Reinhold Environmental Ltd.

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ESP MODELING: AN OVERVIEW

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A WORD TO THE WISE

A model does not a modeler make. Successful modeling requires knowledge, preparation and time.

RECIPE FOR GOOD ESP MODELING

- Understanding of ESP fundamentals
- Use of a proven ESP model
- Understanding of the ESP model
- Development of baseline conditions
- Modeling of baseline conditions
- Extension to different scenarios
- Verification of model input/output

UNDERSTANDING OF ESP FUNDAMENTALS

- Boiler/ESP inlet process conditions
- Electrical operating conditions
- Electric Field
- Particle charging
- Particle collection
- Nonideal effects
- Mass emissions & opacity

BOILER/ESP INLET PROCESS CONDITIONS

- Coal/ash properties
- Boiler coal feed rates and heat inputs
- Boiler and air heater excess airs
- Furnace exit and air heater outlet gas temperatures
- Stoichiometric and measured gas flows and mass loadings
- H_2O and SO_3 concentrations
- Particle size distribution

ELECTRICAL OPERATING CONDITIONS

- Electrode geometry dependent (plate spacing, discharge electrode type, etc.)
- Impact of flyash resistivity affected by ash chemistry, temperature and H_2O/SO_3 concentrations
- Impact of particulate space charge

ELECTRIC FIELD

- Average electric field important in particle charging
- Electric field at the plate important in particle collection
- Particulate space charge impacts the applied voltage (average electric field), current density and electric field at the plate

PARTICLE CHARGING

- Charging of larger particles (> 1 µm) depends essentially only on the applied voltage (average electric field)
- Charging of fine particles (< 1 µm) depends on both the applied voltage (average electric field) and the current (density)

PARTICLE COLLECTION

- Most models in use are based on the Deutsch eq, which assumes uniform, turbulent mixing of particles with a probability that collection will occur in a thin laminar layer adjacent to the plate
- The Deutsch eq. involves migration velocity (depending on particle charge and electric field at the plate), plate area and gas flow

NON-IDEAL EFFECTS

- Non-uniform gas flow
- Gas sneakage
- Non-rapping particle reentrainment
- Rapping reentrainment
- Hopper reentrainment
- Condensed and chemical reaction particles
- Unburned carbon

MASS EMISSIONS AND OPACITY

- Mass emissions and opacity depend on the process conditions entering the ESP, ESP operating conditions and the extent to which non-ideal conditions exist
- Correctly predicting mass emissions and opacity simultaneously is sometimes difficult
- High mass emissions and low opacity can result from reentrainment of agglomerated particulate
- Low mass emissions and high opacity can result from extra fine flyash or particles formed from condensation or chemical reaction

USE A PROVEN ESP MODEL

- Southern Research Institute versions (possibly proprietary)
- Environmental Protection Agency versions
- Electric Power Research Institute versions (proprietary)
- Vendor versions (possibly proprietary)
- Consultant versions (possibly proprietary)
- Whatever model is selected, make sure it has a good track record with substantial published results or work products and has the features necessary to meet the intended needs

UNDERSTANDING OF THE ESP MODEL

- Make sure the model to be used has sufficient documentation to understand the input/output data, physical mechanisms addressed, approximations and limitations and possible applications
- Carefully study the documentation
- Practice using the model in many cases before using it in a design application

DEVELOPMENT OF BASELINE CONDITIONS

- Good baseline conditions are the key to successful modeling
- Obtain data from a unit under study, one that is as similar as possible, and/or relevant literature
- If possible, evaluate, analyze and reduce coal, boiler, ESP and test data covering at least the last 5 years

MODELING OF BASELINE CONDITIONS

- **Using the known baseline conditions, model test and other cases in order to match stack emissions and opacity**
- **Make adjustments to the particle size distribution, non-ideal parameters and other un-measured parameters to get the best agreement with the measured stack emissions and opacity**
- **After the baseline development and modeling is completed, an understanding of ESP operation, response to variables, limitations, problems, etc. should be obtained**

EXTENSION TO DIFFERENT SCENARIOS

- **Changes in process conditions: coal, boiler operation, particle size distribution, mass loading, temperature, flow, etc.**
- **Changes in ESP conditions: plate area, electrical operation (resistivity, electrical sectionalization, discharge electrode, plate spacing), mechanical sectionalization, gas sneakage, non-rapping and rapping reentrainment, etc.**
- **Effects due to boiler additives, SNCR, SCR, SO_3 and NH_3 conditioning, sorbent injection and dry and wet SO_2 scrubbing**

VERIFICATION OF MODEL INPUT/OUTPUT

- After desired results are obtained, make a last check of all input data to ensure that entry points, formats and values of all parameters are as intended and correct
- Carefully examine, analyze and evaluate the output for what appear to be inconsistent or unexplainable results
- In most cases, a multitude of numbers are generated
- QA and QC are very important

