

GAS DILUTERS AND METROLOGY

It's evident that, due to their purpose (quality test for gas analyzers) gas dividers belong to the metrology world. It's also evident that gas dividers outlet is not a measurement : they go through two flow measuring, but at the end the output value, the dilution ratio, is just a number : the ratio between two flows.

It exists at least another "tool" with this property : the piece counting scale. In this case two weight measurements are done (the reference with one or few peaces and the counting hopper with the peaces to be counted). It translates the weights ratio in the pieces number ratio and then the count, knowing the number of pieces in the reference plate and supposing they are equal (same production specification) to the units to be counted..

Two so special devices should receive a special threatment : in the counting tool, everybody expects that the reference for counting is one or some peaces of the same family of that to be counted (but that's an internal reference, apparently violating traceability rule).

But now let's come back to our diluters : we did setup a procedure that gets advantage from the particular structure of gas dividers series BetaCAP60 to give them a self-referring test function.

Self referring test with BetaCAP60

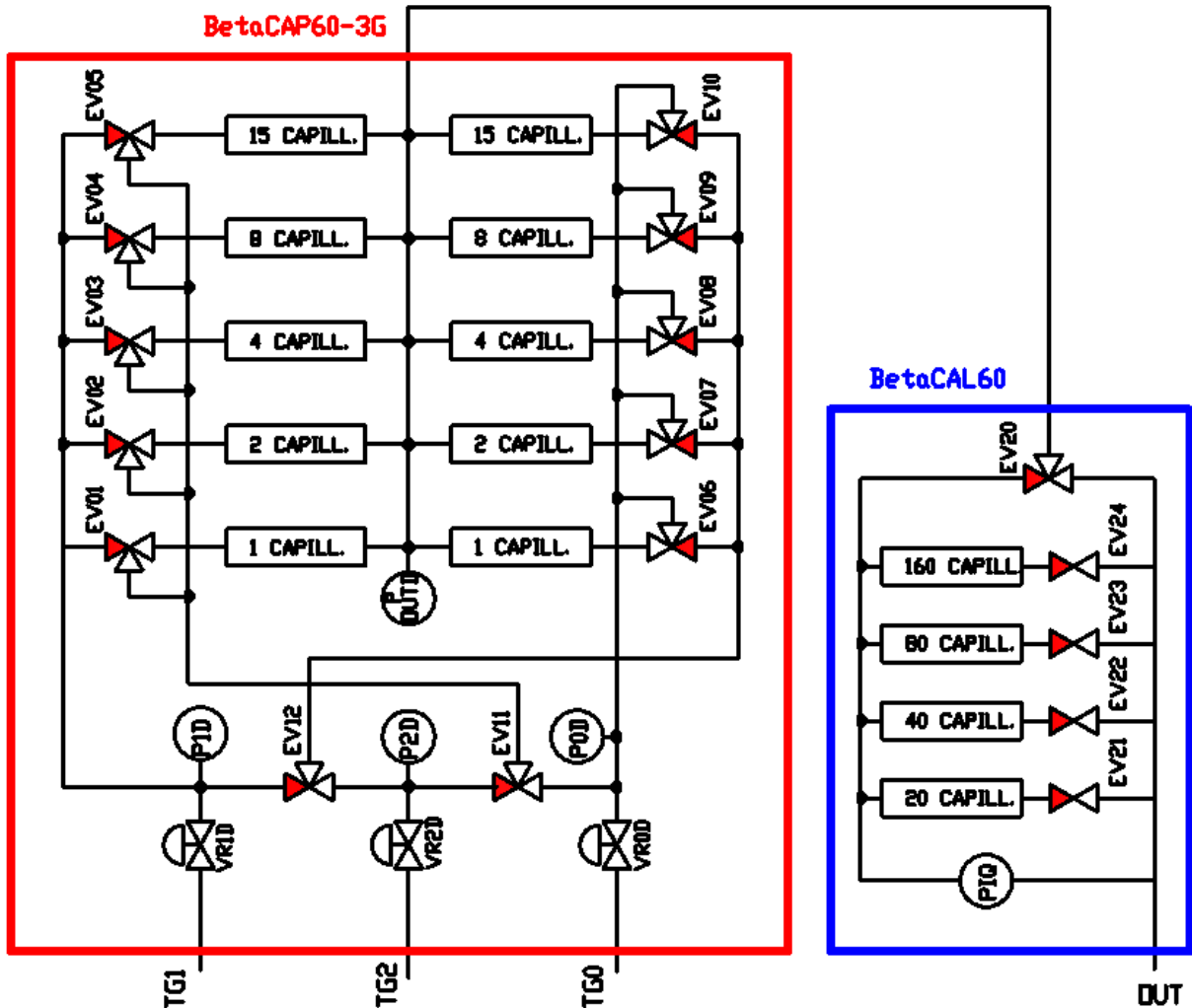
The construction of BetaCAP60 with two equal capillaries benches, each composed by 5 groups of matched capillaries with equal composition two by two. Two groups have 1 capillary each, two have 2 capillaries each two have 4, two have 8 and two have 15 capillaries each. As told in the introduction, the dilution ratio quality must be assured, but the flows used to calculate it just require to be each other in a given proportion : multiplying all of them by the same coefficient the result don't change in terms of dilution ratio.

