

Real-Time Monitoring and Measurement Challenges for Residual Dissolved Ozone

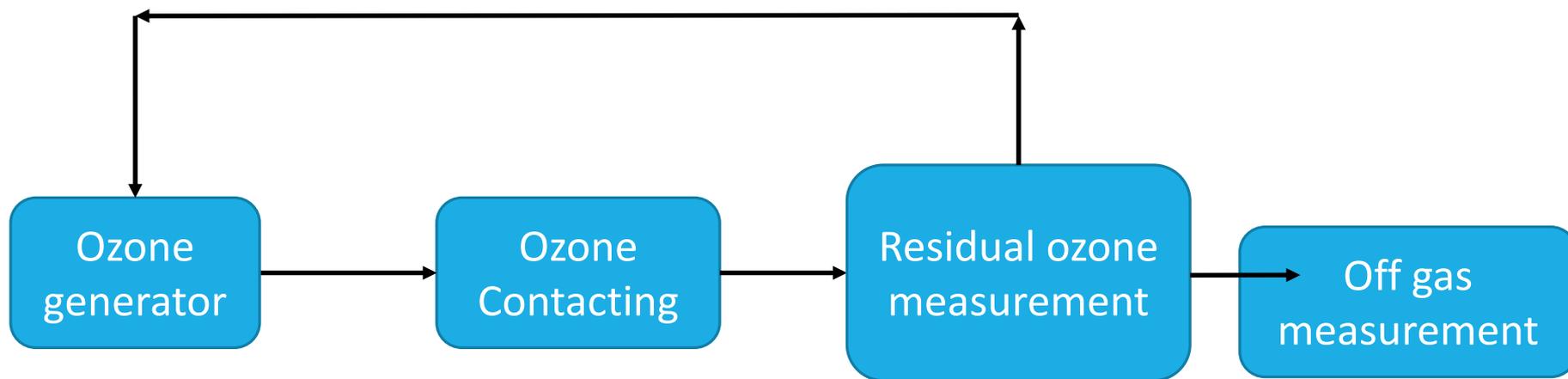
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Ozone residual stability



Error propagates from sampling to generator – Energy costs!

Are current sampling approaches representative?

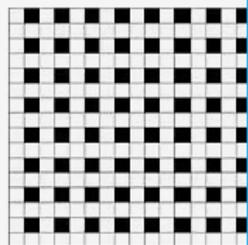
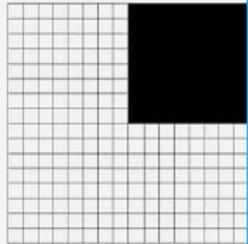


Is the Sidestream “Well Mixed”?

$$CoV = \sqrt{\frac{1}{N} \sum_{i=1}^N \frac{(C_i - C_{mean})^2}{C_{mean}^2}}$$

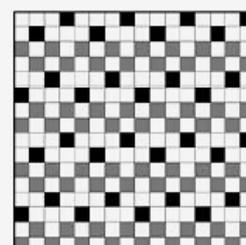
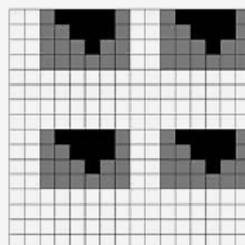
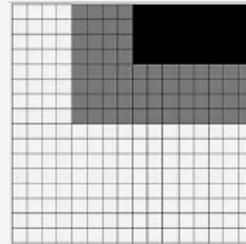
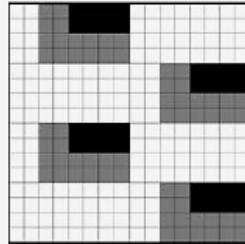


Standard Deviation
Mean



COV = x

Kresta, S. (2013)



