

AMMONIUM CHLORIDE PLUMES

Tim W. Sonnichsen, PE

WHAT'S INVOLVED

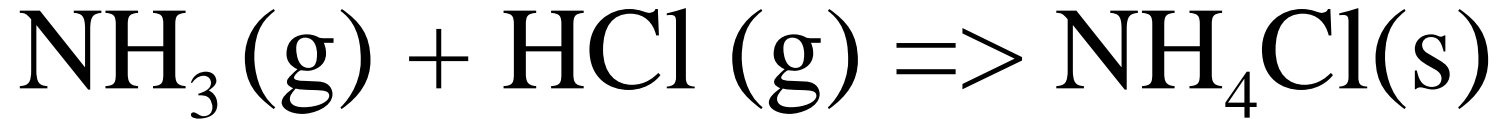
- Wood-Fired Boilers Without Acid Gas Controls
- Equipped With Ammonia or Urea Selective Non-Catalytic Reduction (SNCR) Systems
- Chloride “Contamination”
- Stack Conditions
- Ambient Air Conditions

Ammonia Slip from SNCR

- $\text{NH}_3 + \text{OH} \Rightarrow \text{NH}_2 + \text{H}_2\text{O}$
- $\text{NH}_2 + \text{NO} \Rightarrow \text{N}_2 + \text{H}_2\text{O}$
- $2\text{NH}_3 + \text{OH} + \text{NO} \Rightarrow 2\text{H}_2\text{O} + \text{N}_2 + \text{NH}_3$
- 10 to 25 ppm NH_3 Slip
- Could be Higher
- Always Have Some NH_3 Slip

Sources of Chloride Contamination

- High Alkali Soils
- Salt Water Borne Logs
- Burning “Urban Woodwastes” Containing Plastics
- Municipal Solid Wastes (MSW)
- 1% Cl \Rightarrow 800 to 1000 ppm



- NH₃ and HCl Released as Gases
- Combine and Condense into Aerosol Particles
- Two Parallel Processes Taking Place
 - Rate of Formation Reaction Controlled by Concentrations
 - Rate of Condensation Control by Temperature
- Both Affected by Air Dilution in Plume

NH_4Cl Formation

- Function of the Concentrations of NH_3 and HCl
- These Concentrations Decrease as Air is Mixed into the Stack Plume
- Lower Concentrations \Rightarrow Less NH_4Cl Formed
- Therefore: Air Dilution is Good

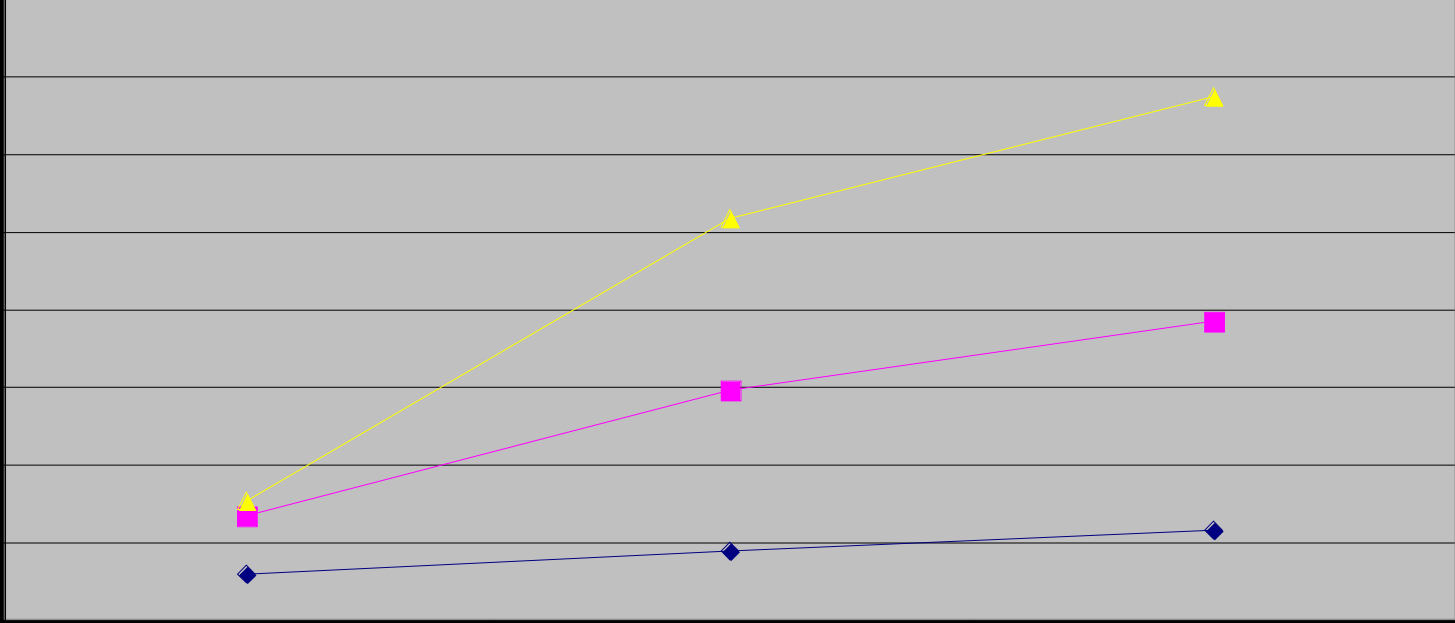
NH₄Cl Condensation

- Condensation into an Aerosol is a Function of the Temperature of the Plume Gases
- “Solid” Aerosol Will Form < 220 F
- Therefore: Cooling by Air Dilution is Bad
- NH₄Cl => Aerosols Occur After Discharge => “Detached Plume”