In this contitions, one capillaries group can be assumed as reference to which all the other capillaries must be realated with flow proportionned to relevant capillaries number in the group. As the reference capillary we did select the one with single capillary placed in the left side module : the flow value that will cross it at a given differential pressure will be the single capillary flow reference.

Test is made by 5 phases : each phase will handle groups containing the same number of equal capillaries: with applied the same pressure, that induces very similar (theoretically equal) flows. The first phase is handling 1 capillary groups, the second 2 capillaries groups, the third 4, the fourth 8 and the fifth 15.

The above flows must be compared : to do that in the diluter it's istalled an optional "not traceable meter" made by a selectable series of capillaries (to produce a differential pressure when crossed by the flow) and a differential pressure sensor calculating the flow from dP. Capillaries selection in the meter is assigning the range : each phase (handling a different number of capillaries), send to the meter a different flow.

Higher flows are measured as differential pressure across the higher number of flow meter capillaries : this way the sensor is subject to similar pressures in all the phases with different flows. Those pressure values are near to the sensor range (the area of better resolution).

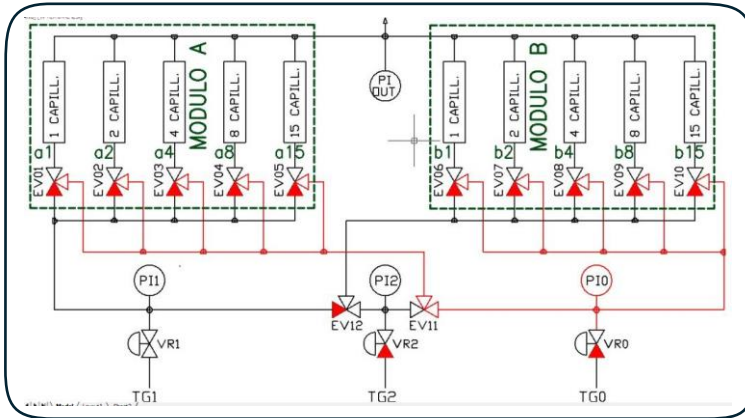


Scope of this test is to measure/calculate the deviations to the rule that wants the flows (induced by the same pressure value) through each capillaries group, proportional to the number of capillaries included in the relevant group.

In fact this is the consequence of the supposed capillaries equality : if they are equal, the above rule is satisfied and dilution is perfect, if not, the flows deviation can be used to calculate (and correct) the dilution deviation. The equality of the capillaries used in the flow meter is not critical : different capillaries in the flow meter are used in different phases and flow measurements made in different phases are not mixed in comparisons.

The flows through the 5 capillaries groups in left side (Module A) of the diluter are named a1,

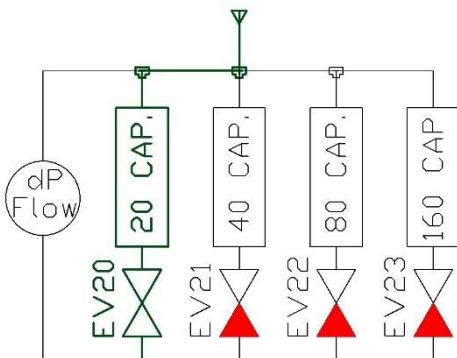
a2, a4, a8, a15 and the flows through the capillaries groups of right side (Module B) are named b1, b2, b4, b8, b15. Flows are also measured on the parallel of two groups with equal capillaries number (one in left side and another in right side) : those flows are named a1b1, a2b2, a4b4, a8b8, a15b15.



Then, let's start with

Phase 1

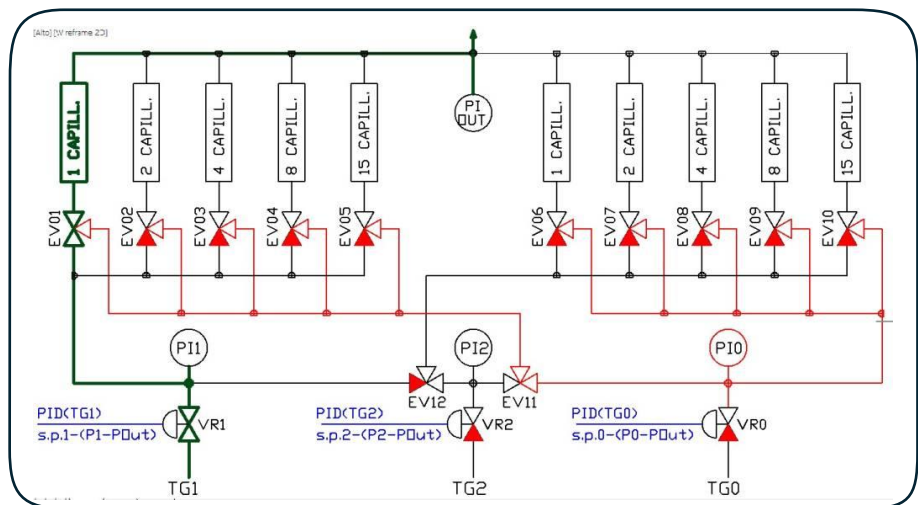
Sensitivities of the different measuring ranges used in each phase are not metrologically related each other, but are near to the reverse proportion with the flow to be measured : this assure a constant high resolution.



