MAJOR FACTORS CONSIDERED IN TEST DESIGN

- Scale of the device
- Device operation during tests
- Measurement methods
- Number and length of measurements

SCALE AND RANGE OF OPERATION

- Scale can be: full - pilot on a slipstream - pilot in a lab
- Range of operation determines applicability of verification statement
- Did not address
  - performance changes over time
  - device-to-device performance variations

NO_x MEASUREMENT METHOD

- EPA Reference Method 7E (30 minute test runs)
- Determine removal efficiency and outlet concentration

EXPERIMENTAL DESIGN

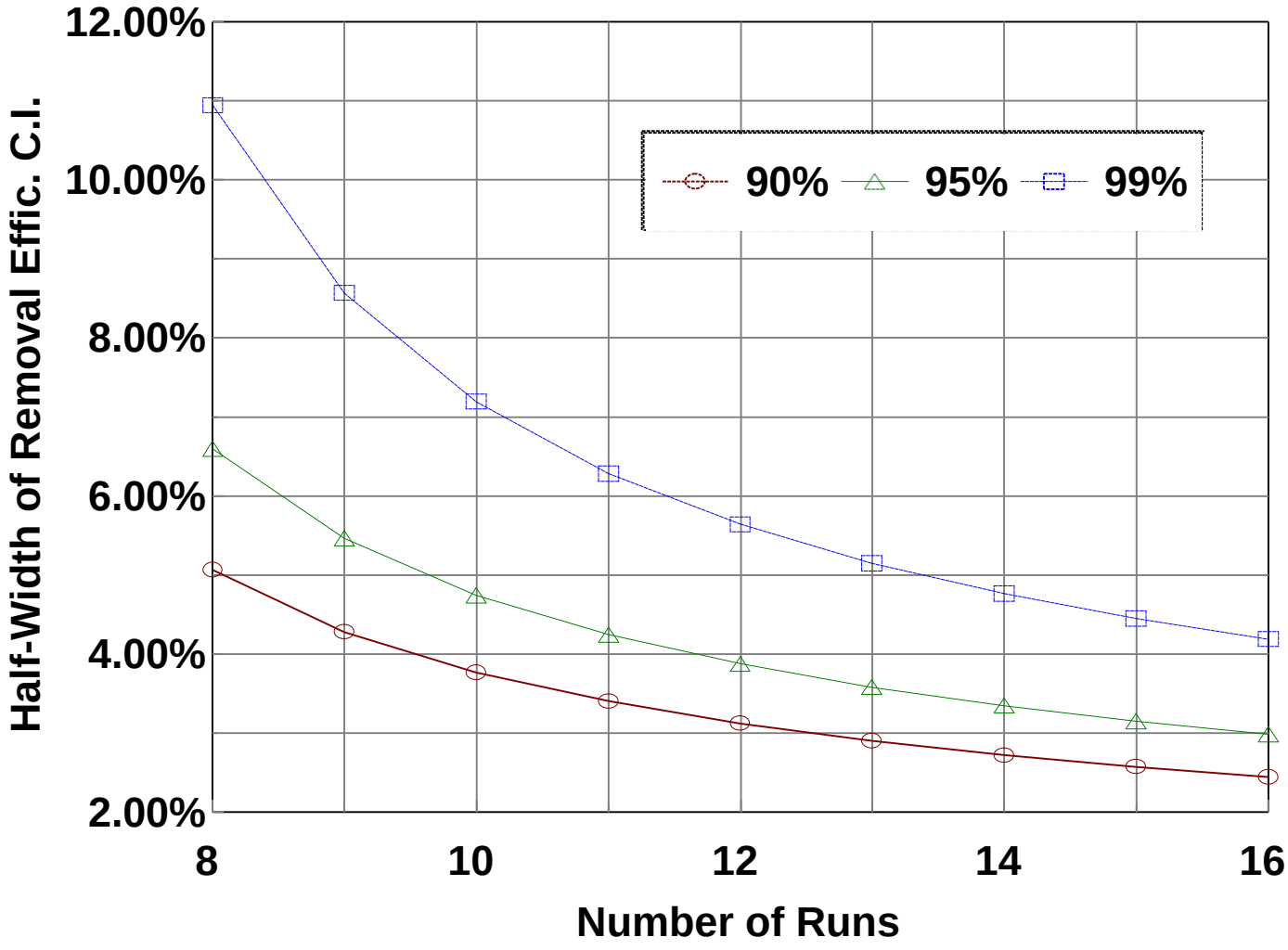
- Primary device operating parameters are:
  (1) inlet NO_x concentration
  (2) reaction zone temperature
  (3) gas flow, i.e., residence time
- 2x2x2 factorial design with each parameter at two levels
- Two replications of each test condition
- Total of 16, 30 min. test runs (about a week of testing)