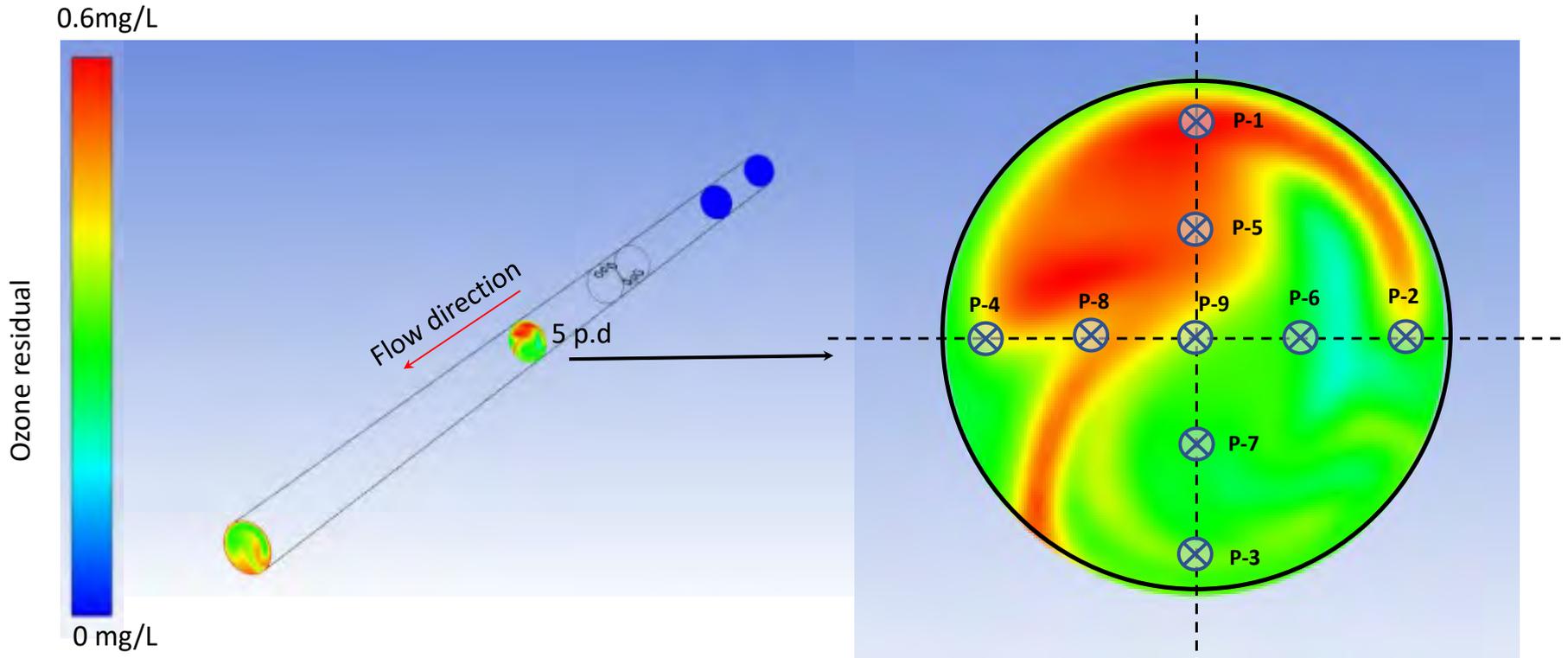
COV = y

Known limitations:

