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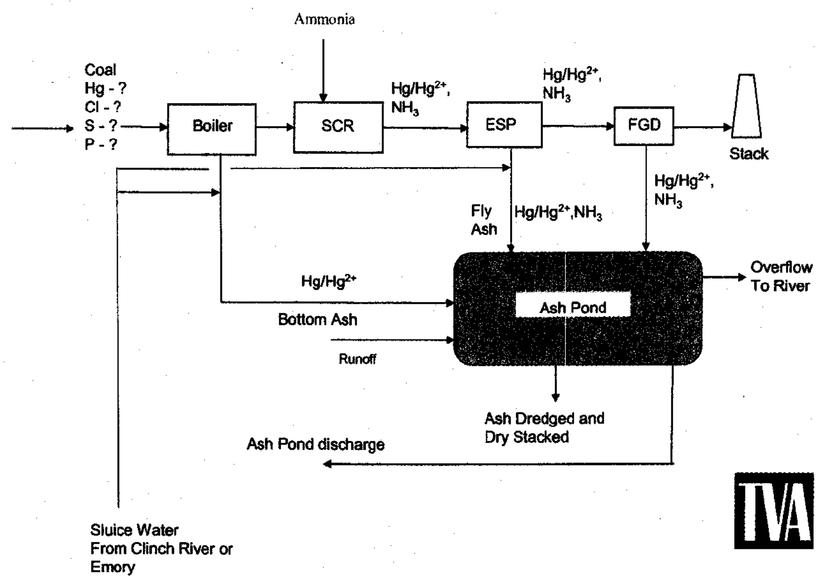
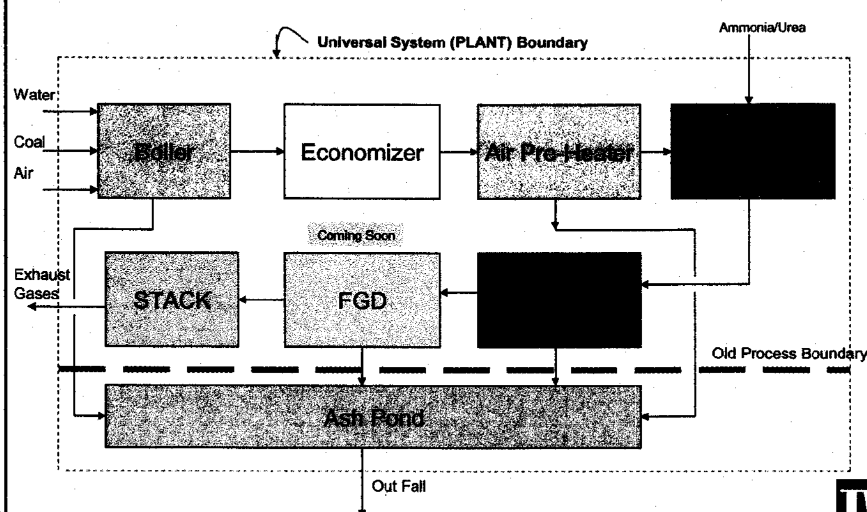
Site (KIF) Specific Schematic



Schematic for Systems Identification for Analyses and Modeling



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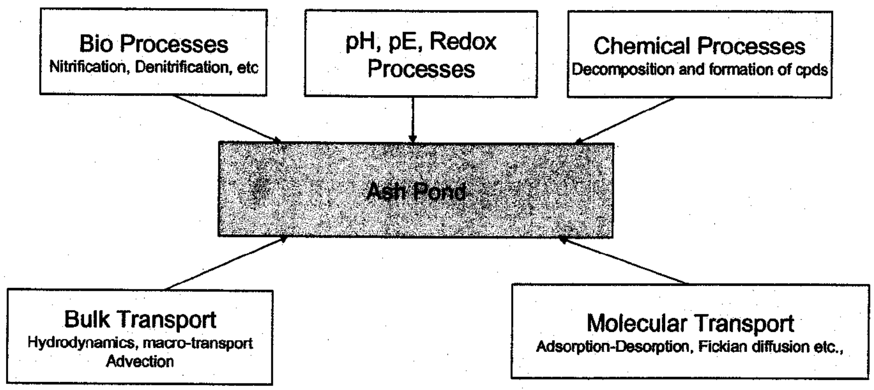
Ash Pond Analyses

Schematic of Ash Pond System Discretized for Modeling



What is pH?