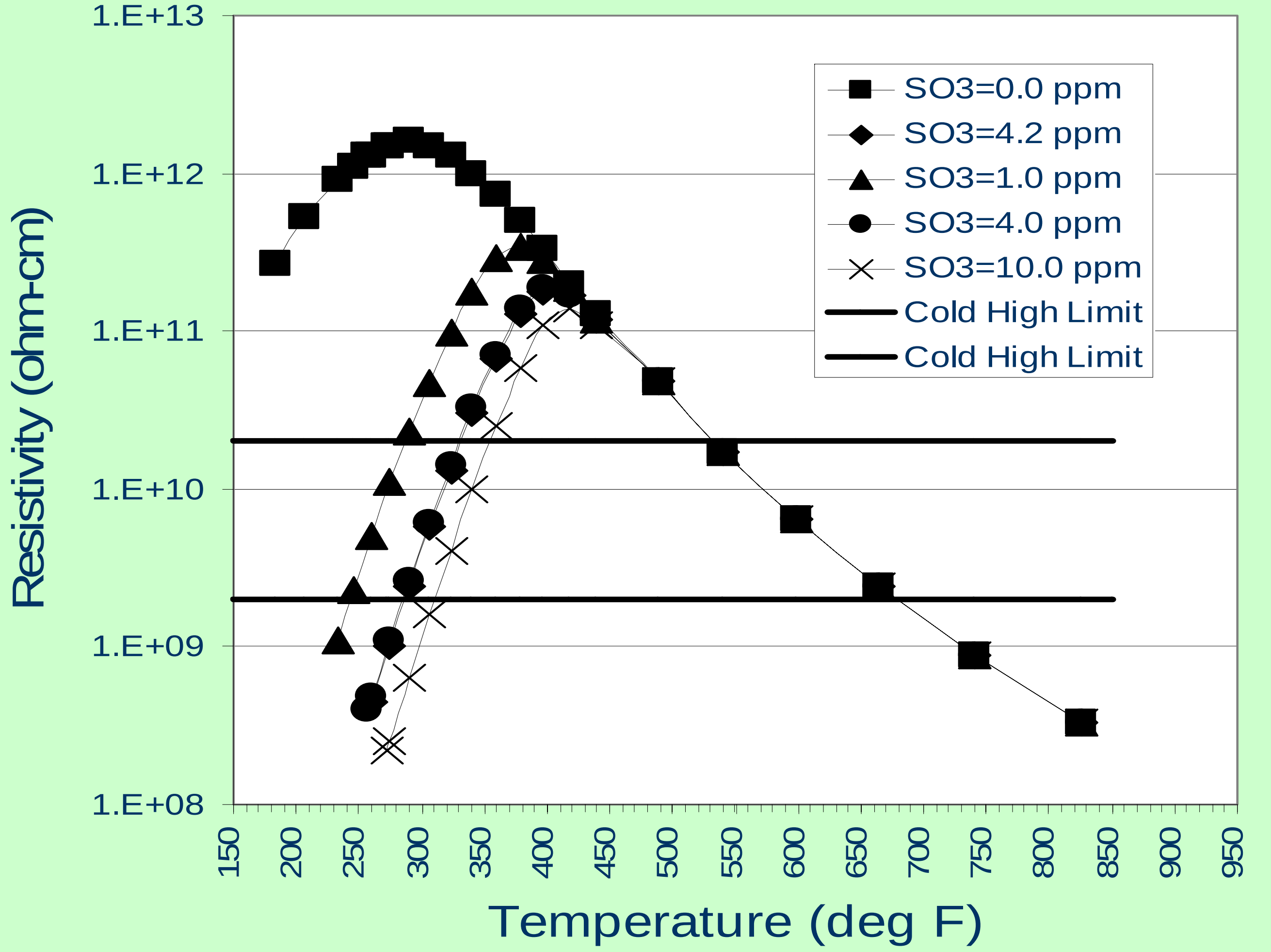
REASONS FOR USING AN ESP MODEL

- Design and sizing of a new ESP
- Diagnostic tool for an existing ESP
- Examination of the impact of the use of different coals for a new or existing ESP
- Examination of the impact of possible ESP upgrade options for an existing ESP
- Examination of the impact of boiler additives, SNCR, SCR, SO_3 and NH_3 conditioning, sorbent injection, and dry and wet SO_2 scrubbing