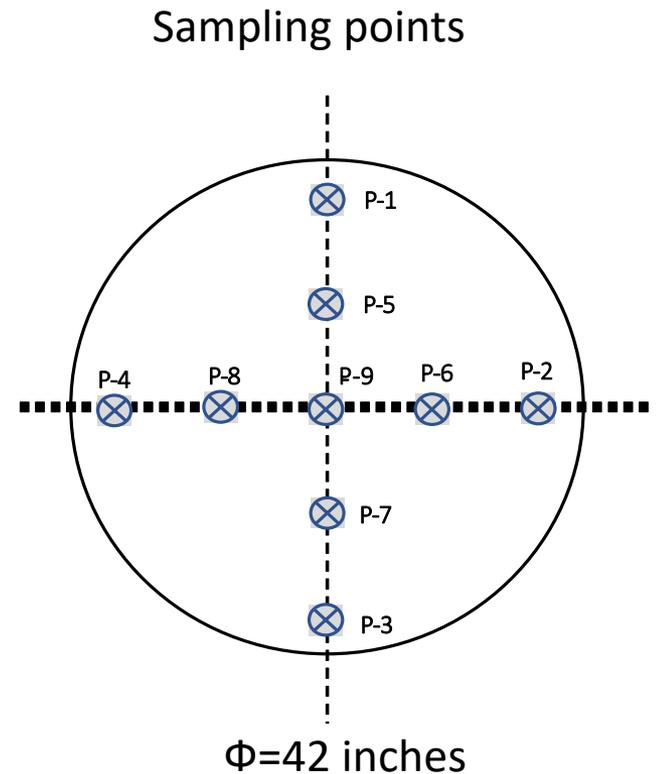
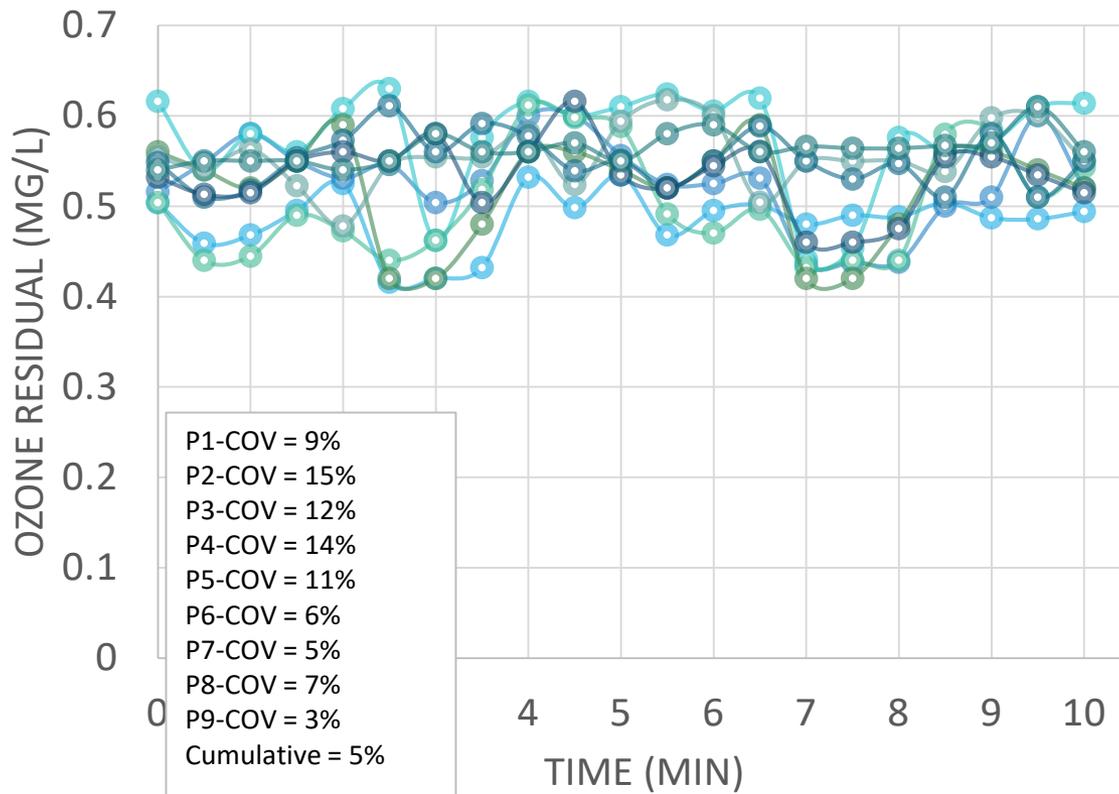
- When the mean value is close to zero, the coefficient of variation is sensitive to small changes in the mean.
- Unlike standard deviation, COV cannot be used directly to construct confidence intervals for the mean.



