

Stratification

What the data shows

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The challenge is as follows:

- **Can 3 points on a line reliably find if the stack is stratified?**
- **Can 6 points on a line reliably find if the stack is stratified?**
- **Can O₂ be reliably used as a surrogate to a pollutant stratification?**
- **Can any pollutant be a reliable surrogate for another pollutant?**
- **Can a short traverse (0.4, 1.2 & 2.0 m from the wall) reliably be used?**
- **Can a de minimis of ~ 0.5 ppm reliably be used to define no stratification?**

Assumptions:

- The extremes from a 12 point traverse (6 points on a traverse 90° apart) in a round stack defines the existence or absence of stratification.
- 43 random traverse data sets defines the universe satisfactorily.

Note: This is the second study of this kind with similar results.

DETERMINATION OF GAS STRATIFICATION AT TEST LOCATIONS

Roger T. Shigehara, Walter S. Smith, & Bill Mayhew,

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The Data

This data has been taken from a collection of 12 point traverses from a range of sources

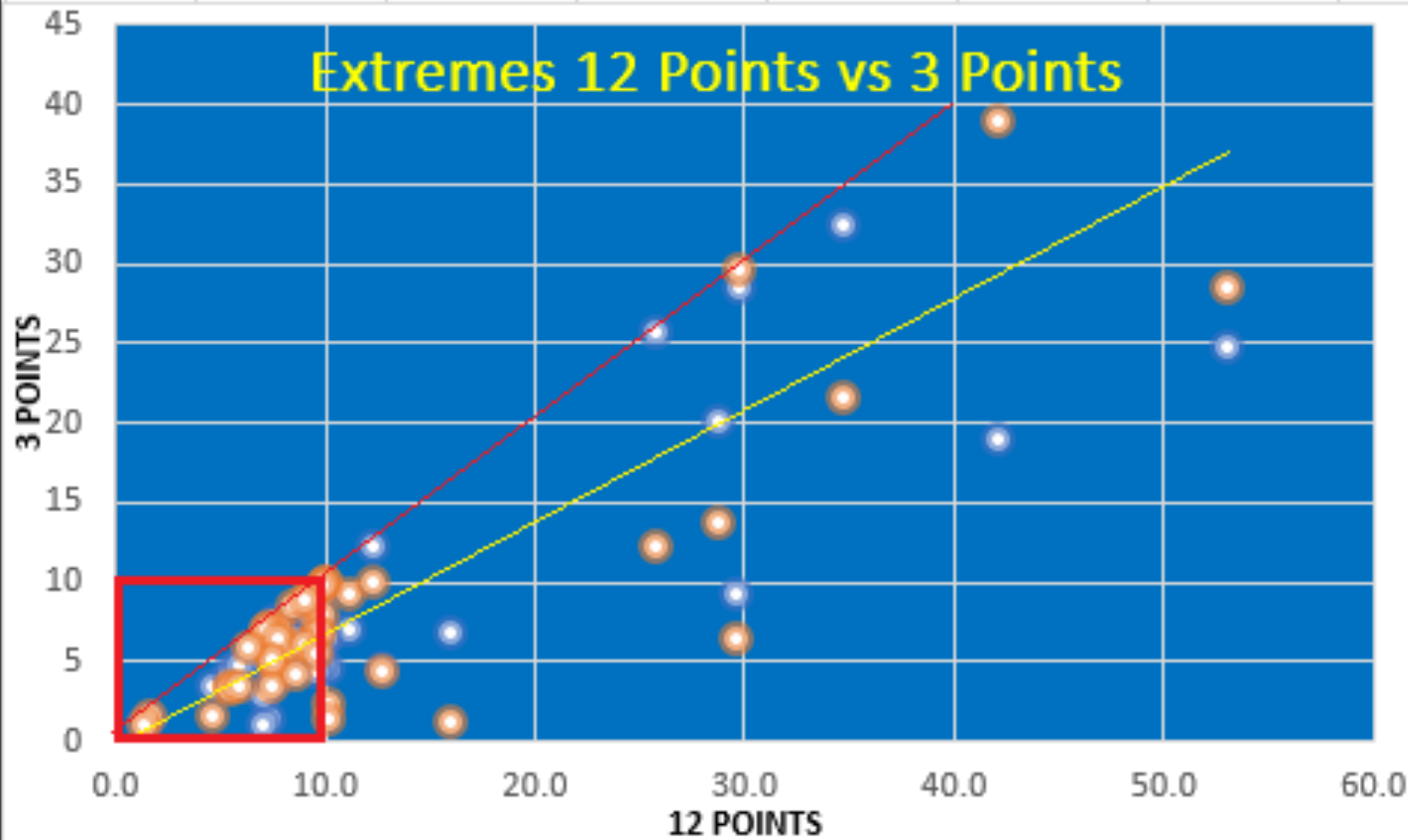
- glass plants to
- gas turbines
- 4 to 12 foot in diameter.
- After scrubbers, SCRs, Dry scrubbers, fans, etc.
- Assume that this 43 random traverse data sets defines the universe satisfactorily.