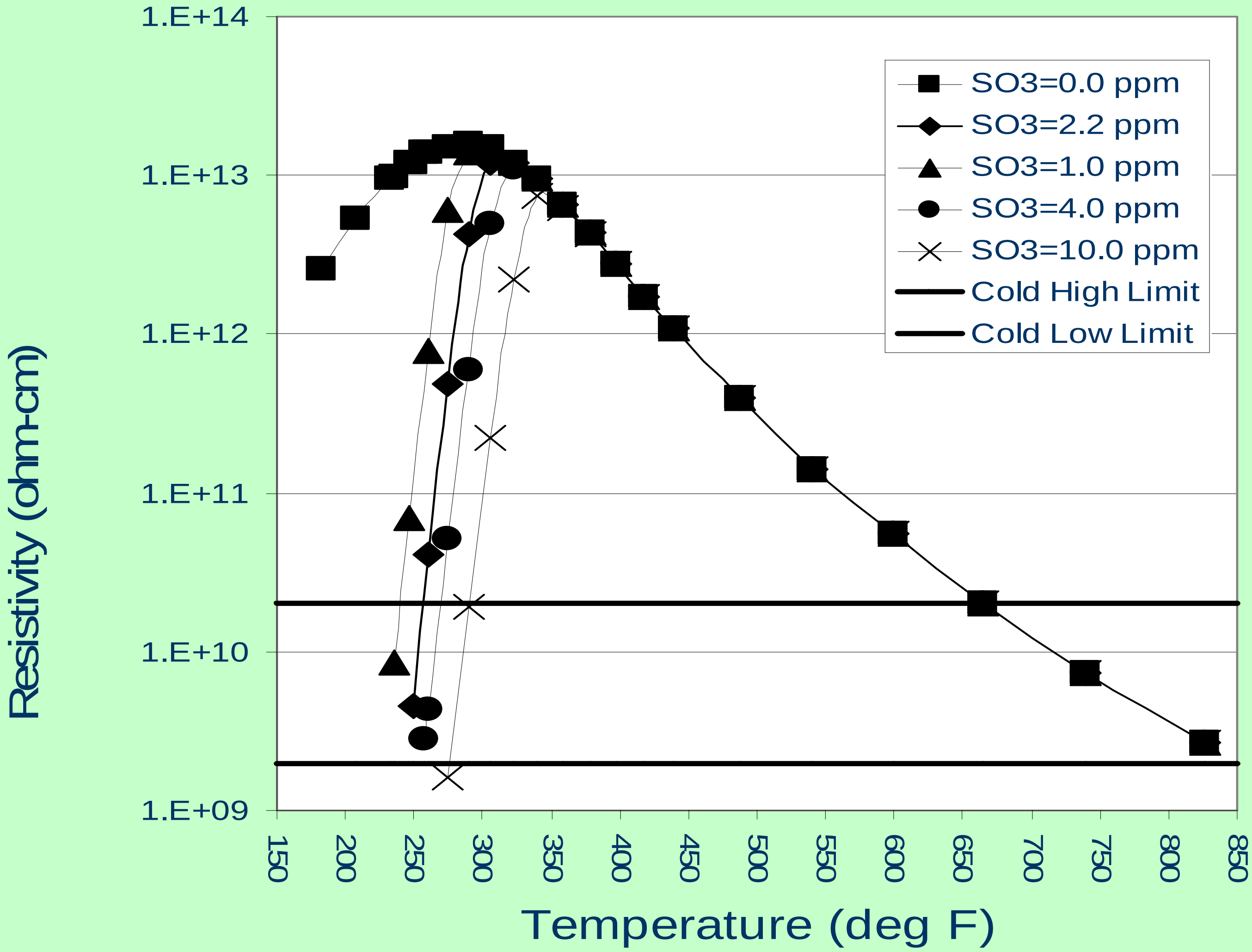
COAL IMPACT ON FLYASH RESISTIVITY

- **Low resistivity eastern coal: S=1.64%, H_2O=4.11%, ASH=12.74%; Na_2O=0.33%, Fe_2O_3=10.04%, SiO_2+Al_2O_3=78.01%, CaO+MgO=2.84%**
- **High resistivity eastern coal: S=0.80%, H_2O=5.70%, ASH=14.00%; Na_2O=0.12%, Fe_2O_3=2.70%, SiO_2+Al_2O_3=88.00%, CaO+MgO=1.15%**
- **PRB coal: S=0.39%, H_2O=24.20%, ASH=5.40%; Na_2O=1.32%, Fe_2O_3=6.42%, SiO_2+Al_2O_3=50.17%, CaO+MgO=22.18%**