- Potential (p) of Hydrogen (H) = pH
- Concentration of Hydrogen ions in gram equivalent molecular weights (molar) in a liter $[H^+]$/Liter

$$pH = -\log_{10} [H^+]$$

- Range “pH=0” to “pH=14”

pH Fundamentals

- pH = 7 neutral amount of [OH-] is equal to [H+]
- pH < 7 down to zero: Acidic, more [H+] than [OH-]
- pH>7 up to 14: Basic or Alkaline, more [OH-] than [H+]

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Major Influencing Factors on Ashpond pH

- Ammonia loading
  - formation of ammonium bisulfate??
  - pH = Hi and low net effect
- Coal blend: Coal "Sulfur" Hi-Mid-Low
  - Sulfates formation = pH low
- Plant Operational Conditions

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Define Problem

<u>Design Criteria</u>:

- Minimum pH in the pond (Lower Limit) pH=5
- Maximum pH in the pond (Upper Limit) pH=10

- Minimum Flow Rate 40 mgd
- Maximum Flow Rate 80 mgd

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Does Ammonia Hike the pH?

- Ammonia Source is the SCR
- Under plant operating conditions the thermodynamics favor the formation of ammonium bisulfate…when hits the water

$NH_4HSO_4 \Longrightarrow NH_4^{+} + HSO_4^{-}$

Ammonium ion Pushes up pH

$HSO_4^{-} \Longrightarrow H^{+} + SO_4^{--}$

Hydrogen ion pulls down pH

[redacted]

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Sulfur's Role in pH Pull-Down

The Source of "S" is COAL

Combustion is an oxidative process, therefore:

$S + \frac{1}{2} O_2 \rightarrow SO_2$

$S + 2/3\, O_2 \rightarrow SO_3$

$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$

SO_2, SO_3 and H_2O will make sulfuric acid H_2SO_4.

$H_2SO_4 \rightarrow 2H^+ + SO_4^{--}$

[redacted]

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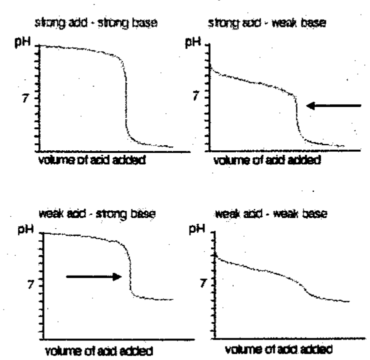
Acid – Base Titration Curves

The way you normally carry out a titration involves adding the acid to the alkali. Here are reduced versions of the graphs described above so that you can see them all together.



Note: Step Change inflection point is good for control

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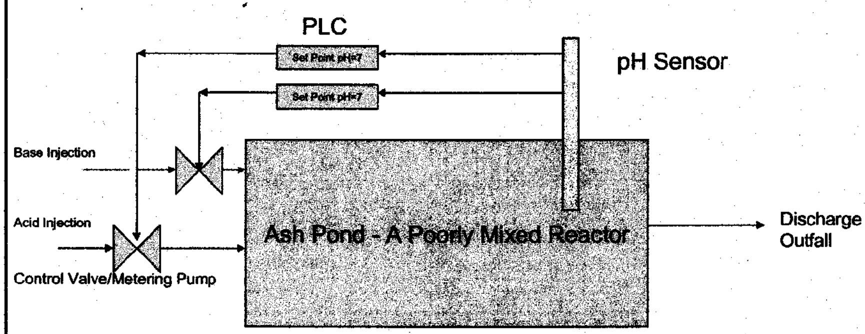
pH Control

