



Stack Flow and Particle Sizing for Estimating Representative Sampling Assessment at Nuclear Plants

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Several Possible Objectives

1. Sampling Efficacy

Collect and Quantify Cs-138 as paired samples from Stack and Sampler. (BWR Only)

2. Flow Rate

Measure Duct Flow Profiles and Calculate Mass Flow Rate for Comparison to Assumed or Indicated Value.

3. Measure Stable Particle Size Distribution and Predict Line Loss.

Model Line Sections

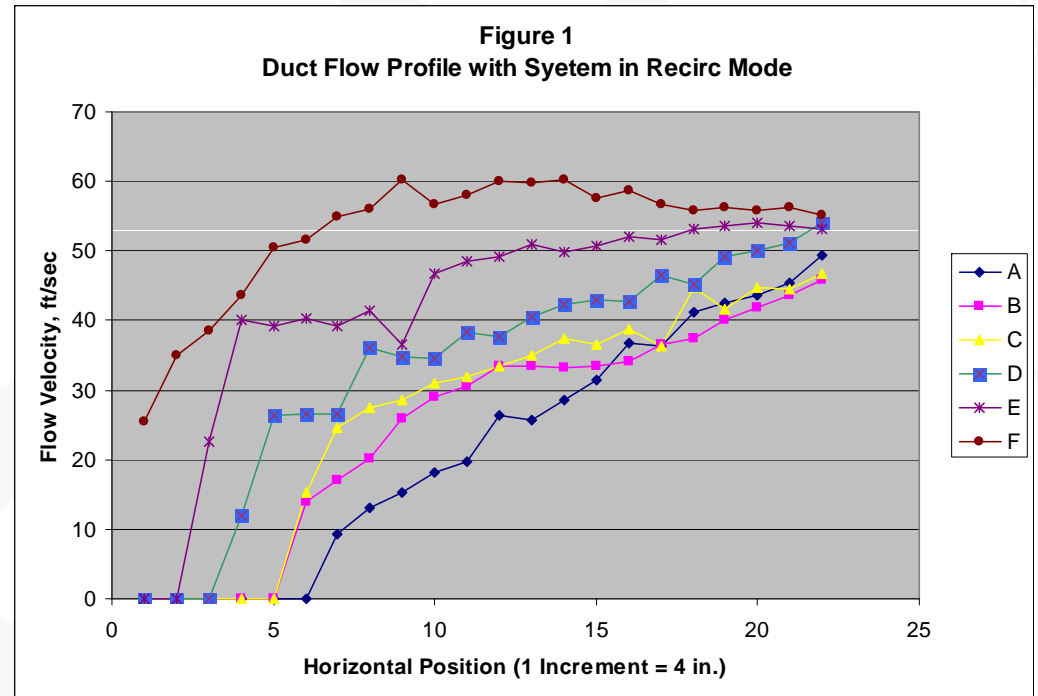
Develop Mock-up and Measure Sub-Set of System for Loss

Challenges Encountered

1. Performing required measurements in ventilation systems in normal operating configurations (e.g., steady state full power)
2. Maintaining all system components in “Operable” status from a Technical Specification perspective.
3. As-built drawings can differ from as-found system configurations