EASTERN COAL WITH LOW FLYASH RESISTIVITY



EASTERN COAL WITH HIGH FLYASH RESISTIVITY



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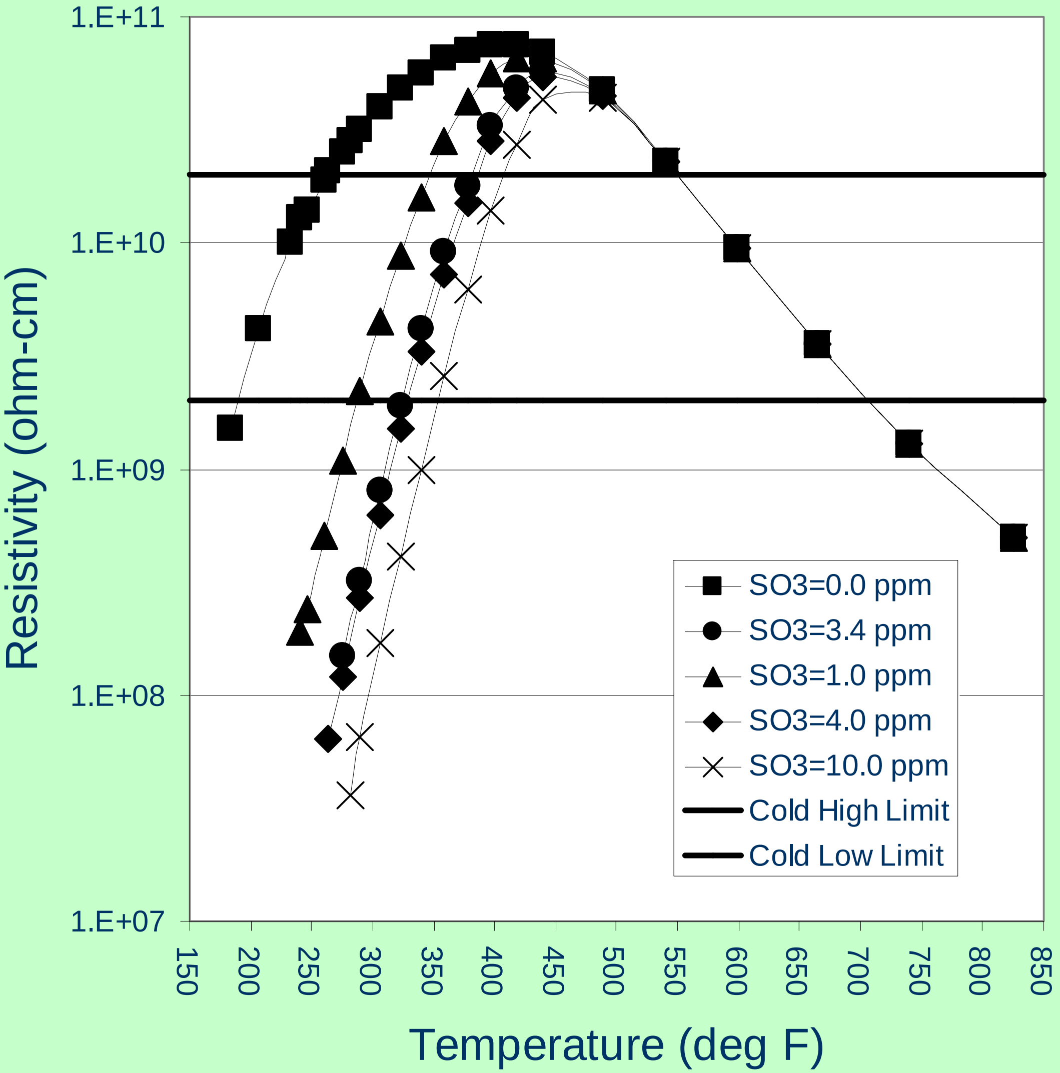
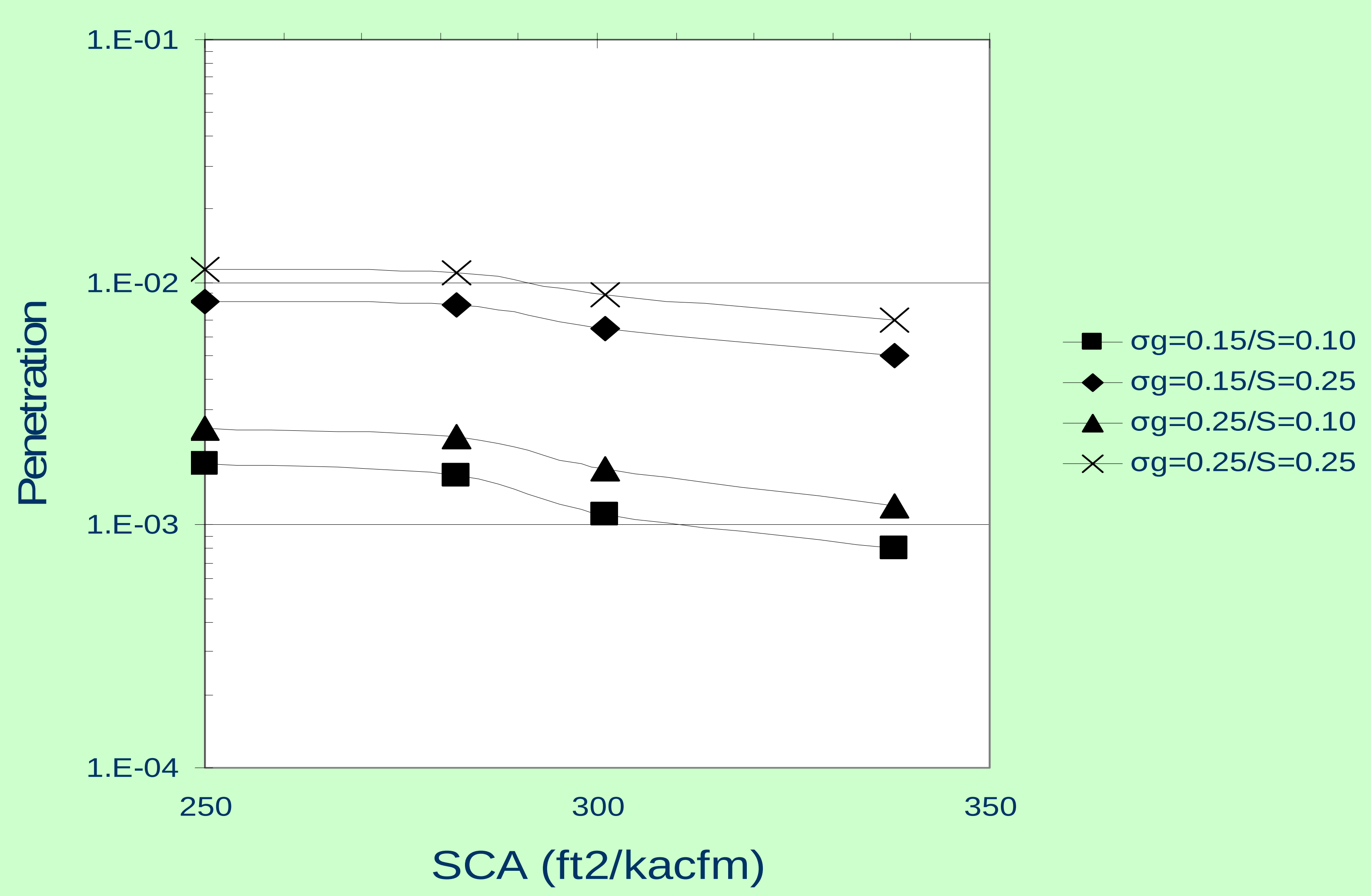
PRB COAL