Schematic of Acid/Base Neutralizing System



Feedback Control System

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Control Systems Considered for High pH

	System	Advantages	Disadvantages
1	Gaseous CO2 Sparging	a)User friendly b)Non-Toxic c) Moderate Capital Cost	a)Very Low Process Efficiencies Solubility b)Could strip O2 = low DO c) Sluggish End-Point = Poor Control
2	Cryogenic CO2 Water Premix	a)User friendly b)Non-Toxic c) Higher Mass Transfer Efficiency	a) Extremely Hi- Capital and Operational Cost
3	Hydrochloric Acid Injection	a)Fast Response b)Low handling volumes c)Low Capital and Op. costs	a)Highly Reactive b)Safety of Vapor Cloud c) Addition of Cl with coal by-products = Dioxin Carcinogen & Endocrine Disruptor
4	Sulfuric Acid Injection	a)Fast Response b)Low handling volumes c)Low Capital and Op. costs	a)Highly Reactive b)Safety of Vapor Cloud c) Addition of S to the effluent
5	Acetic Acid Monitored Injection Concentrated "Vinegar"	a)Fast Response b)Low handling volumes c)Low Capital and Op. costs d) Biodegradable and Environmentally Friendly	
6	Citric Acid Monitored Injection "Lemonade" without sugar	a)Fast Response b)Low handling volumes c)Low Capital and Op. costs d) Biodegradable and Environmentally Friendly	Costlier than Acetic Acid

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Not used in Utility Industry to date.

Control Systems Considered for Low pH

	System	Advantages	Disadvantages
1	Hydrated Lime Injection	a)User friendly b)Non-Toxic c) Moderate Capital Cost	a)Very Low Process Efficiencies Solubility b) Sluggish End-Point = Poor Control c) Large quantities
2	Sodium Hydroxide Injection	a)Non-Toxic b) Higher Mass Transfer Efficiency/solubility c) Cheap d) Low volumes	a) Caustic

Temp. Control ENV.

Control System Recommendations

40gal/day

- For Low pH - Acidic Conditions
  Sodium Hydroxide Injection
- For High pH – Alkaline (Basic) Conditions
  Acetic Acid Injection – "Vinegar"

[redacted]

These two choices will be the most environmentally friendly options

Computational Fluid Dynamics (CFD) Modeling

Determination of the Injection Points

- To characterize the "Reactor," mixing zones are identified
- Flow patterns are crucial to determine the Residence Time Distribution (RTD)
- Stratification is important, whether due to thermo-cline or density gradient
- All the above, impact on the reaction rates

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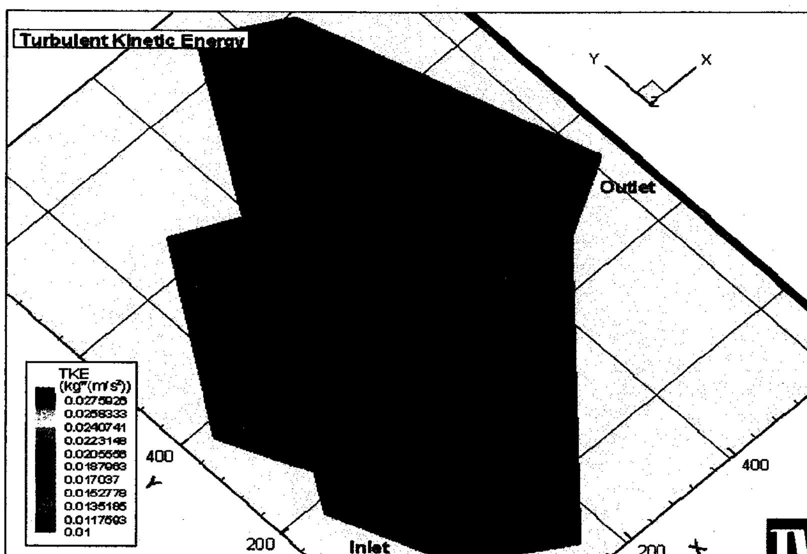
Ashpond Hydrodynamics-Turbulent Kinetic Energy