The Data

- **63 -12 point (6 on dia.) pollutant traverse with**
 - **43 Pollutant traverses with**
 - **20 Accompanied Oxygens**
- **126 -3 point traverses of pollutants with**
 - **40 Accompanied Oxygens**
- **126 Centers with**
 - **40 Accompanied Oxygens**

#	Pollutant	12 point Traverse			3 Point Traverse A			3 Point Traverse B		
		Statistical		O2	Statistical		O2	Statistical		O2
		Avg	extreme	Predicted	Avg	extreme	Predicted	Avg	extreme	Predicted
1	NOx	0	42.0	12.8	20.0	39.0	5.8	16.5	19.0	4.1
2	SO2	0	5.4	12.8	3.2	3.6	5.8	2.8	4.4	4.1
3	O2	0	12.8		2.3	5.8		0.7	4.1	
4	SO2	0	10.1	5.8	1.5	2.4	5.6	1.5	6.7	3.8
5	NOx	0	10.0	5.8	3.2	10.0	5.6	5.1	6.6	3.8
6	O2	0	5.8		0.5	5.6		0.4	3.8	
7	SO2	0	10.1	1.3	1.1	1.4	1.3	1.0	4.7	0.4
8	NOx	0	7.7	1.3	3.3	7.1	1.3	2.3	4.4	0.4
9	O2	0	1.3		0.5	1.3		0.3	0.4	
10	SO2	0	11.1	4.1	1.1	9.3	3.7	2.3	7.0	4
11	NOx	0	10.0	4.1	3.2	10.0	3.7	3.2	6.6	4
12	O2	0	4.1		2.3	3.7		1.9	4.0	
13	SO2	0	12.7	1.3	2.2	4.5	1.3	3.0	4.7	0.3
14	NOx	0	7.3	1.3	1.5	7.1	1.3	0.9	1.4	0.3
15	O2	0	1.3		0.4	1.3		0.2	0.3	
16	SO2	0	9.4	2.0	0.7	9.2	0.8	0.5	7.5	1
17	NOx	0	9.6	2.0	0.9	7.0	0.8	1.3	7.7	1
18	O2	0	2.0		0.3	0.8		0.1	1.0	
19	SO2	0	29.7	5.8	9.9	29.7	0.9	11.6	28.6	1.3
20	NOx	0	16.0	5.8	0.1	1.3	0.9	3.0	6.8	1.3
21	O2	0	5.8		0.3	0.9		1.0	1.3	
22	SO2	0	12.3	3.8	3.7	10.1	3.0	7.9	12.3	2.8
23	NOx	0	34.7	3.8	10.6	21.6	3.0	6.0	32.5	2.8
24	O2	0	3.8		1.2	3.0		2.2	2.8	
25	SO2	0	25.8	4.5	2.0	12.3	2.8	6.8	25.8	4.5
26	NOx	0	53.0	4.5	17.6	28.5	2.8	2.0	24.9	4.5
27	O2	0	4.5		0.6	2.8		0.4	4.5	
28	SO2	0	29.5	4.5	3.0	6.4	3.8	2.8	9.4	4
29	NOx	0	28.7	4.5	10.7	13.8	3.8	14.8	20.1	4
30	O2	0	4.5		3.2	3.8		3.8	4.0	
31	SO2	0	9.3	0.4	4.0	9.3	0.2	2.6	8.1	3.5
32	NOx	0	4.6	0.4	0.0	1.7	0.2	0.2	3.5	
33	O2	0	0.4		0.1	0.2		0.1	0.4	
34	SO2	0	9.9	1.1	1.6	9.9	0.4	1.2	4.8	0.2
35	NOx	0	7.0	1.1	2.5	6.0	0.4	1.7	3.0	0.2
36	O2	0	1.1		0.0	0.4		0.2	0.2	
37	SO2	1	9.9		0.0	8.0		4.1	9.2	
38	NOx	0	7.0		0.2	6.5		0.0	1.0	
39	CO2	0	2.4		0.1	1.6		0.4	1.4	
40	NOx	0	7.5		3.0	4.8		3.7	7.5	
41	SO2	0	8.2		0.2	5.9		1.6	6.7	
42	CO2	0	7.5		2.9	3.5		0.4	4.0	
43	SO2	0	5.4	0.4	0.2	3.3	0.3	0.9	4.1	0.2
44	NOx	0	7.1	0.4	0.8	7.1	0.3	2.5	7.0	0.2
45	O2	0	0.4		0.1	0.3		0.0	0.2	
46	SO2	0	7.7	7.0	2.1	6.5	2.5	2.6	4.0	1.7
47	O2	0	7.0		0.4	2.5		1.4	1.7	
48	NOx	0	8.5	0.3	6.3	8.5	0.1	3.9	6.5	0.1
49	O2	0	0.3		0.1	0.1		0.1	0.1	
50	NOx	0	8.6	1.1	1.8	4.2	0.9	3.0	5.5	1.1
51	O2	0	1.1		0.7	0.9		0.9	1.1	
52	SO2	0	7.5	3.1	0.5	5.2	2.5	1.1	4.8	2.2
53	O2	0	3.1		1.3	2.5		1.3	2.2	
54	SO2	0	9.0	0.9	5.4	9.0	0.3	3.5	5.2	0.7
55	O2	0	0.9		0.0	0.3		0.3	0.7	
56	SO2	0	9.8	2.2	3.6	6.9	2.0	3.1	5.7	1.7
57	NOx	0	9.0	2.2	5.0	6.1	2.0	4.5	5.6	1.7
58	O2	0	2.2		1.4	2.0		1.6	1.7	
59	CO2	0	6.4	2.2	4.2	5.8	2.0	4.9	5.2	1.7
60	SO2	0	5.9	0.7	1.5	3.4	0.4	0.4	4.8	0.7
61	NOx	0	9.5	0.7	1.3	5.6	0.4	0.2	4.3	0.7
62	O2	0	0.7		0.1	0.4		0.4	0.7	
63	CO2	0	1.3	0.7	0.4	1.0	0.4	0.8	1.2	0.7