Case 1: Sampling Efficacy

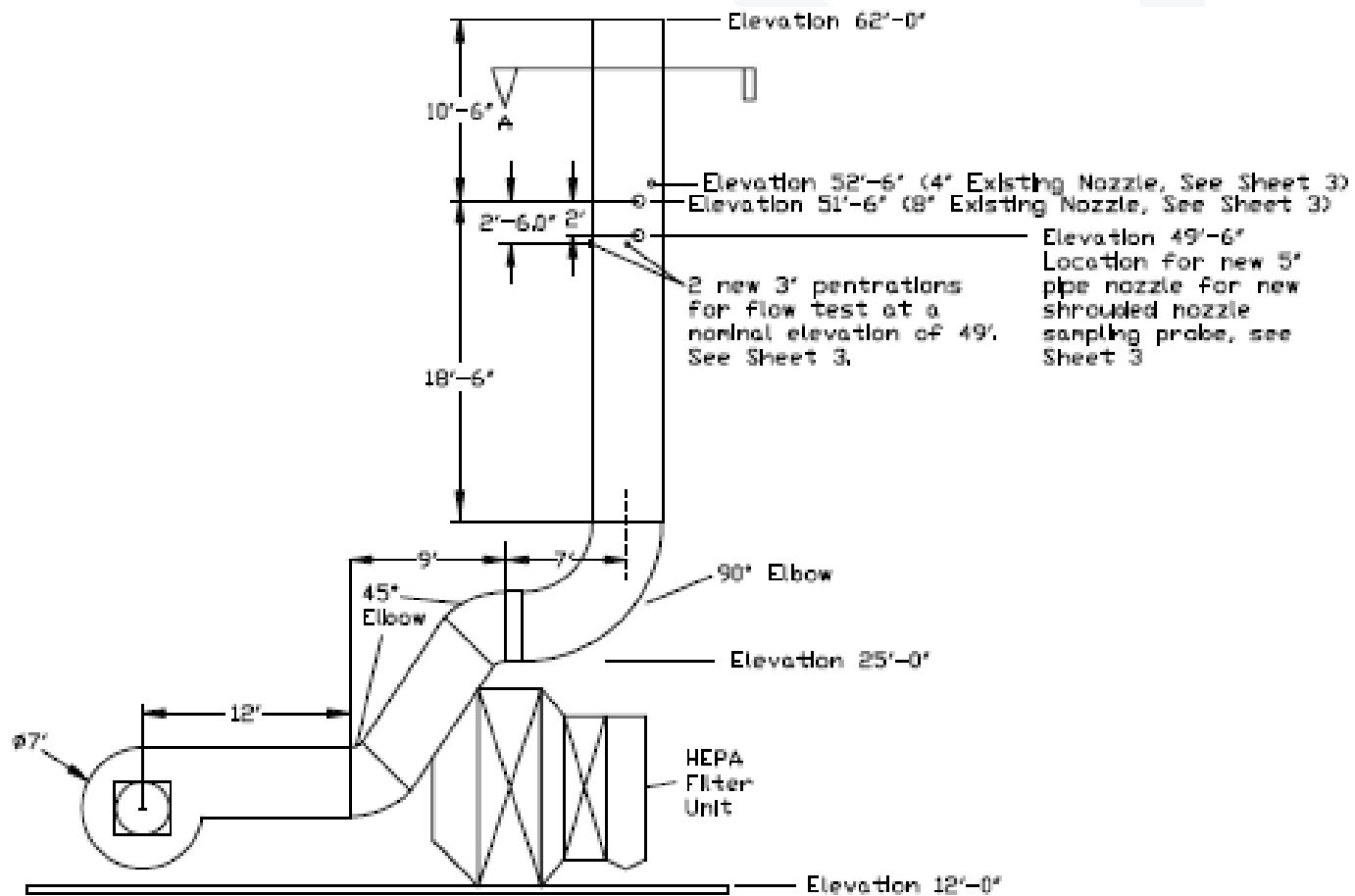
- Continuous Release Cs-138 ($t_{1/2} = 32$ min)
- Stack Flow Profile Sample Each Flow Measurement Location for Cs-138.
 - Concurrent Sample from Stack Particulate Sampler
 - 20 Paired Samples