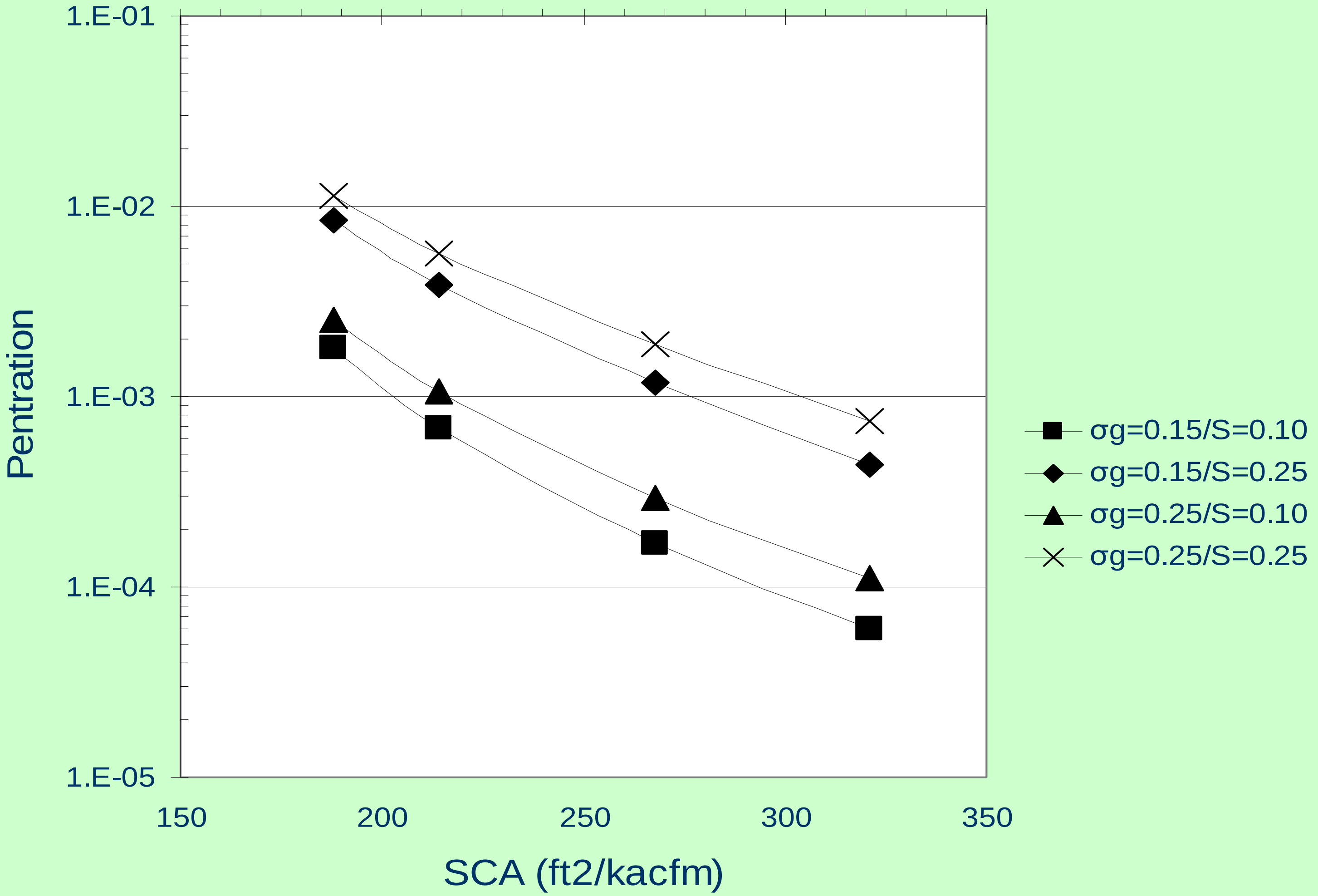


1.E+11
1.E+10
1.E+09
1.E+08
1.E+07
Resistivity (ohm-cm)
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
Temperature (deg F)
■ SO3=0.0 ppm
● SO3=3.4 ppm
▲ SO3=1.0 ppm
◆ SO3=4.0 ppm
× SO3=10.0 ppm
Cold High Limit
Cold Low Limit