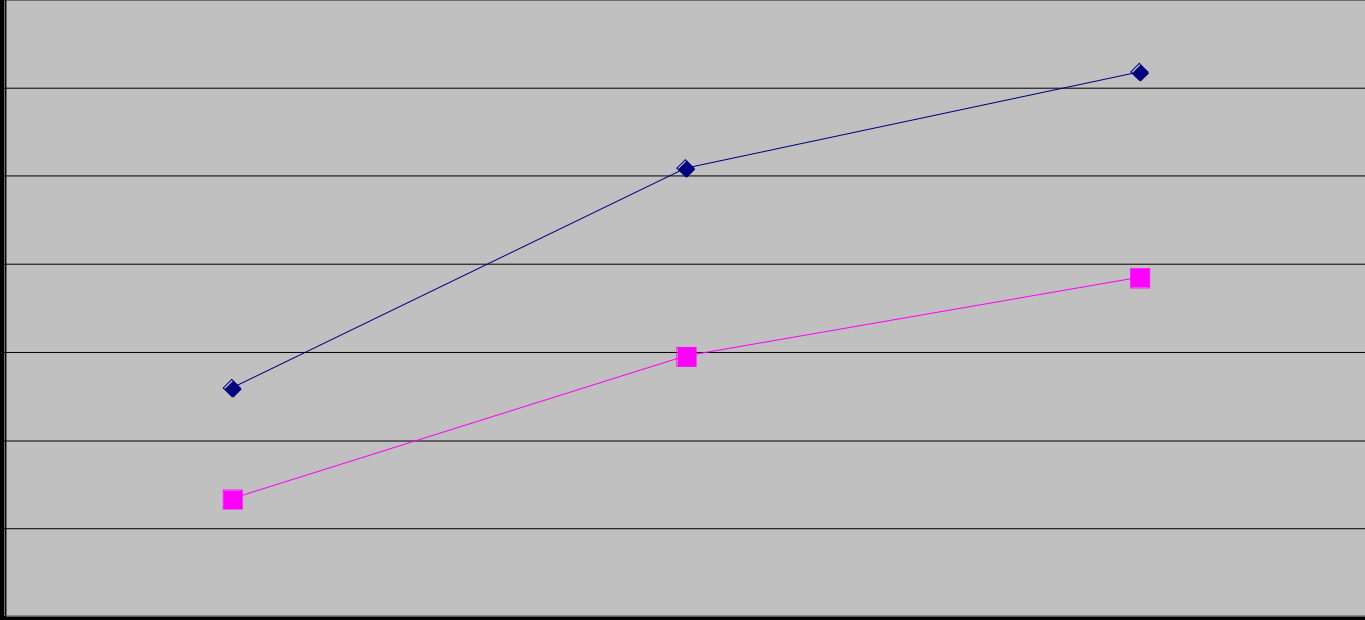
Two Parallel Processes

- Air Addition into the Stack Plume Dilutes and Cools the Gas Temperature
- How Much NH_4Cl is Formed?
- How Visible is the Plume?

NH4Cl (ppm)



NH₄Cl (ppm)



Can We Predict Plume Opacity?

