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FLOW & PRESSURE, FAST

ALICAT SCIENTIFIC · 6TH LEARN & CONNECT SEMINAR ON BIOPROCESSING

Oxygen Uptake Rate and other metrics shaped by flow

Every OUR is also a gas-flow measurement

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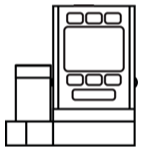
Your OUR is a gas flow times a composition difference

$$\mathrm{OUR} = \frac{Q_{\mathrm{in}}}{V_L\, V_m}\left[y_{O_2,\mathrm{in}} - y_{O_2,\mathrm{out}}\,\frac{1 - y_{O_2,\mathrm{in}} - y_{CO_2,\mathrm{in}}}{1 - y_{O_2,\mathrm{out}} - y_{CO_2,\mathrm{out}}}\right]$$



your flow controller — **your gas analyser**

Total flow error → OUR, CER, q_{O2}	Mixing-ratio error → OUR, CER, RQ	Soft sensors
one to one	**amplified: 1% → 12%**	**inherit the flow error**

Example: 2 L culture on 100 sccm air + 20 sccm O_2, OUR 2 mmol/(L·h), inlet gas not measured: O_2 controller 1% off, OUR 12% off

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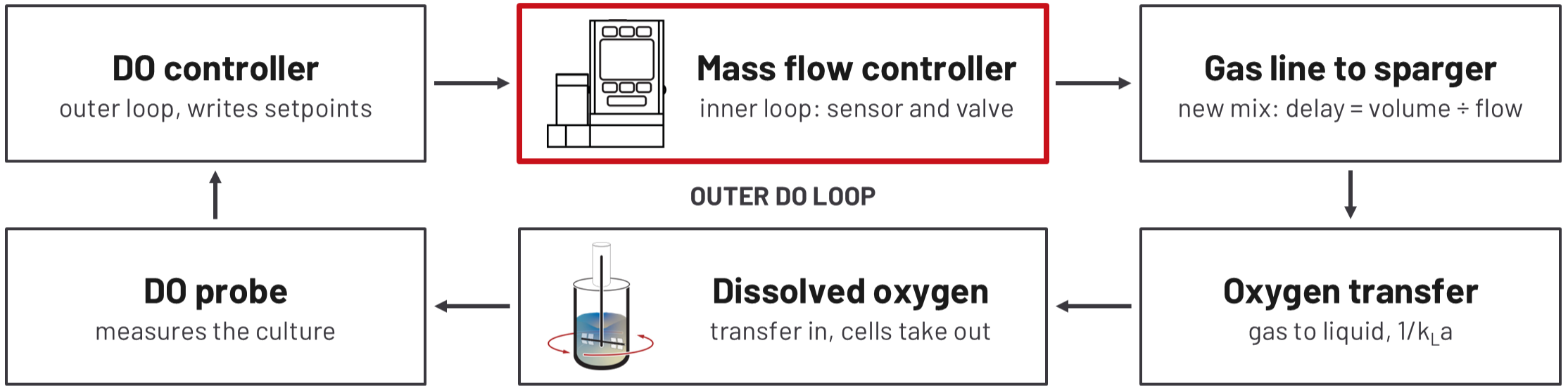
In a DO loop, the flow controller is the inner loop



Cascade rule: the inner loop must settle **5–10 times faster** than the outer loop

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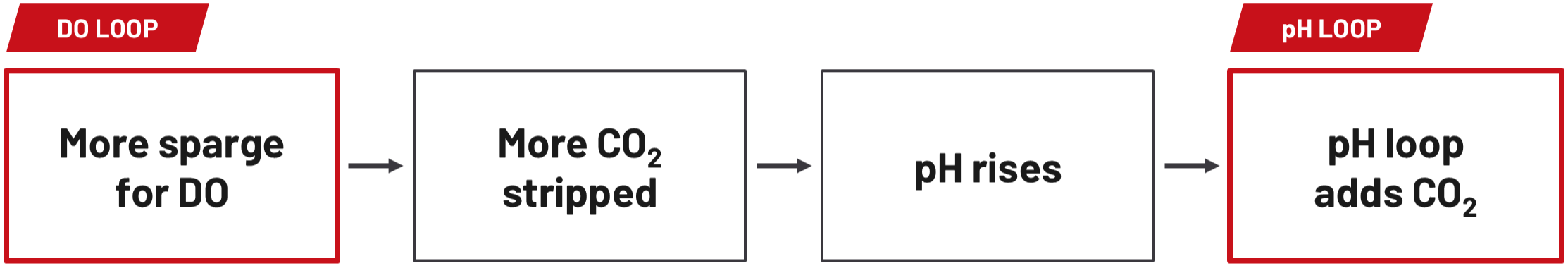
Your DO loop moves your pH