During phase 1 the measured flows are coming from only one capillary, then small flows : to have high measuring resolution the flow meter uses the minimum capillaries number (20) In parallel opening just the solenoid valve EV20 : it's the highest resistance to flow, inducing a proportionally high pressure drop, measured by the dP sensor.

Step 1.1: measuring a1

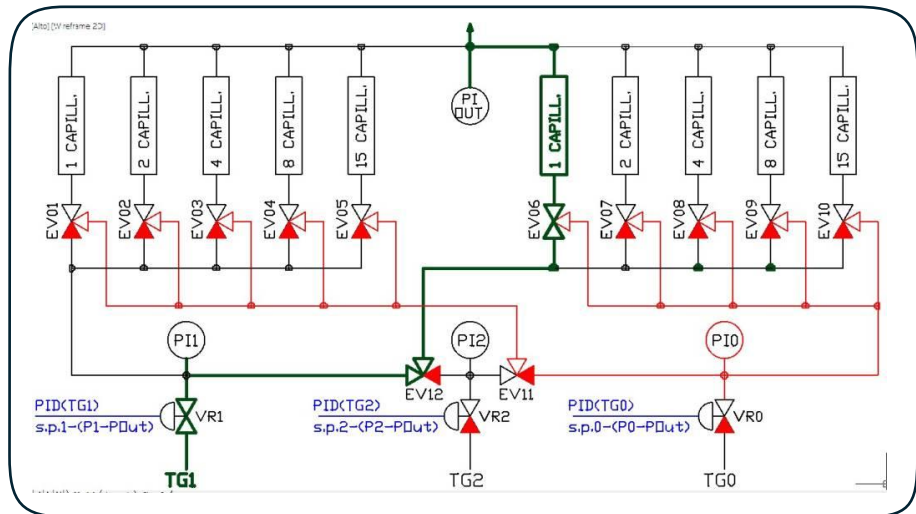
Activating the flow a1 it's measured : the value a1 is assumed to be our reference. We can then confirm that the relative deviation of the flow a1 is $er(a1)=0$



Step 2.1 : measuring b1

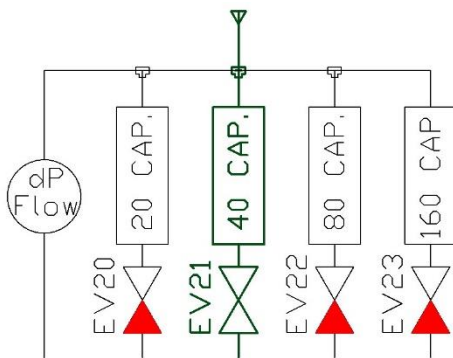
Activating the flow b1 it is measured allowing to solve the formula
 $a1 + a1 \cdot \epsilon_r(a1) = b1 + b1 \cdot \epsilon_r(b1)$.

Note that $a1 \cdot \epsilon_r(a1)$ and $b1 \cdot \epsilon_r(b1)$ are the absolute deviations of the flows a1 and b1.
 Incidentally $a1 \cdot \epsilon_r(a1) = 0$



$\epsilon_r(b1) = (a1 - b1)/b1$. Then we know the relative deviation of the single capillaries groups in left side and right side modules.