Lambert-Beer Law

$$\ln(I/I_0) = -WL/Kp$$

I = Light Intensity

W = Particulate Mass Concentration

L = Path Length

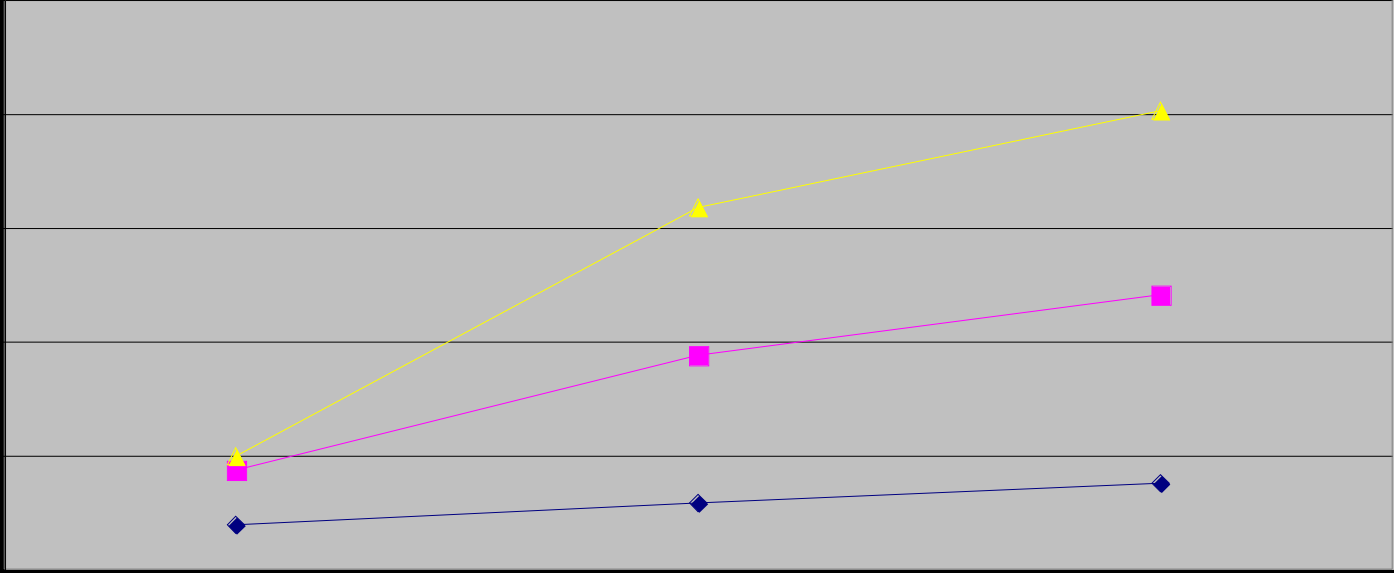
K = Coefficient <= Difficult to
Estimate

P = Particle Density

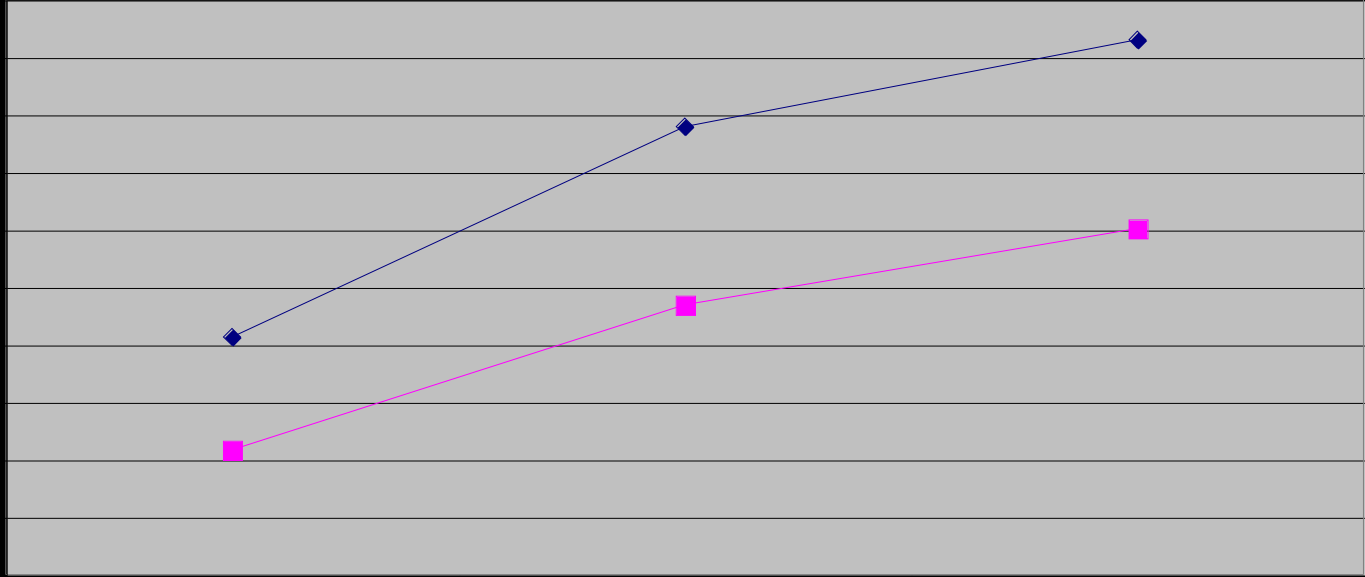
Example Calculation

- $W = 10 \text{ ppm NH}_4\text{Cl} = 0.023 \text{ g/m}^3$
- $L = \text{Stack Diameter} = 1.0 \text{ m}$
- $K = 0.09 \text{ cm}^3/\text{m}^2$
- $P = \text{Particle Density} = 1.53 \text{ g/cm}^3$
- $\ln(I/I_0) = (-0.023)(1)/(0.09)(1.53)$
- $= -0.167 \Rightarrow I/I_0 = 0.846$
- $\Rightarrow 15.4\% \text{ opacity}$

Opacity (%)



Opacity (%)



What Can We Do??

- Minimize (Eliminate Cl) in Wood Fuel
- Install Acid Gas Controls
- Minimize NH_3 Slip \leq Monitor
- High Stack Gas Temperatures
- High Ambient Air Temperatures (Winter Time Problem??)
- Promote Rapid Gas/Air Mixing ??
- Install High Gas Temperature Concentric Stack Annulus ??