

"EQUAL CAPILLARY" GAS DILUTER Model BETACAP30X100 WITH DOUBLE DILUTION RANGES FOR TESTS THAT REQUIRE STRONG DILUTIONS (FROM 100% UP TO 6000:1)

INTRODUCTION

BetaCAP30X100 was born from the union and integration of two autonomous modules: CAP30 and CAP1A100. The first is the well-known 30-capillary diluter, capable of producing 31 equally spaced dilution steps in the range between zero and 100%, while the second produces a fixed 100:1 dilution ratio and can be excluded on command so as not to interfere with the dilution of the CAP30 form. This results in two dilution ranges:

- With pre-diluter excluded, the CAP30 module produces its 31 dilution steps
- With pre-diluter active, the possible dilutions of the CAP30 module overlap with the fixed 100:1 dilution of the CAP1A100 module, determining a second dilution range between $(1/100 \times 1/30) = 1/3000$ and $(1/100 \times 30/30) = 1/100$. In the following, the availability of a continuous dilution range which also uses the spaces between the discrete steps will also be considered.

CHARACTERISTIC NOTES

- Pre-diluter with 100 capillaries (included or bypassed on command) equipped with automatic regulation of the differential pressures at the ends of the 100 capillaries (diluent) and of the single capillary (gas to be diluted)
- Final diluter with 30 equal capillaries, selectable in 31 different combinations to produce 31 main ratios. The differential pressures applied to the groups of capillaries are automatically adjusted with a calculated set-point
- Materials in contact with gases are highly resistant to corrosion by major acidic components and dissolution by solvents. The mechanical construction is made to resist the strong stresses that occur during frequent transport on industrial plants.
- Unrivalled initial accuracy, stability of characteristics for several years of intensive use (cylinder gas only), ready to use as soon as it is turned on.
- Possible unattended remote management via RS485 connection and RS485/USB converter (included). Maximum 3 measurements of the analyzer under test are managed through an isolated data logger (included)

PRINCIPLE OF OPERATION

In the CAP30 module (right side of the diagram) we can see the SV01 solenoid valves.... SV05 which send to each group (groups of 1, 2, 4, 8, 15 capillaries) the diluent gas or (when energized) the gas to be diluted, possibly pre-diluted. The CV02 and CV12 regulation valves control the two applied pressures, on the basis of two calculated sets and the two feedbacks (Pout2-P0.2 and Pout2-P1.2). It is more interesting to observe the interfacing between the two modules: CAP1A100 (when active) is forced by the two valves CV0.1 and CV1.1 to send a constant flow at the output, while the flow requested by the CAP30 module is very variable and depends both from the user setting (output flow) and from the dilution ratio set, from 0/30 (no flow from pre-diluter) to 30/30 (maximum flow from pre-diluter).

To avoid insufficient or, vice versa, excessive pressures at the pre-diluter outlet, the CVby valve discharges the excess flow in real time, maintaining the necessary pressure upstream of CV1.2.

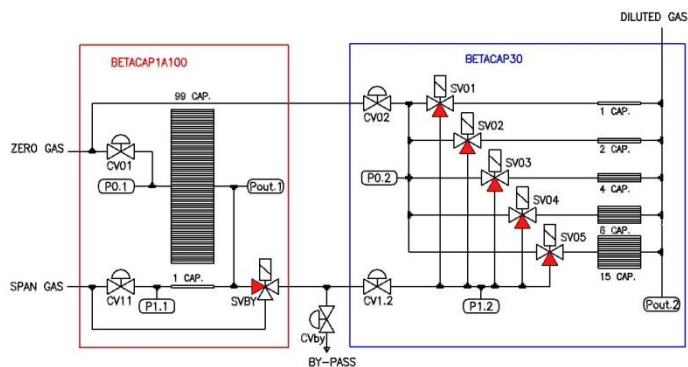
To avoid the two extreme conditions of insufficient pressure upstream of CV1.2 (signaled by LLP alarm on the value of P1.2) or too high pressures, which induce an exaggerated bypass flow (high consumption of diluent gas), the function which varies the set of the CV01 valve, previously responsible for the flow exiting the pre-diluter.

Ultimately, the pre-diluter does not require settings other than the factory ones and the user does not have to worry about them. The related menu has a diagnostic purpose only.