For next requirement, we also calculate $R1 = a1/b1$

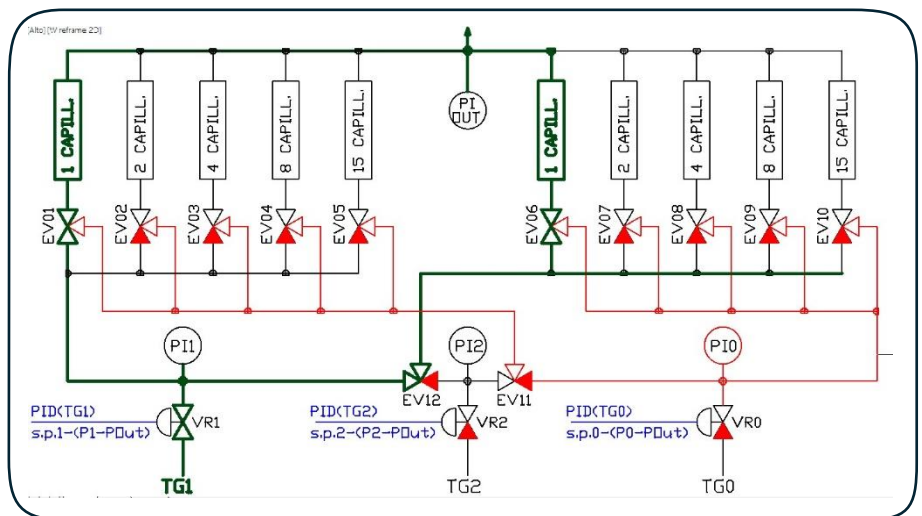


Phase 2

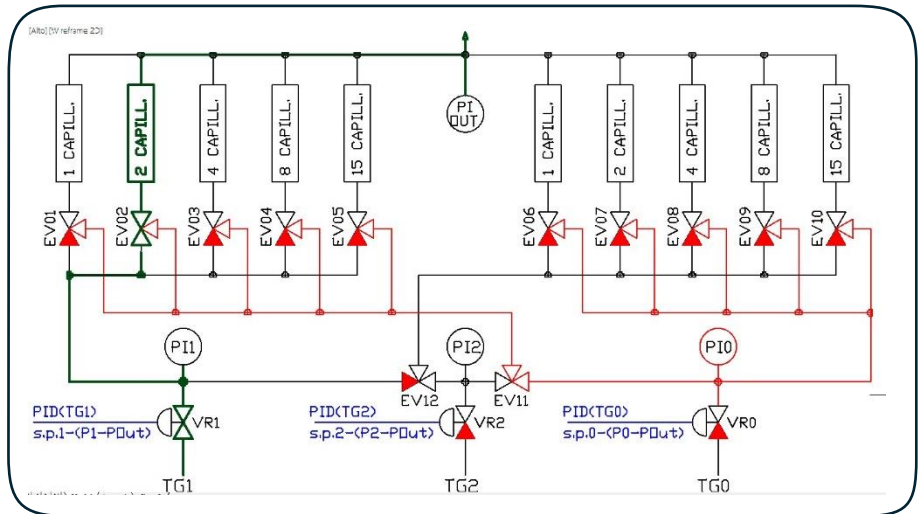
During phase 2 the measured flows are coming from two capillaries at a time : to have a measuring resolution similar to that of phase 1, the measured dP is got with a double number of capillaries crossed by this double flow : 40 capillaries in parallel through the way open by the solenoid valve EV21.

Step 2.1 : measuring the sum of a1 and b1

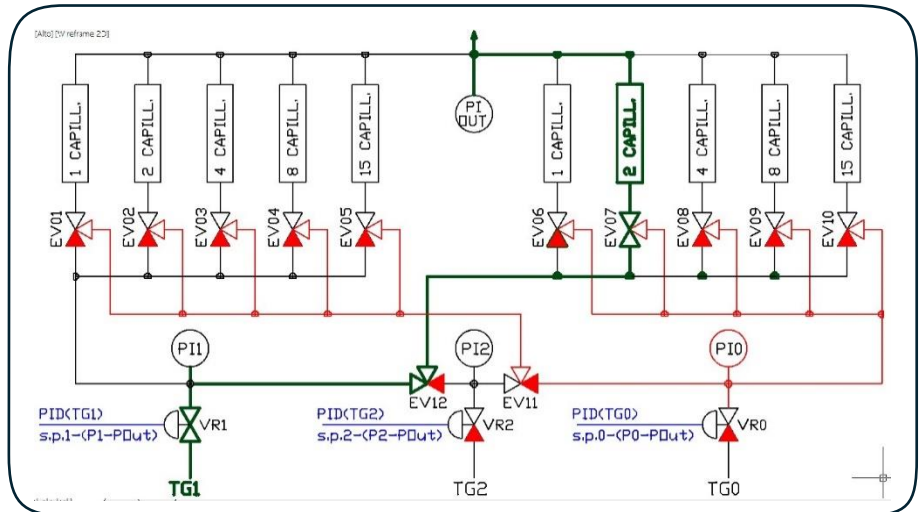
Activating the flows a1 and b1, in parallel, it's measured
 $a1 + b1 = a1 + b1$



Step 2.2 : activating the flow
a2, it is measured



Step 2.3 Activating the flow
b2, it's measured



Then it appears we can write
two equations:

$$a_1 b_1 - \epsilon_r(a_1) \cdot (a_1') - \epsilon_r(b_1) \cdot (b_1') = a_2 - \epsilon_r(a_2) \cdot a_2$$

$$a_1 b_1 - \epsilon_r(a_1) \cdot (a_1') - \epsilon_r(b_1) \cdot (b_1') = b_2 - \epsilon_r(b_2) \cdot b_2$$

But that's not correct ! we know that flow measurements cannot be mixed in the same equation if not measured in the same phase : (a1') and (b1') are measured in phase 1 but a2 and b2, are measured in phase 2.

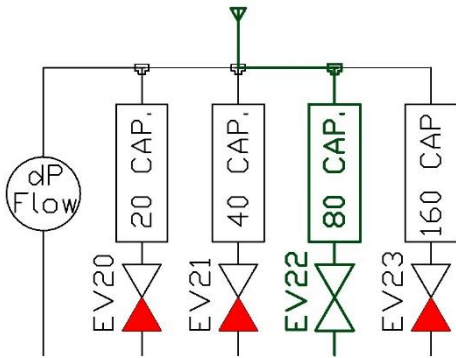
In fact measuring sensitivities in different phases are different and the ratio between them is known just with big approximation.