In bicarbonate media, CO_2 is the **acid side of pH control**

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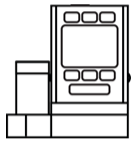
The flow controller is the fastest part of the loop

DO controller
outer loop, writes setpoints
settles in minutes

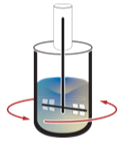


Mass flow controller
inner loop: sensor and valve
30–100 ms (T63)

Gas line to sparger
new mix: delay = volume ÷ flow
seconds to minutes

New mix through 1 m of 4 mm ID line at 10 sccm: 75 s

DO probe
measures the culture
tens of seconds



Dissolved oxygen
transfer in, cells take out
demand changes over hours

Oxygen transfer
gas to liquid, $1/k_La$
minutes in cell culture

Dead time sets the speed limit

Linear delivery: one tuning from inoculation to peak density

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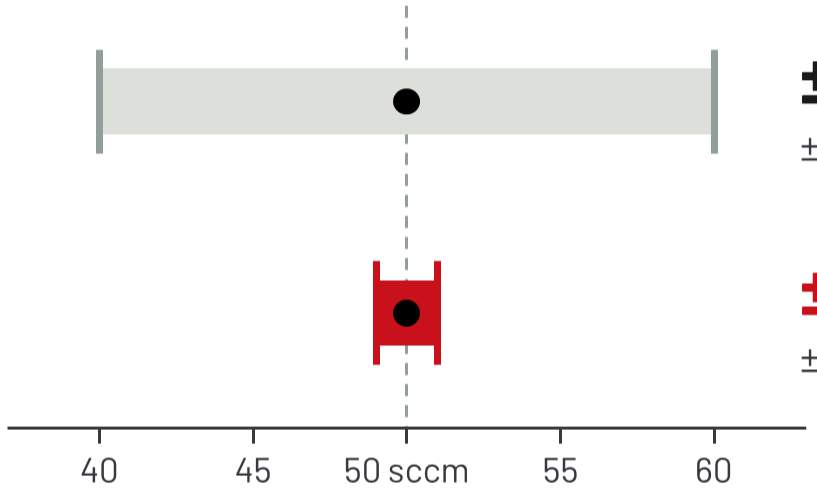
At low flow, the form of the spec sets your error bar

A 1 slpm controller running at **50 sccm**

±1% of full scale
a common form

±0.6% of reading or ±0.1% of full scale
whichever is greater · Alicat, 10 sccm–20 slpm ranges



2 L cell culture at 0.01–0.1 vvm
= **20–200 sccm**

Parallel vessels: a controller difference
looks like biology

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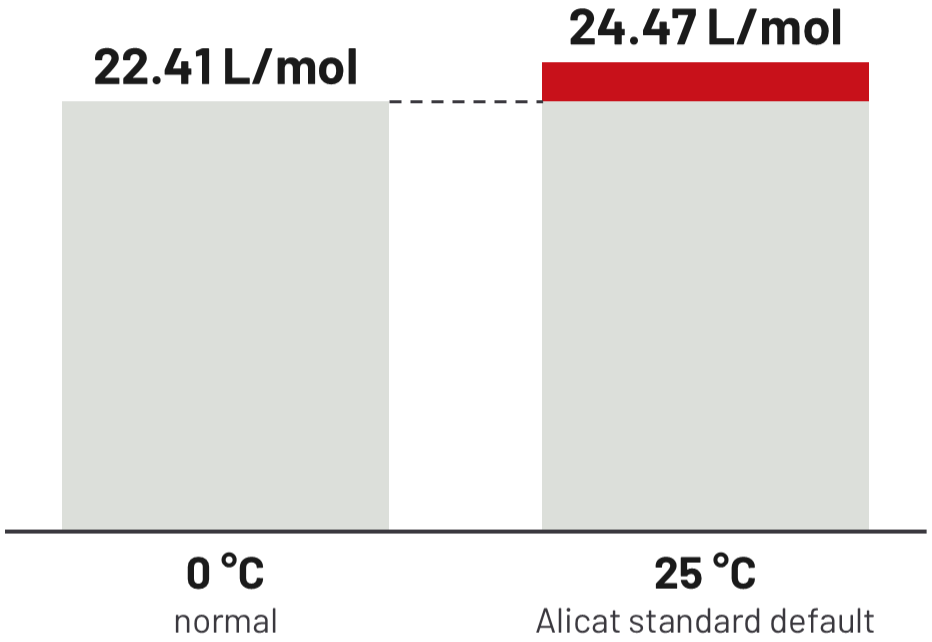
An sccm at 0 °C is not an sccm at 25 °C

9.2%

OUR overstated when the flow is reported at 25 °C and the molar volume is taken at 0 °C



In your methods and your metadata: reference conditions, and the accuracy at the flow you ran