2X2X2 FACTORIAL DESIGN

Run	Inlet NO_x	Inlet Temperature	Flow
1	Low	Low	Low
2	Low	Low	High
3	Low	High	Low
4	Low	High	High
5	High	Low	Low
6	High	Low	High
7	High	High	Low
8	High	High	High

CONFIDENCE INTERVAL ON MEASURED REMOVAL EFFICIENCY DEPENDS ON

- Variability of NO_x measurement (assumed +/- 5 percent)
- Desired level of confidence
- Number of test runs, i.e., degrees of freedom
- Level of removal efficiency


12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
Half-Width of Removal Effic. C.I.
90%
95%
99%
8
10
12
14
16
Number of Runs

EXAMPLE 1 VERIFICATION TEST DATA

Run Number	NO_X	Temp	Flow	Removal Efficiency
1	53.6	288	20,500	97.826
2	53.6	288	29,700	97.623
3	53.6	312	20,500	97.922
4	53.6	312	29,700	97.688
5	290.5	-288	20,500	96.962
6	290.5	288	29,700	96.484
7	290.5	-312	20,500	96.891
8	290.5	312	29,700	96.666
9	53.6	-288	20,500	97.925
10	53.6	288	29,700	98.112
11	53.6	-312	20,500	97.724
12	53.6	312	29,700	97.574
13	290.5	-288	20,500	97.315
14	290.5	288	29,500	96.870
15	290.5	-312	20,500	97.206
16	290.5	312	29,500	96.722

RESULTS OF ANALYSIS OF VARIANCE - EXAMPLE 1

Source	P-Value (significance)	Significant at 5% level
NO_X	0.000	**T**
Temp	0.405	
Flow	0.039	**T**
NO_X1*Temp	0.615	
NO_X1*Flow	0.172	
Temp*Flow	0.857	
NO_X1*Temp*Flow	0.499	

RESULTS OF ANALYSIS OF VARIANCE (ONLY NO_x & FLOW)

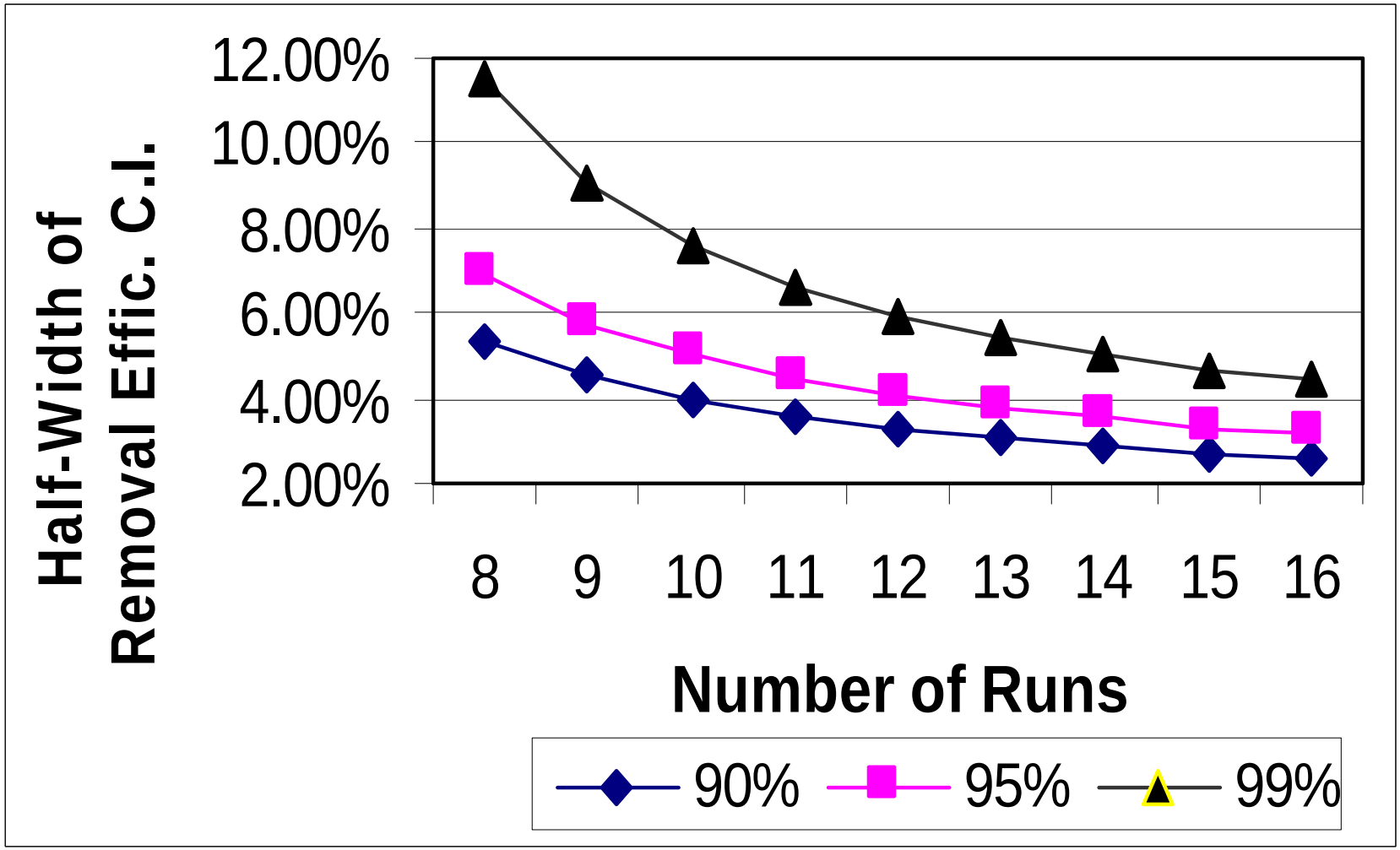
Source	P-Value (significance)	Significant at
NO_x	0.000	1%·level
Flow	0.022	5%·level