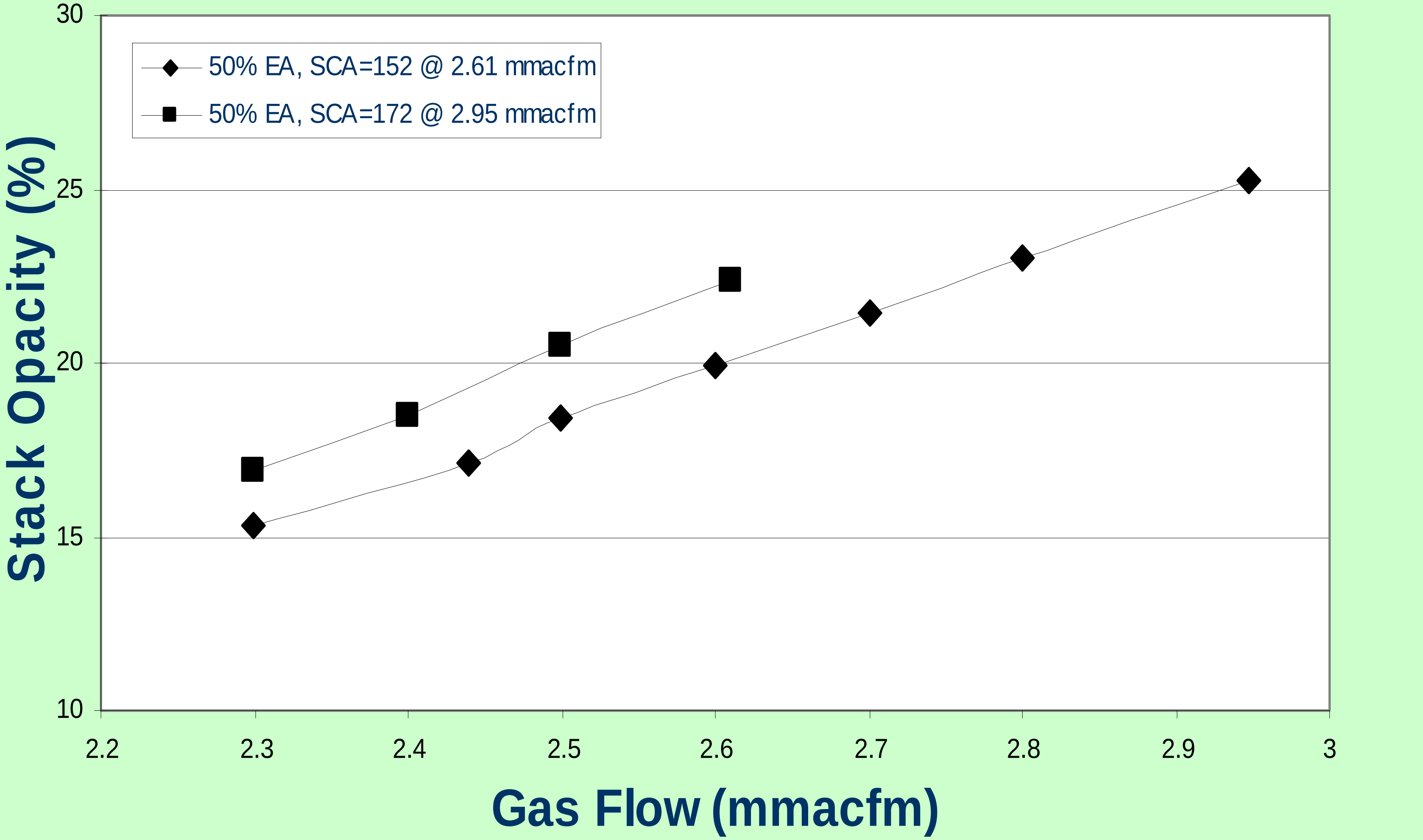
PLANT A REBUILD SIZING: EASTERN COAL, W.W. DESIGN AND SO3 CONDITIONING