Case 1: Results

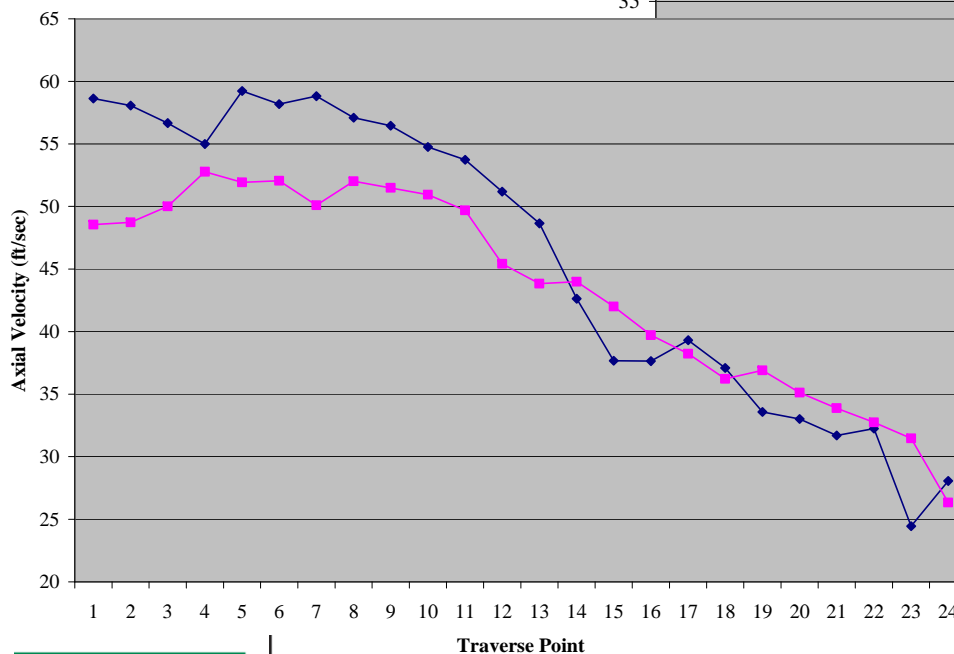
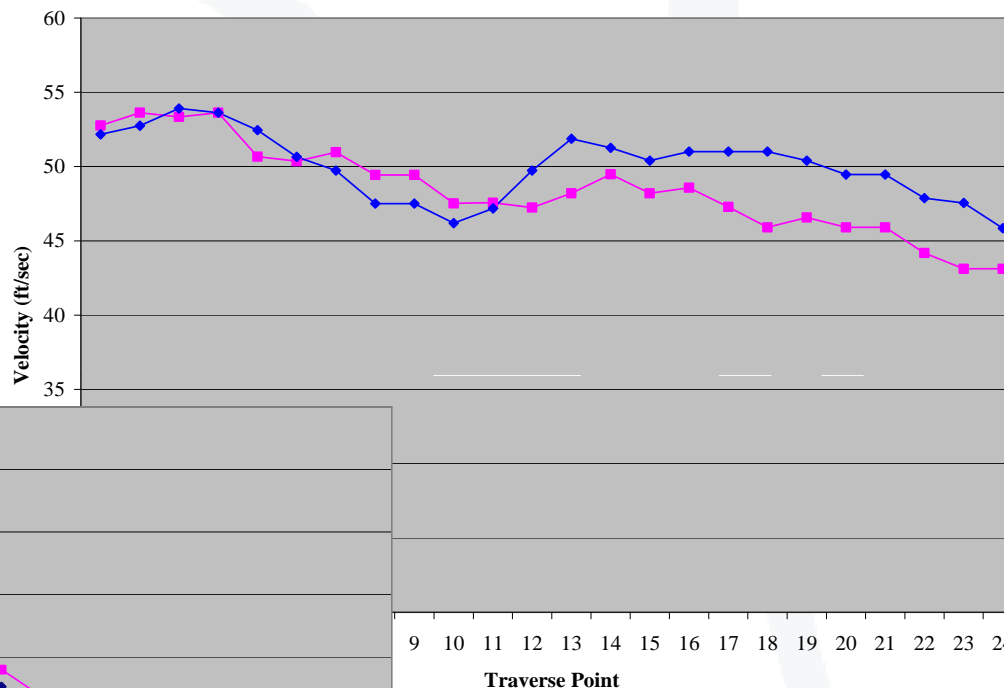
- Quantified Mass Flow Rate in two operating modes
- Established Transmission Factor
 - 0.76 +/- 11%
- No Particle Size Determinations

Case 2: Physical Arrangement



Case 2: Stack Flow Results

EPA Method 2



EPA Method 2F
(Cyclonic Flow)



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Case 2: Data Assessment

- Criteria- ANSI N13.1 – 1999
 - %CV Across Center 2/3 of Stack $\leq 20\%$
 - Average Flow Angle $< 20\text{deg}$.
 - Results
 - %CV (Method 2) $< 15\%$
- Passed*
- Average Flow Angle (Method 2F) = 13.9 deg.