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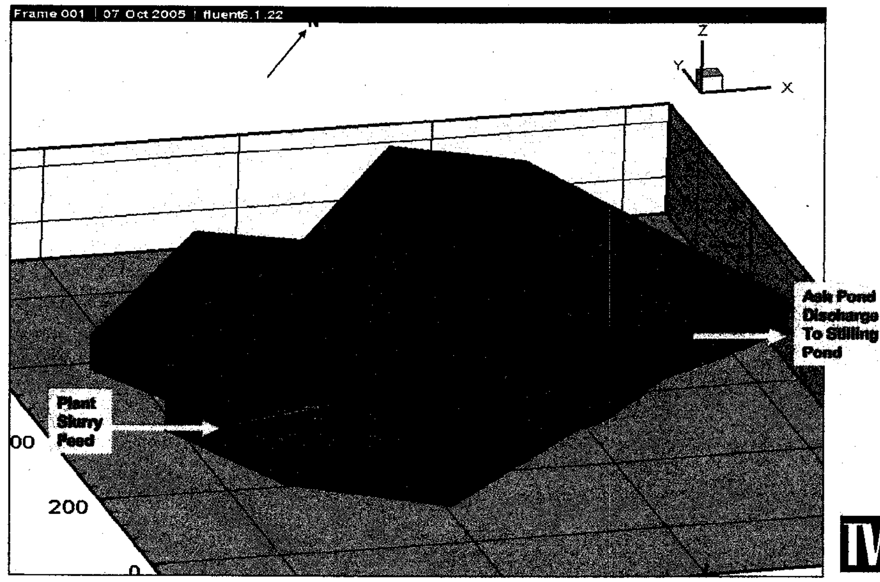
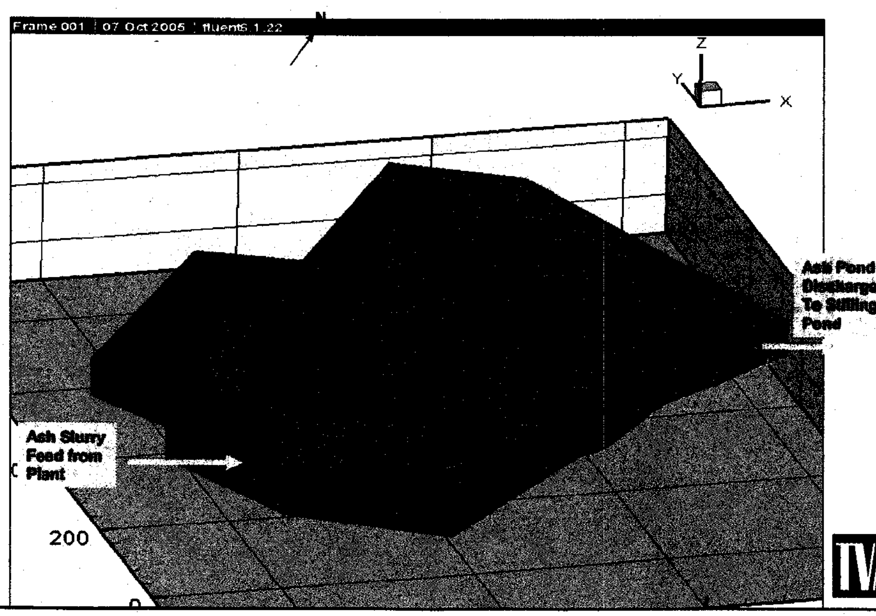
KIF Ash Pond Mixing Zones – CFD Model Results

