and the remaining (TOT-N) crossed by the diluting gas, and provided that the viscosity of the two gases is the same, one realizes the mixing of two gases in a proportion well-defined according to the ratio:

2) Q(N) / Q(TOT) = N / TOT = Kdil. (dilution ratio)

If "i" is one of the components present in the mixture to be diluted with concentration C (i) and is absent in the diluent gas, the concentration of component i in the diluted gas (at the exit from the diluter) is equal to C (i) x Kdil .

If instead the same component "i" is also present in the diluent gas having concentration D (i), the diluted component concentration is C(i) x Kdil + D(i) x (1- Kdil.).

REALIZATION

The theory of capillaries based diluters becomes even easier when the flows in the formula that defines the dilution ratio 2) are substituted using the formula 1).

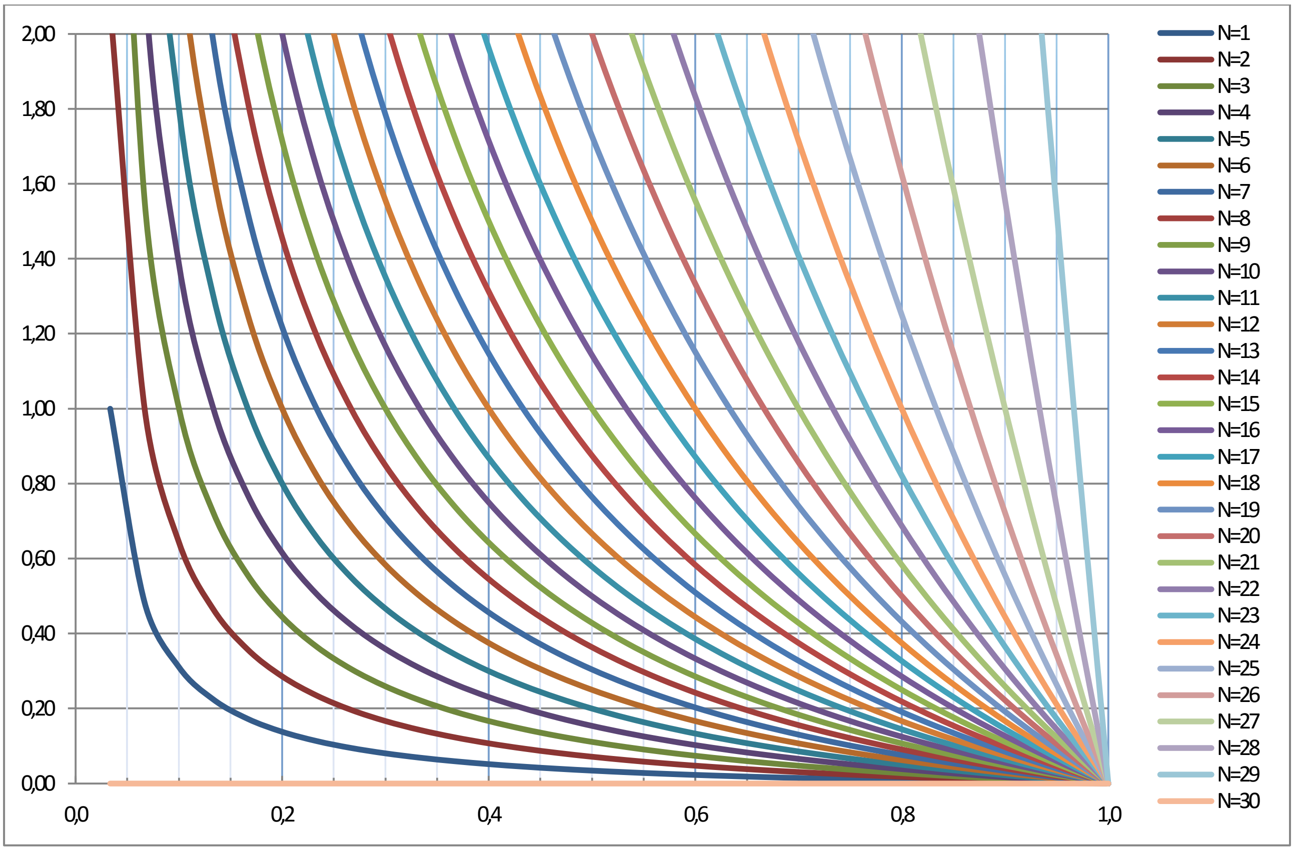
Being a ratio of flow with equal capillaries, we did simplify the dimensional parameters and the coefficients (equal) and therefore remains the dilution factor expressed in function of the number of capillaries assigned to the two incoming gas, the pressure applied and the viscosity of the gas:

3) $$\text{Kdil.} = \frac{N}{N + (TOT - N) \times P_0/P_1 \times \eta_1/\eta_0}$$

where :
N is the number of capillaries crossed by the diluent gas and TOT is the total number
P_0/P_1 is the pressures ratio (the indexes 0 and 1 refers to the diluend and diluting gases)
η_1/η_0 is the viscosities ratio

The use of the product P0/P1 x η1/η0 is evident when it comes to compensate for differences in viscosity: it is sufficient to apply to the two inputs (from diluting gas and diluend gas) pressures in direct proportion to the viscosity.

Acting on the ratio between the applied pressures (at equal viscosity) it's possible to see also analytically the possibility of correcting in a continuous manner and in both senses the dilution ratio . The following graphs represent in the ordinate the value of P0/P1 and in abscissa the actual value of the corresponding dilution ratio. The different curves are obtained for different N (number of capillaries affected by the gas to be diluted) while 30 is the total number of capillaries.

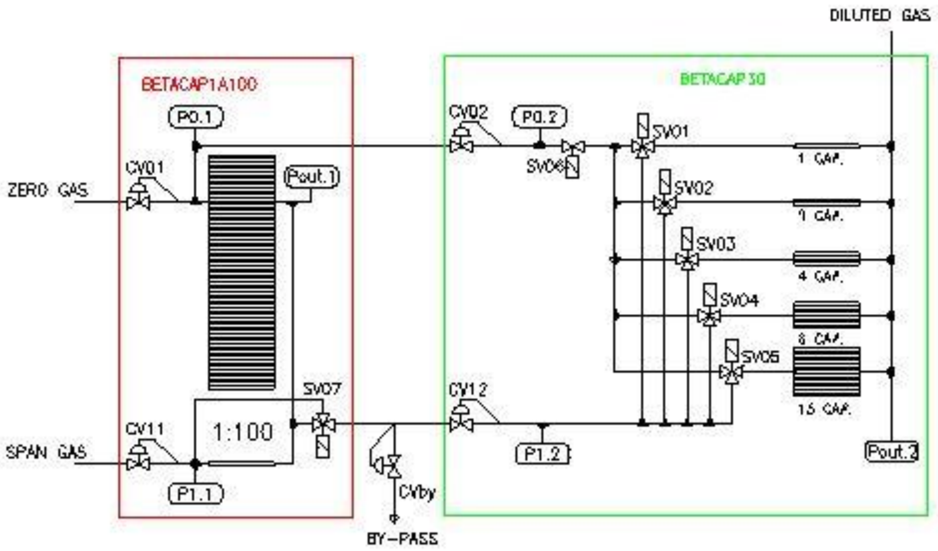


It is observed that, for P0/P1 = 1.00 for each trace N = integer, the dilution ratio corresponds exactly to N/30, and with increasing or decreasing the ratio P0/P1, the dilution ratio falls (conversely increases) to reach lower or higher values

When P0/P1 = 0, the dilution ratio Kdil = 1 (no more dilution, than 100% gas to be diluted))

In fact, for the purpose that we have set ourselves (full coverage of the field of possible dilutions), it is sufficient to move from N/30 to (N-0,5)/30 or (N+0.5)/30, leaving to the next or previous capillaries combination (N-1 or N+1) the task of covering the remaining half of the intermediate field.