The SV07 solenoid valve activates or excludes the pre-diluter depending on the dilution required.

The functions mentioned below faithfully represent the physics of the flows in the diluter by replacing the values of the flow rates exiting each capillary (modified Poiseuille formula) in the dilution formula, both for the CAP30 module (K dil.d) and for the CAP1A100 module (K dil.p).

In addition to setting $K_{dil.total} = K_{dil.p} \times K_{dil.d}$, the user can request the production of a diluted concentration



chosen from the results corresponding to dilutions in the range 0.5/3000...29.5/30 (in addition to zero and span), free from the constraint of discrete steps.

$Kdil.d = \frac{N * Q_{(1cap)TG1}}{N * Q_{(1cap)TG1} + (30 - N) * Q_{(1cap)TG0}}$	$Q_{(1cap)} = \frac{\pi * R^4}{16 * L * \eta} * \frac{P_{in.a}^2 - P_{out.a}^2}{P_{out.a}} = \frac{\pi * R^4}{16 * L * \eta} * \frac{dP * (dP + 2 * P_{out.a})}{P_{out.a}}$
$Kdil.p = \frac{Q_{(1cap)TG1}}{Q_{(1cap)TG1} + 99 * Q_{(1cap)TG0}}$	$Q_{out} = Q_{TG1} + Q_{TG0}$

This function uses the same equations indicated above, where the distribution between the capillaries (which would result in a decimal number Nd/30 or Nd/3000) is approximated to the nearest integer numerator, while the approximation error is corrected by the application of the dP pressures (TG1d) and dP(TG0d) calculated accordingly. The uncertainty of the dilutions obtained with this method is the same as that obtained with the step-by-step dilutions.

The pre-diluter always produces the 100:1 dilution, except in the range (which would otherwise be uncovered) between 0.5/30 and 1/100: in this range, with the same calculations seen above, the pre-diluter is brought to produce a fixed dilution of 1/60 using calculated dP(TG1p) and dP(TG0p).

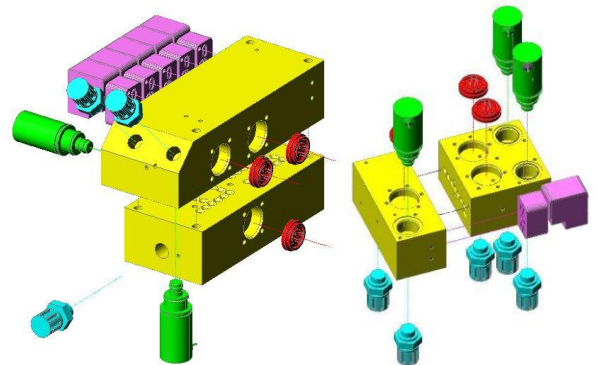
In all these operations, viscosity compensation is active: for dilutions that do not involve the pre-diluter, this correction is entrusted to the CAP30 module, while when the pre-diluter is active, it is entrusted to the pre-diluter alone. In fact, the pre-diluted gas at the inlet of CAP30 is 60 or 100 times more similar to the diluent gas than it was at the inlet of the pre-diluter. The user enters the viscosity values of the two incoming gases or mixtures (η_1 and η_0) calculated on the basis of the cylinder compositions from the Excel sheet downloadable at the link :

https://www.beta-strumentazione.it/wp-content/uploads/2019/09/Viscosita%C3%A0_Miscela_ITA.xlsx

The deviations resulting from the metrological certificate are also corrected on the basis of the calculation which, for each required dilution, calculates the total deviation and shifts the dilution target by the same amount as the calculated deviation, but in the opposite direction.

DILUTER CONSTRUCTION DETAILS

Analyzing the functional scheme of both the CAP30 and CAP1A100 modules we observe that the number of junctions (mainly TEE type) that connect the various devices (capillaries, valves and sensors) exceed one hundred. A solution different from the "wired" one was therefore necessary: each module is composed of two solid blocks, machined so that the capillaries remain incorporated between the two blocks and held in position by the same sealing o-rings, while all the other components are mounted in designated slots or in contact with the surface. All connections are made through crossing holes. Stainless steel balls are inserted into all entry holes that need to be closed. This construction has produced the most robust assembly imaginable: even the glass capillaries are not subjected to such a risk as to put their safety at risk. The blocks mentioned can be in fluorinated plastics (PVDF), standard or in stainless steel (AISI 316L), as an option.