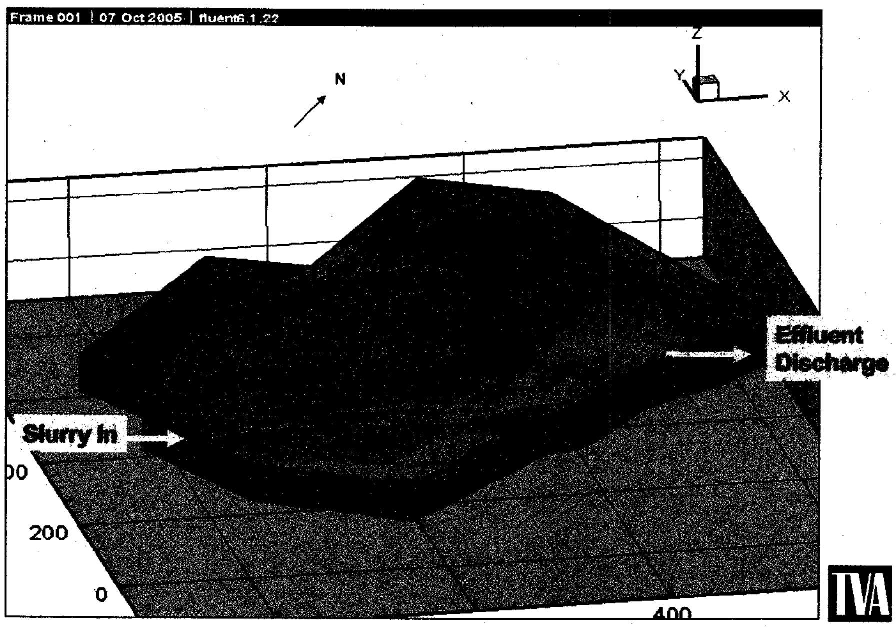


8-10 hrs to go through pond.

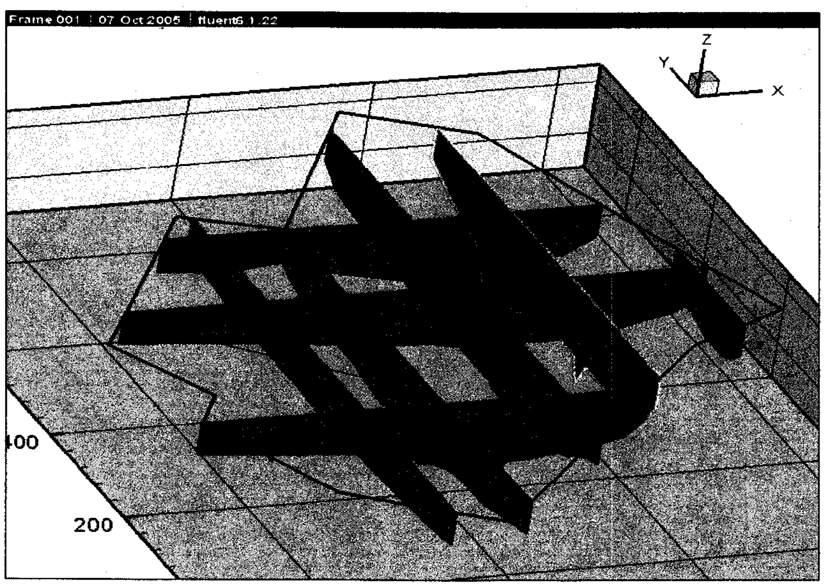
KIF Ash Pond Temperature Zones – CFD Model Results



KIF Ash Pond Fluid Stream-Lines – CFD Model Results



KIF Ash Pond Fluid Mixing Vertical Cross Sections – CFD Model Results



Summary

- ▶For the design of the "Ashpond" pH control the inside primary ashpond parameters should be considered system
- ▶All contributing factors outside the boundary should be considered
- ▶To control alkalinity the "best" choice is "Acetic Acid" injection
- ▶To control acidity the "best" choice is the sodium hydroxide injection

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Conclusion

- Chemical Engineering Design should be incorporated with the Civil and Mechanical Engineering Designs
- Perform a Comprehensive Cost Benefit Analysis
- A Final Decision Based on Best Science and Engineering Practices

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