Hopefully we have two useful information : $R_1 = a_1/b_1$ that, as a flows ratio can be used wherever based on measurements made in phase 1 (but it's a ratio) and $a_1 b_1 = a_1 + b_1$ measured in phase 2 and then directly available in phase 2 equations

Joining in a system the two equations, $R_1 = a_1/b_1$ and $a_1 b_1 = a_1 + b_1$ we get $a_1' = R_1 \cdot a_1 b_1 / (1 + R_1)$ and $b_1' = a_1 b_1 / (1 + R_1)$

Using those values in the comparison formulas, we can then calculate $\epsilon_r(a_2)$ and $\epsilon_r(b_2)$, the relative deviations of groups with 2 capillaries left side and right side

For next requirement, we also calculate $R_2 = a_2/b_2$

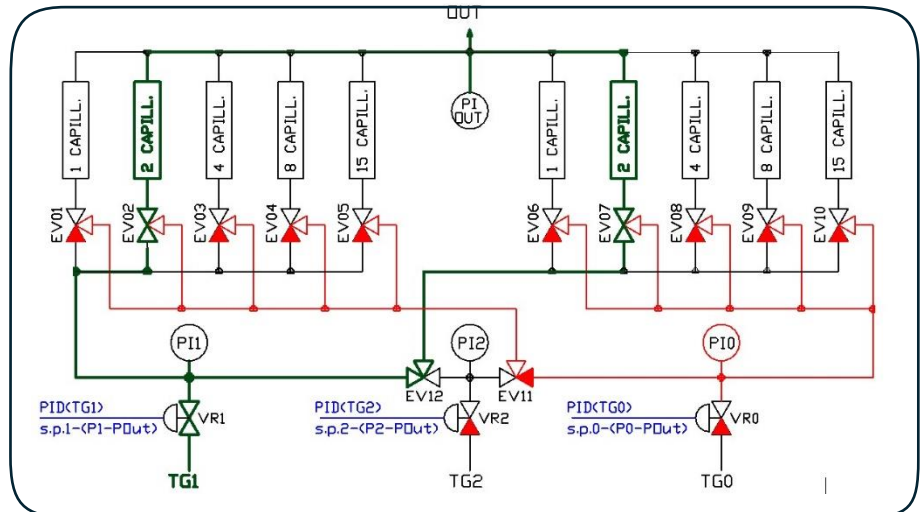


Phase 3

During phase 3 the measured flows are coming from four capillaries at a time : to have a measuring resolution similar to that of phase 1 and 2, the measured dP is got with an increased number of capillaries crossed by this four times flow : 80 capillaries in parallel through the way open by the solenoid valve EV22.

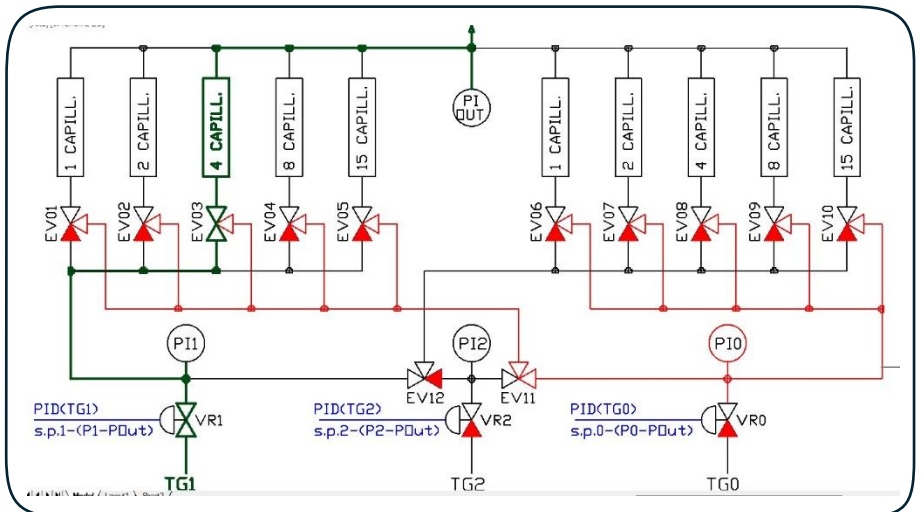
Step 3.1 : measuring the sum of a2 and b2