Passed

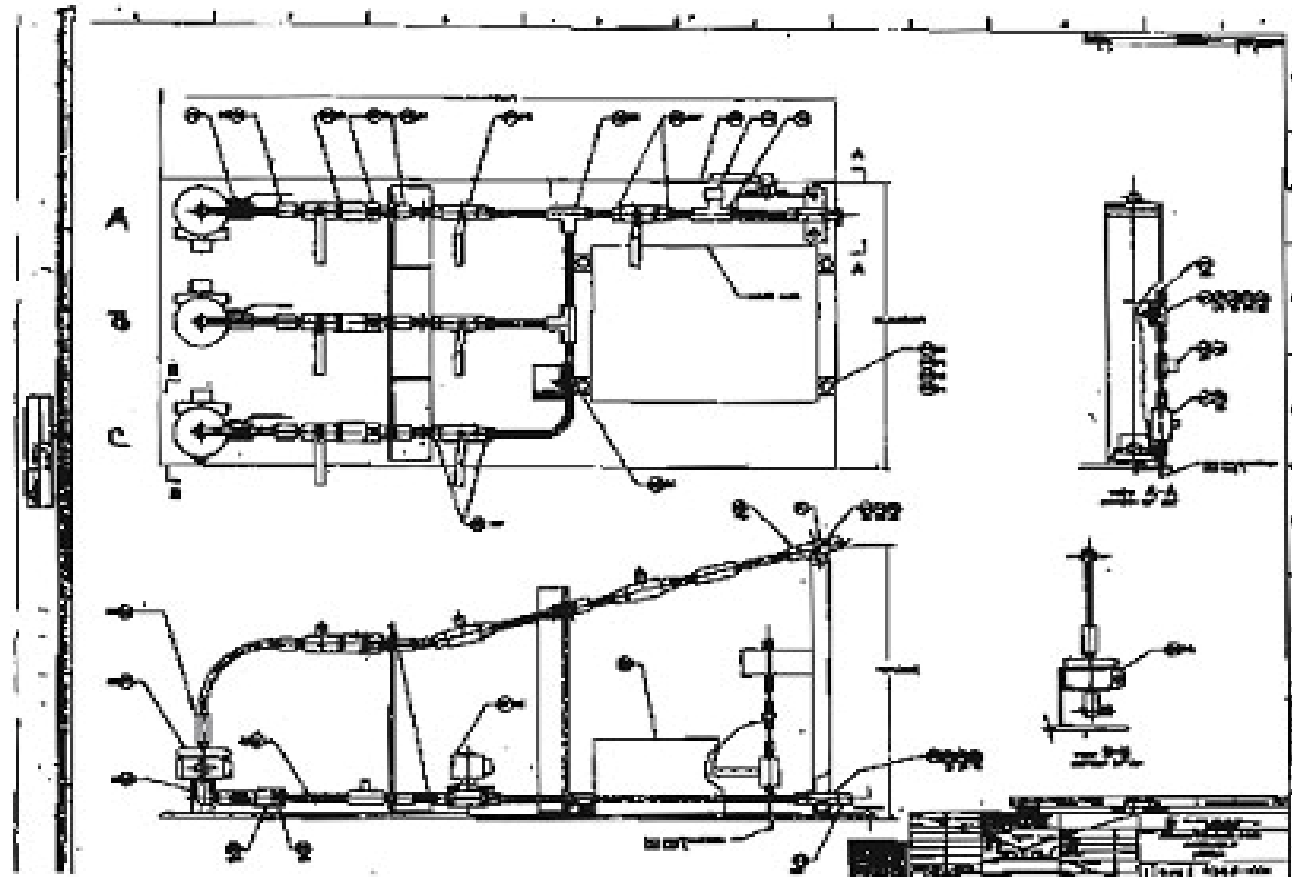
Case 3: 2 Unit BWR

- 2 Reactor Building Roof Exhausts
- Main Vent Stack
- 2 Turbine Building Exhausts
- Hot Shop Exhausts

Modeling Transmission

- “Deposition-2001a” particle transport and deposition model
 - (M.C. McFarland Texas A&M)
 - nozzles, tubes, bends, expansion/contractions and splitters
- Inputs
 - Geometry (Limited to 9 Segments)
 - Particle Size Distribution
 - Ambient Pressure (760 mm Hg)
 - Particle Density (1 g/cm³)