EXAMPLE 1 RESULTS (NO_x & Flow)

Factor	Least squares mean	Removal efficiency interval at 95% confidence
Low NO_X	97.799	+/- 0.15%
High NO_X	96.889	+/- 0.15%
Low flow	97.471	+/- 0.15%
High flow	97.217	+/- 0.15%

EXAMPLE 1 RESULTS (NO_x only)

Factor	Least Squares Mean	Removal Efficiency interval at 95% confidence
Low NO_X	97.799	+/- 0.18%
High NO_X	96.889	+/- 0.18%


Half-Width of Removal Effic. C.I.
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
8
9
10
11
12
13
14
15
16
Number of Runs
90%
95%
99%

EXAMPLE 2 VERIFICATION TEST DATA

Run Number	Inlet NO_X	Inlet Temperature	Flow	Removal Efficiency
1	54.0	288	20,500	97.6
2	54.0	288	29,700	96.3
3	54.0	312	20,500	97.9
4	54.0	312	29,700	96.1
5	301.5	288	20,500	98.4
6	301.5	288	29,700	97.4
7	301.5	312	20,500	94.1
8	301.5	312	29,700	98.2
9	54.0	288	20,500	98.1
10	54.0	288	29,700	93.8
11	54.0	312	20,500	92.0
12	54.0	312	29,700	89.6
13	301.5	288	20,500	98.7
14	301.5	288	29,700	96.2
15	301.5	312	20,500	97.2
16	301.5	312	29,700	97.0

RESULTS OF ANALYSIS OF VARIANCE - EXAMPLE 2

Source	P-Value (significance)	Significance at 5% Level
Inlet NOx	0.220	
Inlet Temp	0.269	
Flow	0.254	
NOx * Temp	0.403	
NOx * Flow	0.468	
Temp * Flow	0.276	
NOx * Temp * Flow	0.403	

RESULTS EXAMPLE 2

RE = 96.0% $\pm$ 1.4% at the 95% confidence level

EXAMPLE 3 VERIFICATION TEST DATA

Run Number	Inlet NO_X	Inlet Temperature	Flow	Removal Efficiency
1	54.0	288	20,500	97.6
2	54.0	288	29,700	96.3
3	54.0	312	20,500	97.9
4	54.0	312	29,700	96.1
5	301.5	288	20,500	98.4
6	301.5	288	29,700	95.0
7	301.5	312	20,500	95.2
8	301.5	312	29,700	98.2
9	54.0	288	20,500	98.1
10	54.0	288	29,700	93.8
11	54.0	312	20,500	92.6
12	54.0	312	29,700	94.5
13	301.5	288	20,500	98.6
14	301.5	288	29,700	96.8
15	301.5	312	20,500	97.2
16	301.5	312	29,700	97.0

RESULTS OF ANALYSIS OF VARIANCE - EXAMPLE 3

Source	P-Value (significance)	Significance at 5% Level
Inlet NO_x	0.198	
Inlet Temp	0.409	
Flow	0.277	
NO_x * Temp	0.619	
NO_x * Flow	0.659	
Temp * Flow	0.078	
NO_x * Temp * Flow	0.743	

RESULTS EXAMPLE 3

RE = 96.5% $\pm$ 0.95% at the 95% confidence level