Activating the flows a2 and b2, in parallel, it's measured
 $a2b2 = a2+b2$



Step 3.2

It's measured the group a4

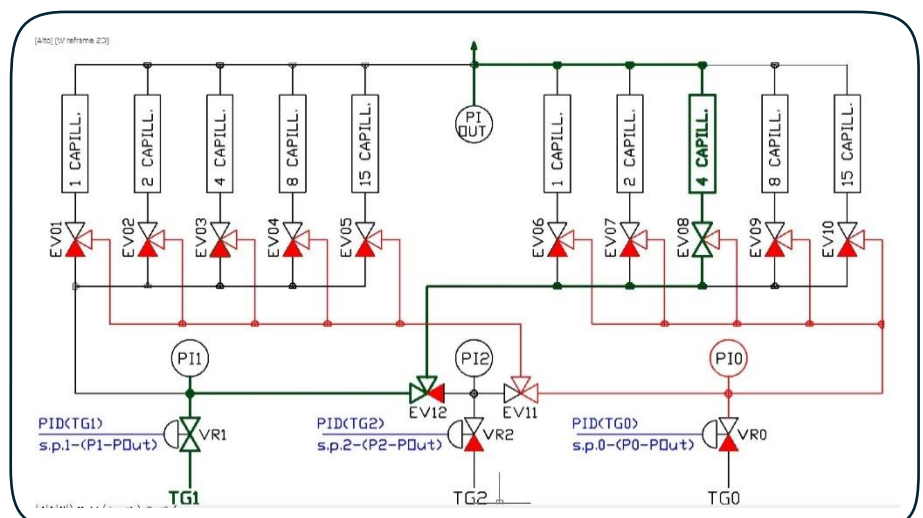


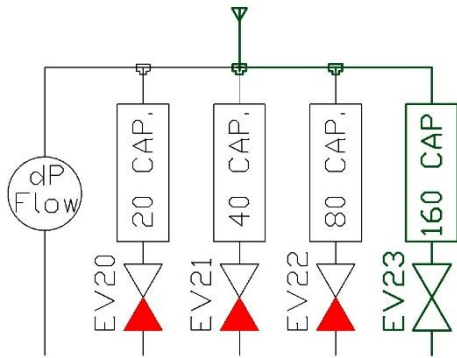
Step 3.3

It's measured the group b4

It's enough to change the indexes of the previous equation from 1 to 2 and from 2 to 4 to calculate

er(a4) and er(b4)





Phase 4

During phase 4 the measured flows are coming from eighth capillaries at a time : to have a measuring resolution similar to that of phase 1, 2 and 3, the measured dP is got with an increased number of capillaries crossed by this four times flow : 160 capillaries in parallel through the way open by the solenoid valve EV23.

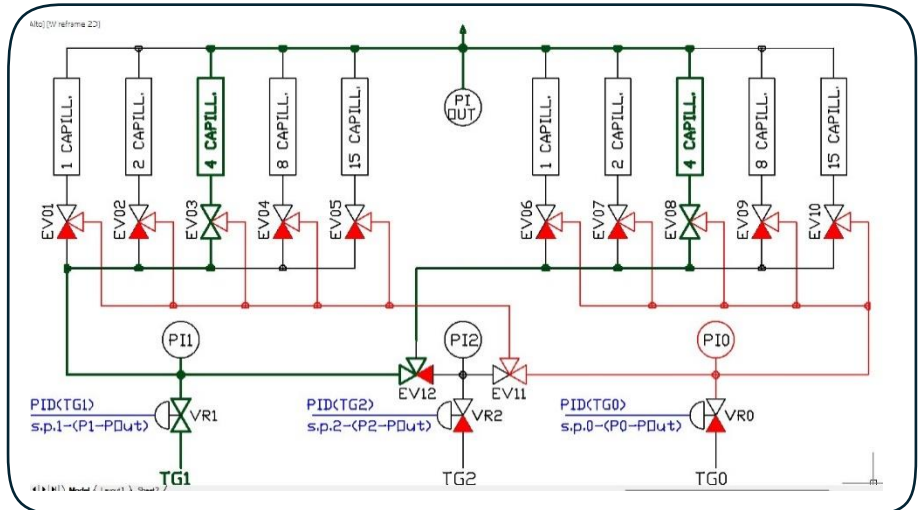
Step 4.1 measuring the sum

of a4 and b4

Activating the flows a4 and b4, in parallel, it's measured

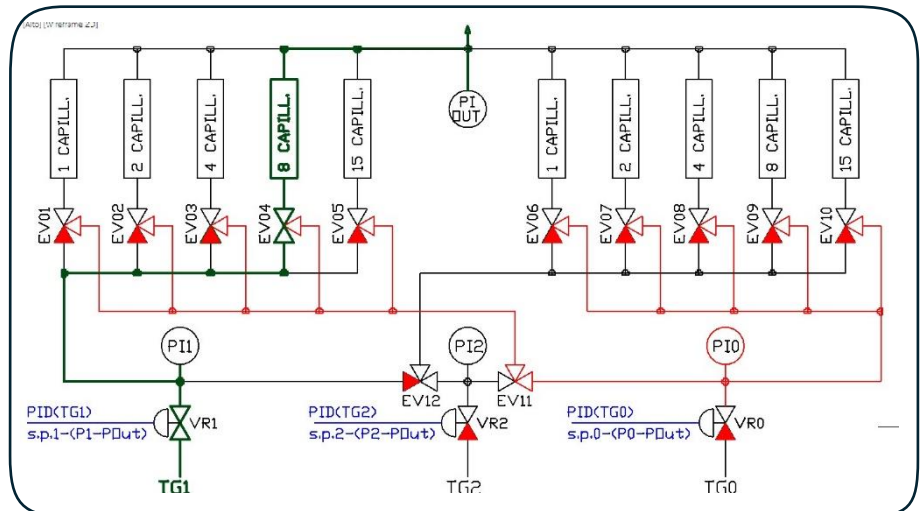
$$A4b4 = a4 + b4$$

I



Step 4.2

It's equal to phase 3.2 :