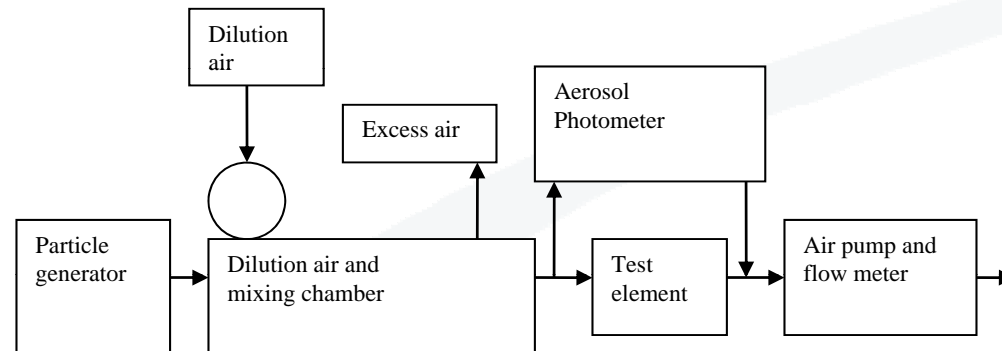
Sampling Skid Diagram



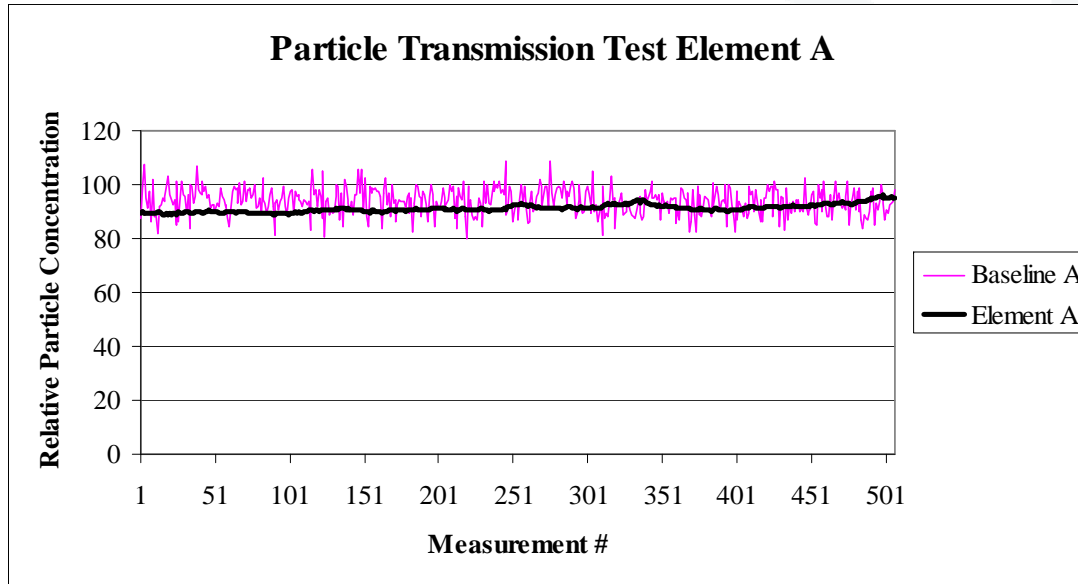
Sampling Skid



Laboratory Test System



Test Element A



Case 3: Example Modeling Results

	NOZZLE	PART 1	PART 2	PART 3	RB2 Combined
Ambient Temperature	32°C	32°C	32°C	32°C	32°C
Ambient Pressure	760mm Hg	760mm Hg	760mm Hg	760mm Hg	760mm Hg
Particle Density	1 g/mL	1 g/mL	1 g/mL	1 g/mL	1 g/mL
Flow Rate*	9.5 L/min	28.4 L/min	47.2 L/min	56.6 L/min	N/A
Free Stream Velocity	9.1 m/s	9.1 m/s	9.1 m/s	9.1 m/s	9.1 m/s
Tube Diameter (I.D.)**	10.9 mm	9.4 mm	16.6 mm	22.1 mm	N/A
Particle Penetration (5um)	81.2%	98.5%	99.0%	76.6%	60.7%
Particle Penetration (3 um)	89.9%	99.6%	99.6%	91.1%	81.2%
Particle Penetration (1 um)	96.9%	100.0%	100.0%	99.3%	95.4%

Measuring Particle Size Distribution

- Challenges
 - Operating Systems
 - Difficult Access
- Non-Radioactive Particle Size
 - MMAD vs AMAD



Case 3: Particle Size Example Results

Particle Size (um)	Particle Volume (cm ³)	Average # Particles in System Duct (particles/ft ³)	% Penetration	Total Mass Particles (g/ft ³) in System Duct	Mass Penetrated (g/ft ³) through Sample System	% Total Mass Penetrated through Sample System
RB Unit 2						
0.3	1.41E-14	55741.8	95	7.88E-10	7.48E-10	
0.5	6.54E-14	24794.2	95	1.62E-09	1.54E-09	
1	5.23E-13	1239.3	95.4	6.49E-10	6.19E-10	
3	1.41E-11	19.8	81.2	2.80E-10	2.28E-10	
5	6.54E-11	7.2	60.7	4.69E-10	2.85E-10	
10	5.23E-10	1.0	0	5.23E-10	0.00E+00	
				4.33E-09	3.42E-09	79%

Conclusions

- Modeling and Particle Size Measurements Can be Used to Determine Transmission
- Assumption: MMAD ~ AMAD
- Transmission for Case 3 Ranged from 0.79 to 0.92