DILUTER MANAGEMENT

For use, the operator is faced with a simple interface: alphanumeric display (4 x 40 characters) and 5 function keys, with which he selects the desired menu and sets the few parameters necessary to operate.

There are four "parent" menus of the hierarchy

- Initial parameters: concerns the construction of the diluter (installed options, basic calibrations, PID constants of the pressure regulators and certified error correction parameters, which, based on the metrological certificate, neutralize the deviations found)

- Calibrations: concerns the calibration of the isolated signals for three concentration measurements receivable by the analyzer under test and of the three pressure measurements. The calibration of pressure measurements is static (in the absence of flow) and does not require "referable" references (the sole purpose is to balance the sensitivities of the two groups of three sensors having first eliminated the zero shifts).

- Operating parameters: they concern the concentration in the cylinder of gas to be diluted, a basic set of pressure adjustments for both the pre-diluter and the final diluter (flow rate setting) and possibly the few settings of the RS485 serial port

- Operational functions: dilution in "choice of the dilution factor" mode, in "choice of the concentration to obtain in the diluted gas" mode, dilution in "remote" mode managed by the program on the PC.

The first two groups of menus are accessible via password.

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FACTORY PARAMETERS      Int.T =+19.6°C
CALIBRATIONS             Env.P = 971hPa
USER PARAMETERS
OPERATING FUNCTIONS
  
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TECHNICAL SPECIFICATIONS

Dilution ratio in discrete steps:	settable between 0:30 and 30:30 in 31 evenly spaced steps and between 1:3000 and 30:3000 in another 30 evenly spaced steps
Dilution ratio (continuous mode):	between 0.0167% and 98.33% of the gas to be diluted, including zero and span
Dilution accuracy:	better than 0.2% of reading + 0.00005% of input concentration
Operating pressure:	up to 5 Bar at the inlet fittings
Diluted gas flow rate:	depends on the pressure applied and the size of the capillaries
- small size	(1 hole for 0.1mm capillary) from 0.2 to 2 L/min.
- large size	(3 holes for 0.1 mm capillary) from 0.6 to 6 L/min.
Inlet gas connections:	gas to be diluted and diluent gas
Output:	diluted gas and bypass (to vent excess of pre-diluted gas)
Type of pneumatic connections. :	4 x 6 mm PVDF compression fittings (AISI316L on request)
Metrological certificate:	optional, LAT from European laboratory (recognised by Accredia)
Materials in contact with gas:	AISI 316, borosilicate glass, PVDF, PPS, PEEK, Kalrez,
Main analog measurements:	3 pressures for pre-diluter and 3 pressures for final diluter
Other measurements:	barometric pressure and internal temperature of the diluter
Analyzer measurement acquisition:	3 measurement signals from the analyzer (isolated inputs in a group)
Serial communication interface:	RS485 (including converter for USB) with open protocol
Electrical power supply:	from 100 to 240 Vac - 0.8 A max.
Dimensions and weights:	19" std. h 3UT prof. 250 mm - weight 10 kg

OPTIONS AND VERSIONS

BetaCAP30X100 can be built using different materials

A) Diluted gas flow rate (without price changes)

Maximum 2 L/min with the use of 1 hole diam. capillaries. 0.1mm x L 35mm

Maximum 6 L/min with the use of 3-hole capillaries diam. 0.1mm x L 35mm

In both cases, the flow rate can be selected by the User in the range 10...100% of the maximum

B) Construction of manifolds, pneumatic connections and fittings

Standard construction is fluorinated plastic (PVDF) with DN4x6 connections and fittings

As an option, "all steel" construction is possible with AISI 316L manifold, 1/8" tubes and double ferrules stainless steel fittings. Steel construction is recommended when toxic or explosive gases are used

C) Type of container (without price changes)

The standard construction is a 19" 3HU rack with a depth under the panel of 250 mm

Construction in a portable box (with handle) is also possible. The bypass flow meter present in the 19" Rack version is not supplied, but the bypass flow is now managed automatically and does not require the User's attention.

Dimensions: 41.66 x 22.12 x 33.4 cm