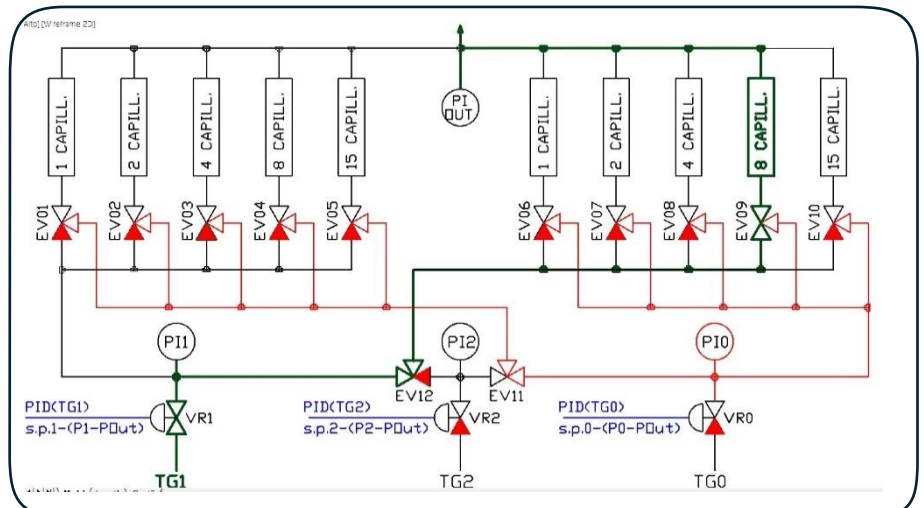


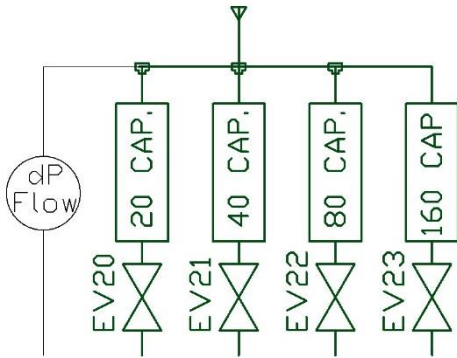
STEP 4.3

It's equal to phase 3.3 :

it's enough to change the indexes from 2 to 4 and from 4 to 8 to calculate

er(a8) and er(b8)





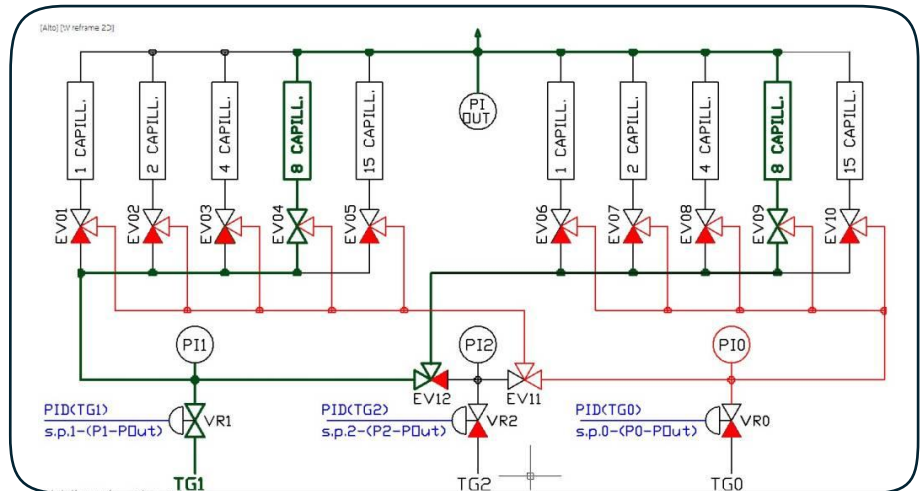
Phase 5

Here are measured flows coming from 15 or 16 capillaries: not to saturate the dP sensor, flows to be measured are crossing 30 capillaries in the flow meter.

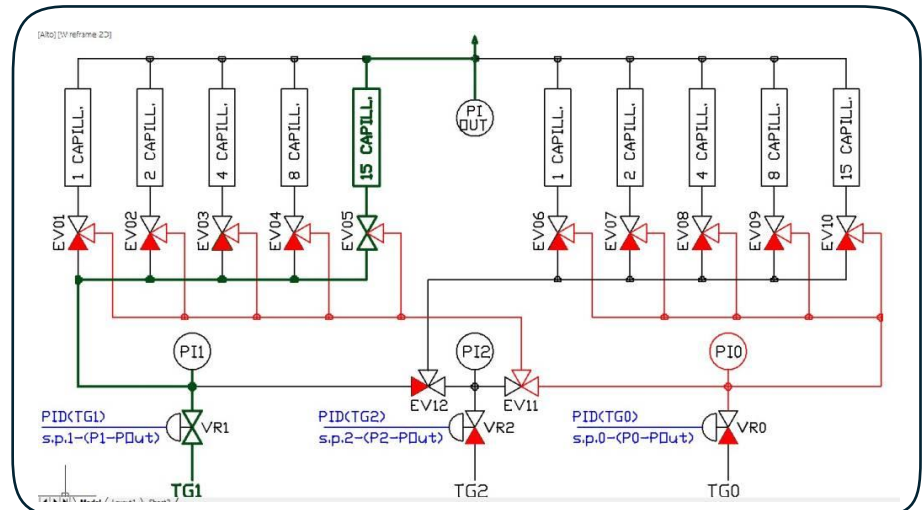
The solenoids EV20, EV21, EV22m EV23 are open. In this configuration 300 capillaries in parallel, crossed by the diluter flow, create the differential pressure suitable to

measure in the sensor the actual flow.