Gas Distribution in Pipe



Effect of Sampling Location



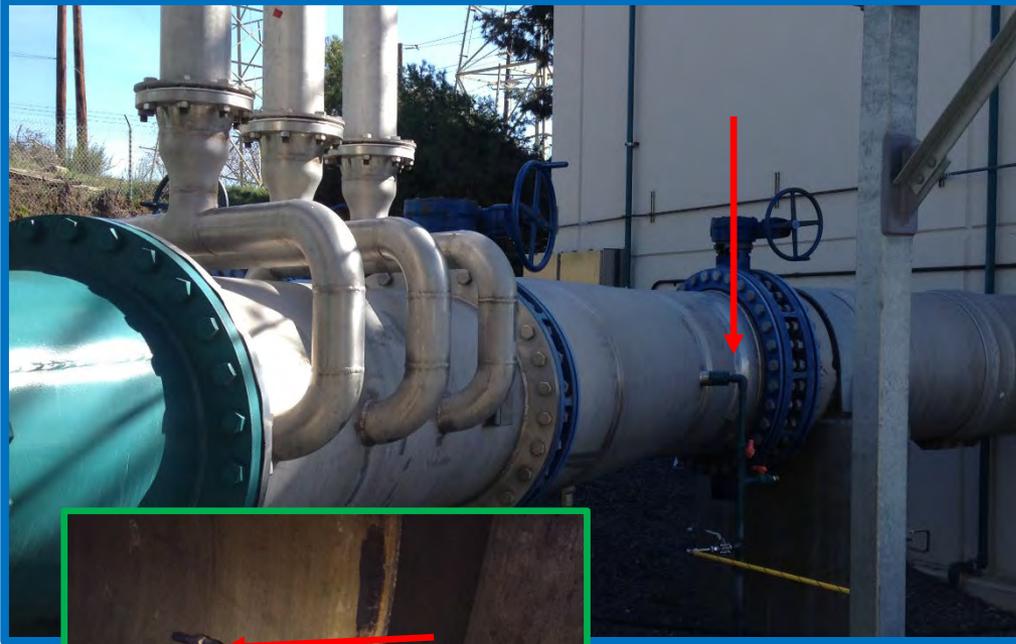
—○— P1 —○— P2 —○— P3 —○— P4 —○— P5 —○— P6 —○— P7 —○— P8 —○— P9



Measurement in Practice



Measurement in Practice



Common themes:

- **Single point sample**
 - Is the aliquot representative?
- **Non-ideal location**
 - Is the flow fully developed?
 - Is flow separation at fittings accounted for?

- **Unobtrusive, full cross-section sampler design** required at **carefully chosen location(s)** downstream while accounting for:

- **Dead zones/short-circuiting**
- **Flow separation**
- **Gas stratification**
- **Partially developed flow**
- **Other hydraulic anomalies**



Representative Sampling of Dissolved Ozone Residual

A sampler must-

- Obtain a representative volume sample across entire cross-section of pipeline
- Minimum allowable volume of sample shall be obtained without significantly impacting established steady-state flow pattern in main flow
- Physical obstruction of sampler shall not impede established steady-state flow pattern in pipeline
- Keep representative sample mixed as it is carried to the analyzer
- All above processes shall occur with minimal residence time in order to prevent ozone decay in the sampler line
- Ease of installation and maintenance.



Design Philosophy

Driving Variables for Design:

- Pipeline velocity profiles
- Ozone dose and concentration
- Gas:liquid ratio (both sidestream and mainline)
- Sidestream flow ratio
- Mainline pressure
- Analyzer input flow rate