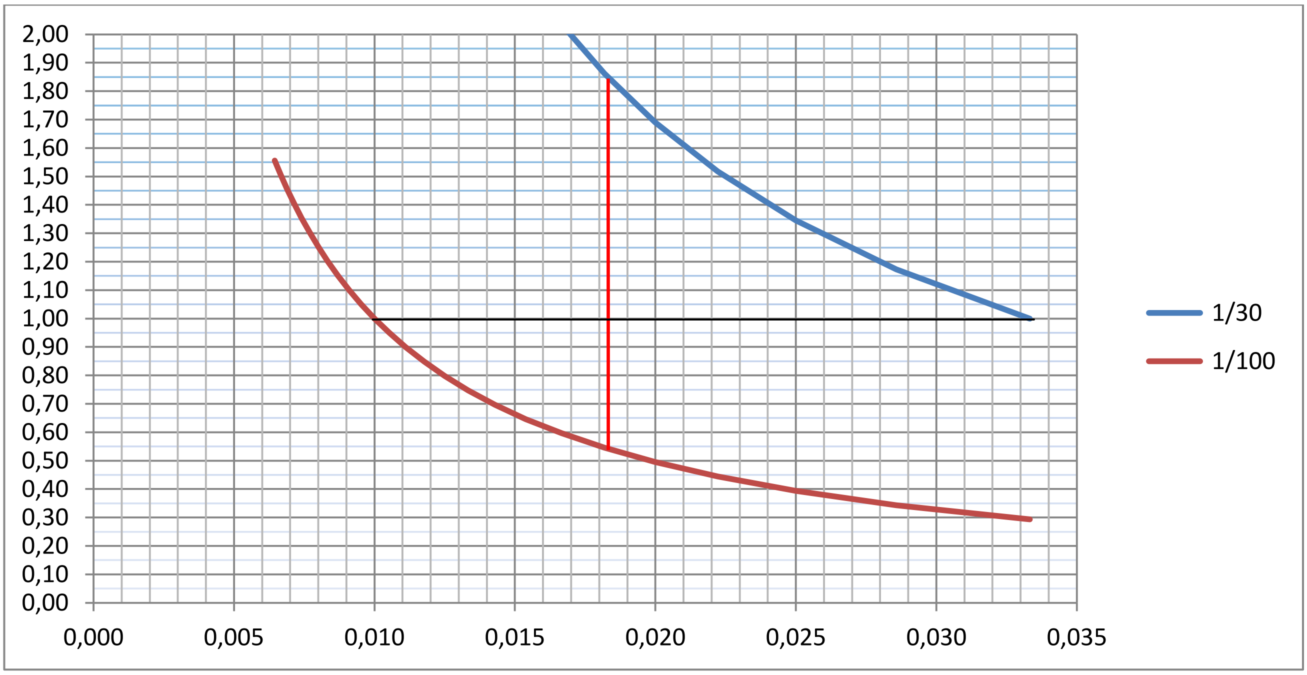
By using the fixed dilution 100:1 prescaler, nothing changes : the full coverage of the range 0.5:30 to 29.5:30 is moved to the range 0.5:100...0.5:3000.



It was therefore checked successfully the possibility of continuously covering the dilution ranges from 29.5:30 to 0.5:30 and from 0.5:100 to 0.5:3000 and it remains to verify if it's possible to cover the dilutions interval between 0.5:30 and 0.5:3000

The following graph till gives a picture of the P0/P1 ratios versus dilution rate in the two cases :

a) with prescaler bypassed and diluter capillaries distribution set to 1:30
b) with prescaler inserted in series and diluter not diluting (ratio = 30:30 capillaries)



You can also check graphically that applying P0/P1 ratios in the range 1.85 ... 0.55 it's possible to get a full coverage in the interval between 1:30 and 1:100 dilution rate.

The real diluter BetaCAP30 with 30 equal capillaries automatically applies the calculations that underlie the graphs shown here actually to provide complete coverage of the dilutions between 1:30 and 29:30, as well as the extremes 0:30 (only diluting gas) and 30:30 (only span gas). When equipped with the pre-diluter BetaCAP1A100, the bandwidth of the dilutions covered with continuity extends from 1:6000 up to 29.5:30 (in addition to the extremes).

It's provided also the case of two gas (diluting and diluent) with different viscosity: in this case BetaCAP30 calculate and compensate the different viscosities influence, while correcting the dilution to get the wanted concentration in the diluted gas.

Note that only the ratio between the pressures applied to the capillaries affects the dilution ratio, not their individual values: to assure the due accuracy for the ratio, a calibration cycle is provided (zero and span) that does not necessarily use traceable references. For each section (pre-diluter and diluter) zero is calibrated by applying simultaneously to the respective three sensors (2 inputs and one output) the atmospheric pressure and the span is calibrated by statically pressurizing the whole inner volume (and therefore the three sensors) with a known pressure (the reference accuracy is absolutely not critical)

The ratio P0/P1 is handled by changing the set point of pressure regulators according to the calculation:

$P0 = Prel._{0} - Prel._{OUT} = P0/P1 \times (Prel._{1} - Prel._{OUT})$

P0 and P1 are in fact the differential pressures between the corresponding input and output (the pressure actually applied to capillaries ends). The linearity and repeatability on the regulated pressures are better than ± 1 mbar
The intrinsic stability of the capillaries is now enforced by the continuous dilution capability.
The advantage is that in this way you can choose the concentration values to be applied to the instrument under test without being obliged to select discrete steps.