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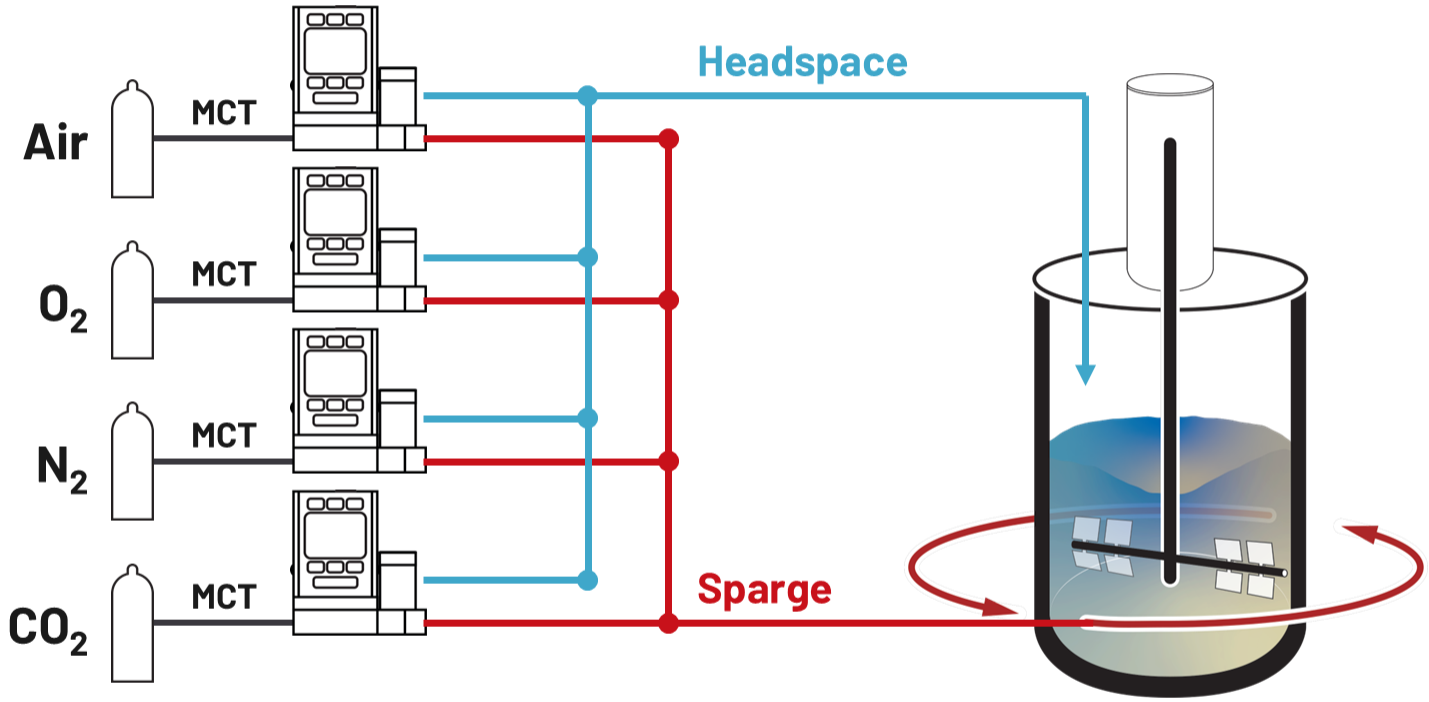
Mix the gas at the vessel, not at the rack