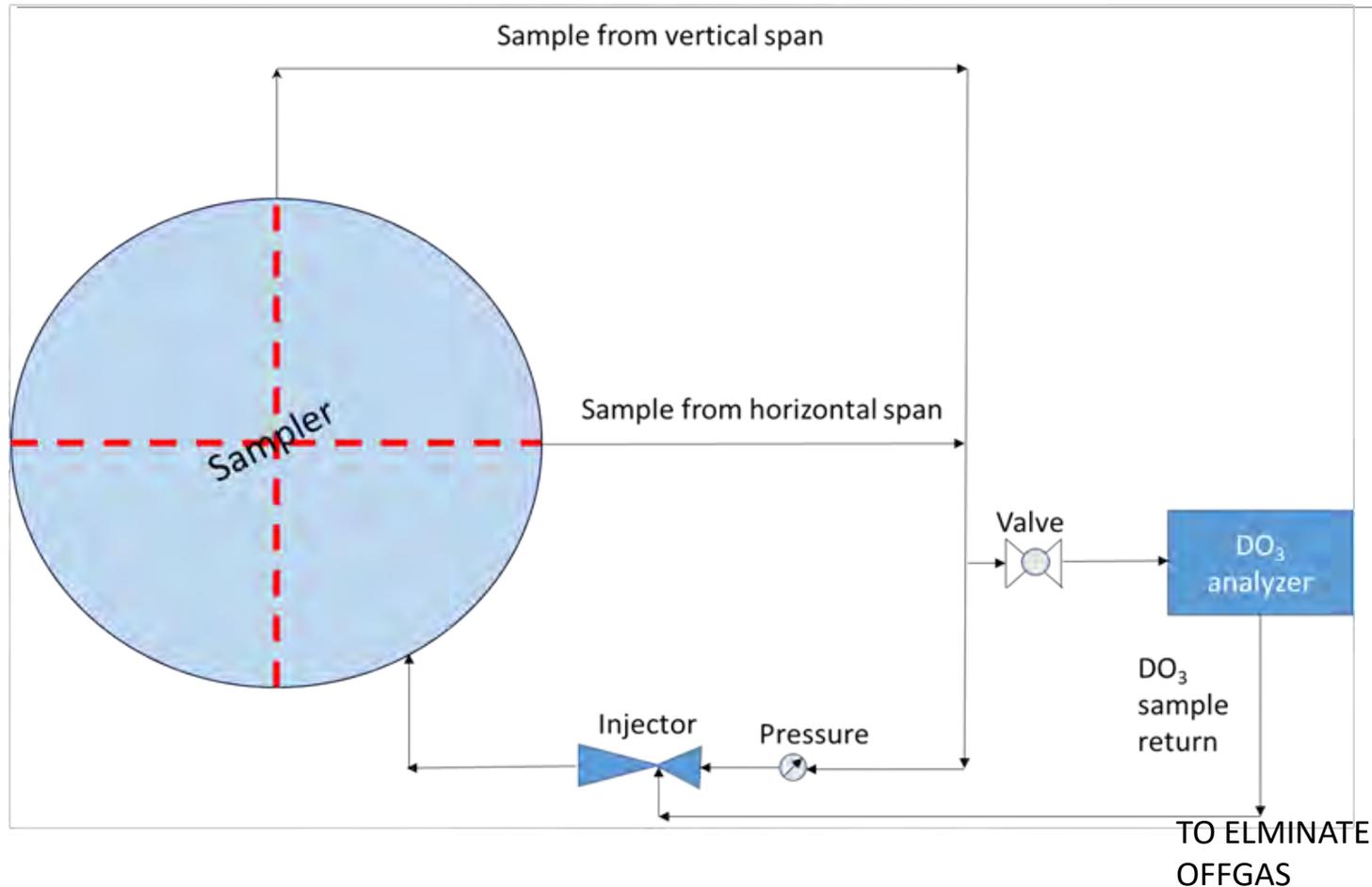
Design Constraints:

Non-reactive material, structurally stable and robust installation – Finite Element Analysis used

CRUCIAL TO CONSIDER ALL INTER-RELATED VARIABLES WHILE DESIGNING SAMPLER FOR EACH SPECIFIC APPLICATION



Sampling System Design



Sample draw from each port

Vertical sampler		% of total draw	Horizontal sampler		% of total draw
Size 1	v1	8%	Size 1	h1	7%
	v2	7%		h2	7%
	v3	8%		h3	8%
	v4	8%		h4	8%
	v5	8%		h5	9%
	v6	8%		h6	9%
	v7	8%		h7	8%
Size 2	v8	9%	Size 2	h8	9%
	v9	9%		h9	8%
	v10	9%		h10	9%
	v11	9%		h11	9%
	v12	9%		h12	9%



Conclusions

Cross-sectional mechanism devised for ozone residual sampling

- **Minimal effect on flow regime**
- **No sample wastage or requirement for off-gassing (returned to flow)**
- **Easy sample flow control**
- **True inline measurement**

Stabilizes ozone generator operation to minimize energy costs

Enables real-time accurate dosing



References

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Thank you! Questions?