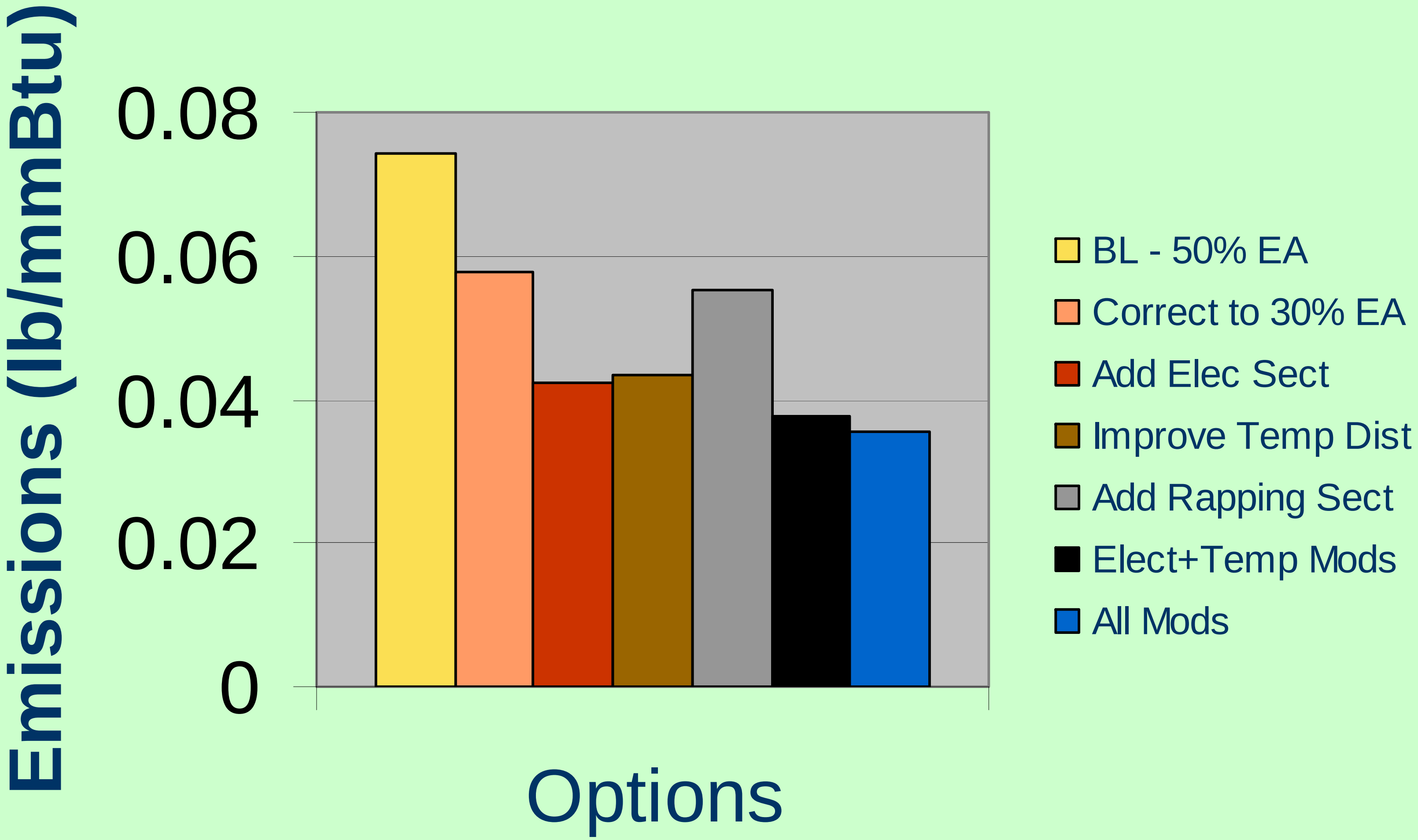
PLANT A REPLACEMENT SIZING: EASTERN COAL, RDE DESIGN AND SO3 CONDITIONING



PLANT B: MODELING OF EFFECT OF EA AND GAS FLOW ON OPACITY (PRB+EASTERN COAL, Sg=0.25, S=0.14)