Extremes 12 Points vs 3 Points



Percent of all data that was found partially stratified or stratified

Extreme	% All data		% Pollutants Only	
	12 Point	3 Point	12 Point	3 Point
>10	25%	15%	35%	19%
>9.9	28%	15%	40%	20%
>9.5	32%	15%	47%	20%
>5	68%	44%	95%	65%
Average	10%	3%	10%	3%

The odds of a 3 point traverse finding an existing partially or stratified gas

Between 2 out of 5 and 12 out of 3

Extreme	All Data	Pollutants
>10	38%	35%
>5	39%	41%

What are the odds of a 6 point traverse finding an existing partially or stratified gas?

A little better than a 3 point traverse.

Extreme	All Data	Pollutants
>10	41%	34%
>5	45%	42%

What are the odds that a O₂ traverse can find a partially or stratified pollutants?

12 O₂ points predicts
1 in 16 to 1 in 6

While

3 O₂ points predicts
0 to 1 to 4

% Total Pollutants & Diluents				
	12 Point Traverse		3 Point Traverse	
Extreme	Total	O ₂ Predicted	Total	O ₂ Predicted
>10	25%	2%	15%	0%
>9.9	28%	2%	15%	0%
>9.5	32%	2%	15%	0%
>5	68%	14%	44%	1.8%

% of total Pollutants				
	12 Point Traverse		3 Point Traverse	
Extreme	Total	O ₂ Predicted	Total	O ₂ Predicted
>10	33%	2%	18%	0%
>9.9	38%	2%	19%	0%
>9.5	44%	2%	19%	0%
>5	89%	16%	61%	4%

Can any gas other than a diluent predict a surrogate stratification for another?

57% of the time,

However, other gases do not ever pick the correct category of

- stratified**
- partially stratified**
- not stratified.**

Can a short traverse (0.4, 1.2 & 2.0 m from the wall) reliably be used?

Of the 12 point stratified traverses, when using the short traverse the following was found:

- 37% were minimally Stratified**
 - 87% of these were oxygen**
- A short traverse of O₂ is as useless as a O₂ surrogate of a pollutant.

Can a de minimis of 0.5 ppm reliably be used to define no stratification?

- $\leq 5\%$ of the Extreme defines no stratification so 0.5 ppm is for a 10 ppm span.
- Likewise, $\leq 10\%$ of the Extreme defines minimally stratified so 1.0 ppm is for a 10 ppm span.
- Therefore EPA must be assuming that **no** spans below 10 ppm are stratified.

Can a de minimis of 0.5 ppm reliably be used to define no stratification? Continued

- **Since many states and cities require spans ≤ 10 ppm and use 7E as the reference, I suggest**
- **EPA remove the de minimis values because they only cause misuse in their application.**

Why are the gasses stratified?

Examples of why there is stratification.

- Leak in the fan or duct work
- Dry spot in a scrubber
- uneven flow or ammonia injection or bad catalyst in an SCR.
- A combination of the above.

Conclusions:

- I think We and EPA need to rethink the definition stratification.
- This includes most of the wet gas methods and all the instrumental methods.
- **We should think everything is stratified and use 12 points with the exception of proof of non stratified.**