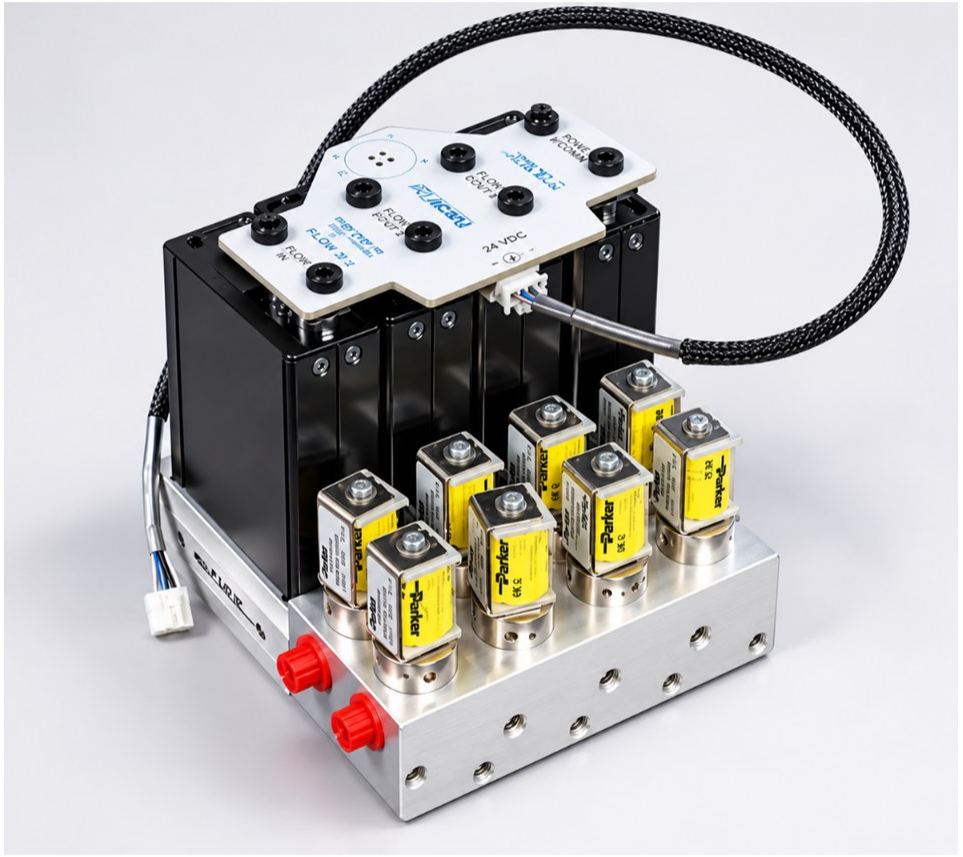
One stream-switching mass flow controller (MCT) per gas, each with two outlets

Short line,
small dead time

One setpoint per gas,
to either outlet

Change gas in the device,
no recalibration

The Alicat MCT module



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Three things to take home

1. Your OUR, CER and q_{O2} carry your flow's error **one to one**
2. The flow controller is your inner loop: **linear and repeatable beat fast**
3. **Mix the gas close to the vessel**

Scan the code or open the link for more information and to get the presentation
go.alicat.com/learn-connect-delft-2026

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Thank you!

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BACKUP · OPTIONAL SECTION 6

At low flow, a new gas mix crawls through the line

Delay for a new gas mix, per metre of line from mixing point to sparger

Line bore	10 sccm	100 sccm	1,000 sccm
2 mm	19 s	1.9 s	0.19 s
4 mm	**75 s**	7.5 s	0.75 s
8 mm	5.0 min	30 s	3.0 s

Delay = line volume ÷ total flow in the line, near atmospheric pressure. At 2 bar absolute the line holds twice the gas and the delay doubles.

75 s

1 m of 4 mm ID line at 10 sccm, before the culture sees the new mix

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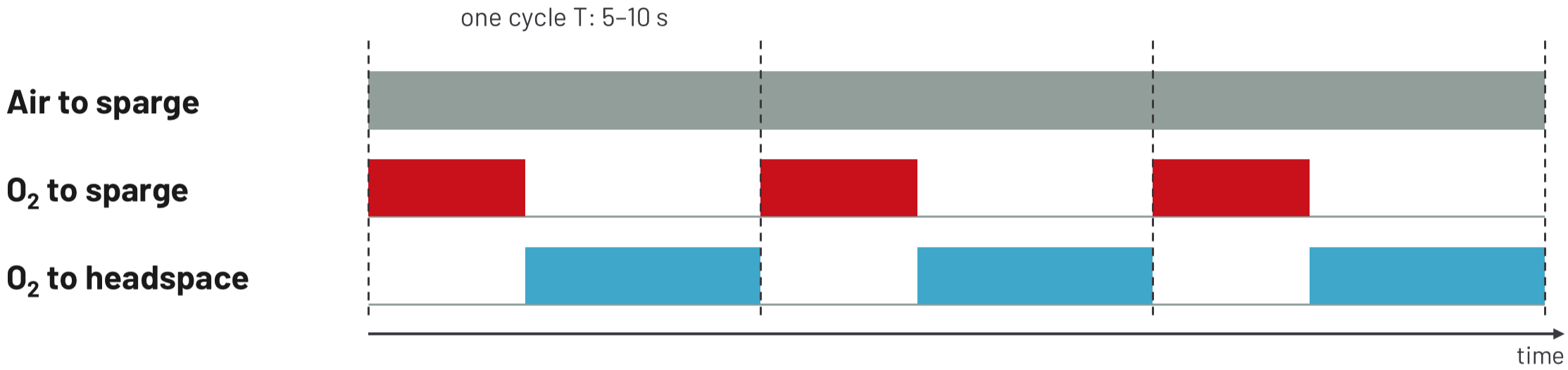
One controller can serve two outlets by alternating



$$\Delta \mathrm{DO}_{\mathrm{pp}} = \tanh\left(\frac{T}{4\tau}\right)\Delta C^{*}, \qquad \tau = \frac{1}{k_L a}$$

The culture sees the mean: a 5–10 s cycle keeps the DO ripple under about 2%

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