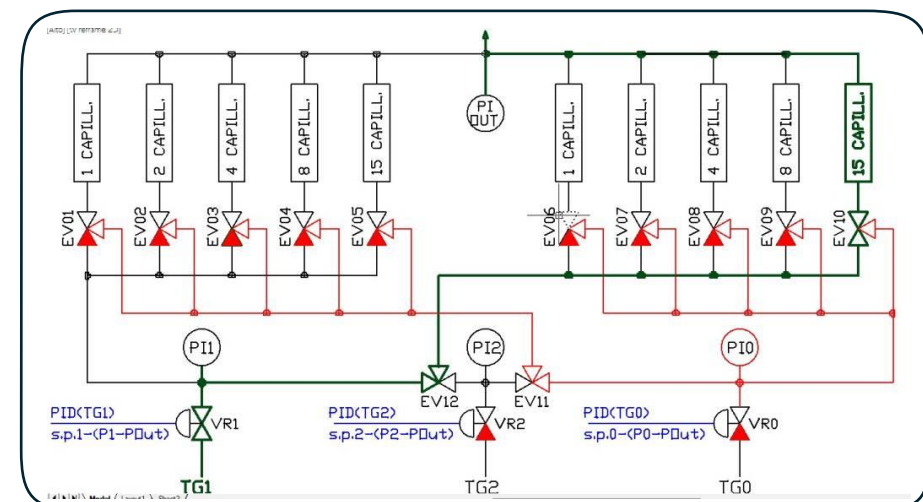
Step 5.1, measuring a4 and b4



Step 5.2, measuring a5



Step 5.3, measuring b5



It seems arrived a further difficulty, but it's not : the comparison is not between groups with the same total capillaries number, but two groups have 8 capillaries and the bigger group have 15.

It's enough to include in the equations a corrective factor 15/16

$$[a_8 b_8 - \varepsilon_r(a_8)(a_8') - \varepsilon_r(b_8)(b_8')] * 15/16 = a_{15} - \varepsilon_r(a_{15}) * a_{15} \quad [a_8 b_8 - \varepsilon_r(a_8)(a_8') - \varepsilon_r(b_8)(b_8')] * 15/16 = b_{15} - \varepsilon_r(b_{15}) * b_{15}$$

a_8' and b_8' are calculated from the system between the measurement $a_8 b_8 = a_8 + b_8$ (measured in phase 5) and the ratio $R_5 = a_8 / b_8$ (measured in phase 4, but can be used in whichever phase being a flows ratio)

Then we got the relative deviation of each capillaries group in the diluter $\varepsilon_r(a_1)$, $\varepsilon_r(b_1)$, $\varepsilon_r(a_2)$, $\varepsilon_r(b_2)$, $\varepsilon_r(a_4)$, $\varepsilon_r(b_4)$, $\varepsilon_r(a_8)$, $\varepsilon_r(b_8)$, $\varepsilon_r(a_{15})$, $\varepsilon_r(b_{15})$ and we can correct the theoretical flows to real measured flows, and finally the real dilution ratio and the deviation from the dilution target. Believing that data it's possible to correct the target (deducting the deviation) to get the right dilution.

Final considerations

Repeating different runs of the complete procedure it's possible to observe very low variance not specially on the measured flow values, but mainly on the calculated relative deviations : this is a good index of reliability. Another important point is the constant high resolution of measured flows and calculated relative deviations, not depending on flow size.

Beyond these observations, it's normal that the violation of the main prescription in the legal metrology (it's a set of legal assumptions or of logical-mathematical analysis ?) is not allowing to accept this method as replacing traceable way.

Some application can be exempted from respecting the official metrology rules :

- Some agreement can be accepted to move the frequency of gas divider metrological audits (more or less frequent) depending on not traceable tests that define the drift higher or lower that initially supposed.
- In the research world, all internal measurements are not obliged to follow legal metrology
- The same in production, during intermediate and end of line tests : the "PASSED" is under the responsibility of the producer and whichever affordable instrumentation can be used complying with quality dept.

Two words more about the flow meter : the ranges selection is managed (automatically) in a way that lower sensitivities are applied when high flows (through many diluter capillaries) are to be measured and vice versa for higher sensitivities. That way the measured differential pressure is always in a narrow band of the DP meter and this used band is near the upper range, where measuring resolution is maximum. That's the reason of the high accurate results.

The importance of measuring flows ranges and measuring resolution is evident comparing this method with traceable methods : each type of diluter need for his setup (components choice or

trimming and response linearizing) to measure accurately the flows in many points of the dilution range : in this task, measurement of the higher flows (generally with dilution factor near to 1) is easy selecting the meter range or the diluter flow and resolution can reach 0,1%. When the diluter can offer strong dilutions (like 1/100 or more) the lower flows are measured with resolution in the order of 10% or more and this is not acceptable. Some is obliged to use multi-range meters, but each step down in ranges causes additional uncertainty, because all the reference chain changes.