PLANT B: MODEL RESULTS FOR UPGRADE OPTIONS



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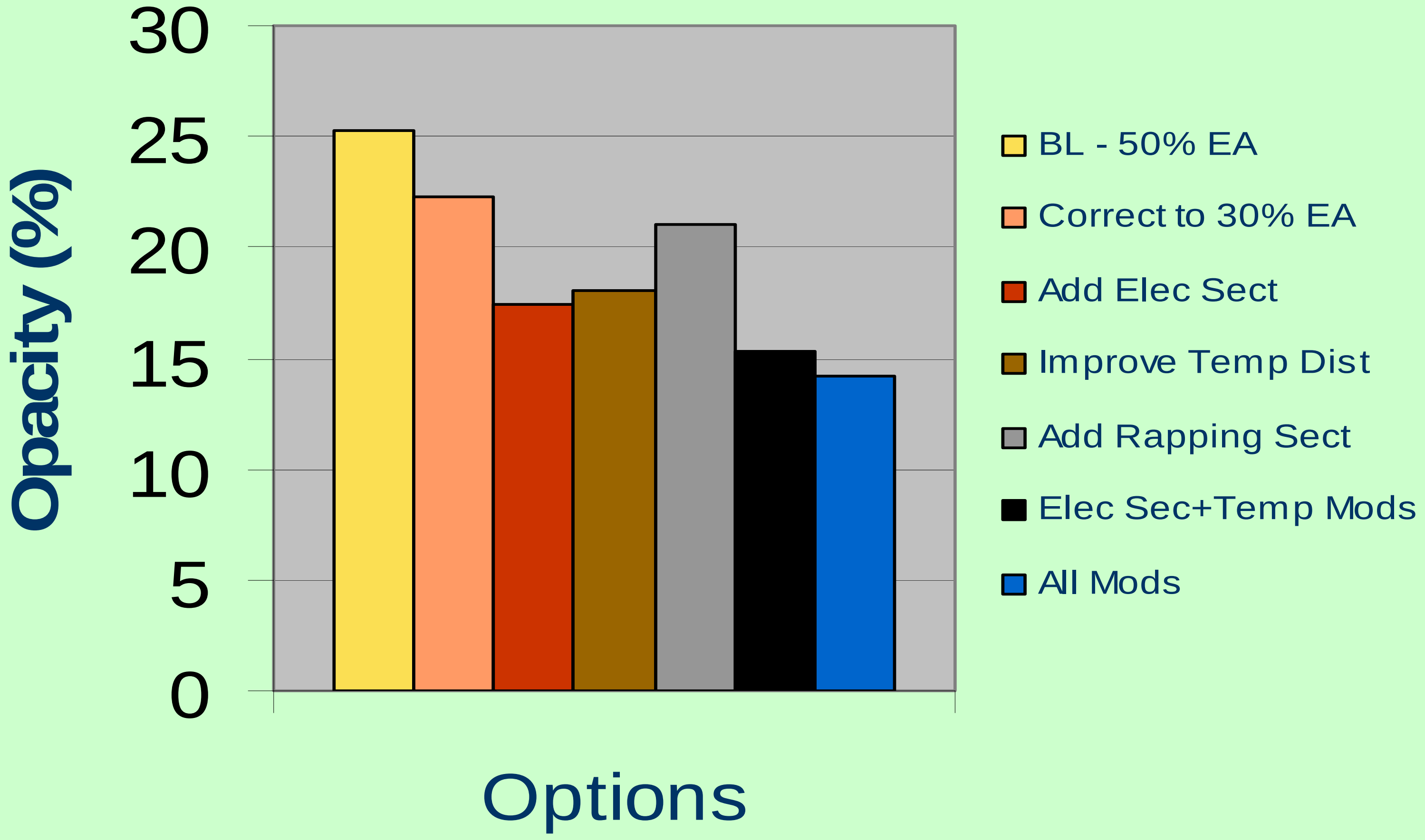
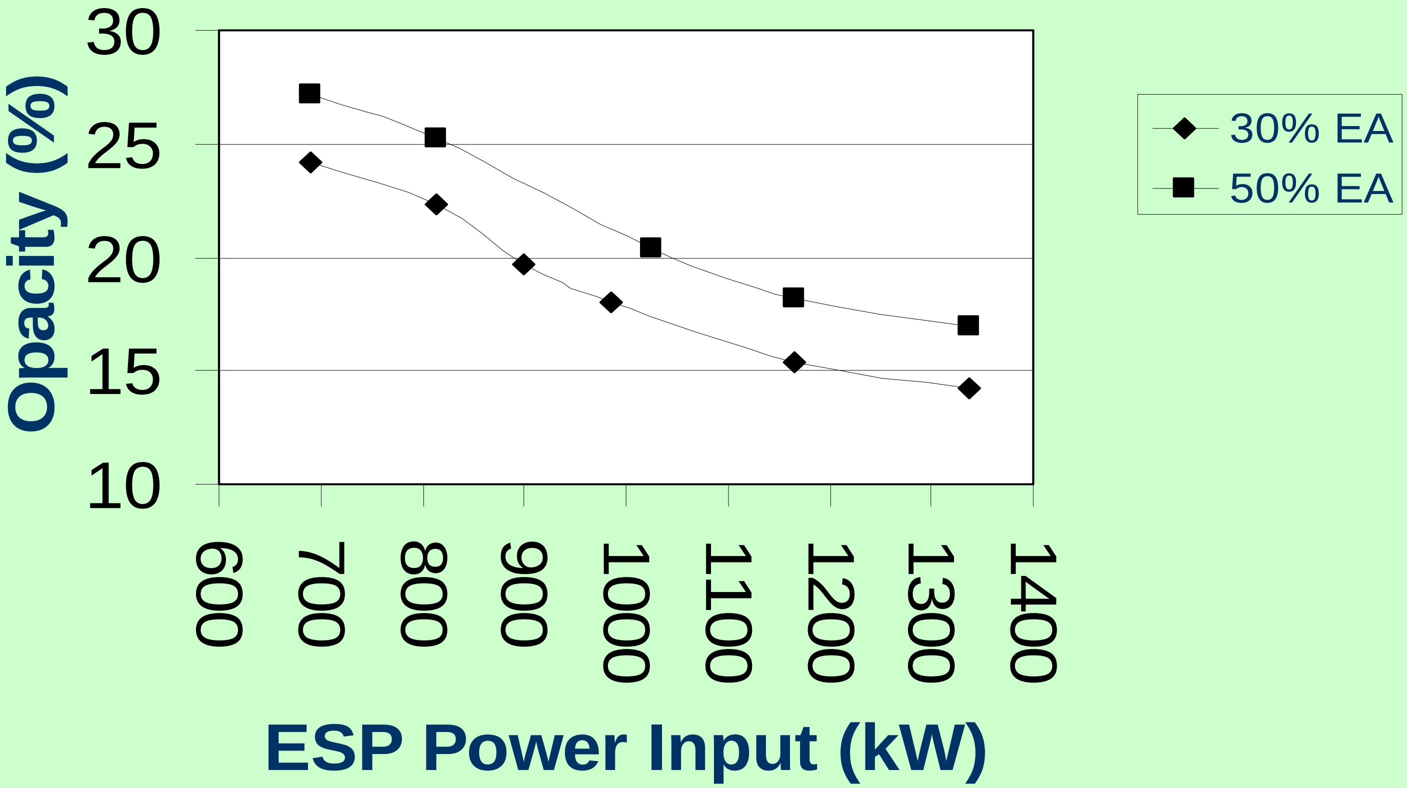
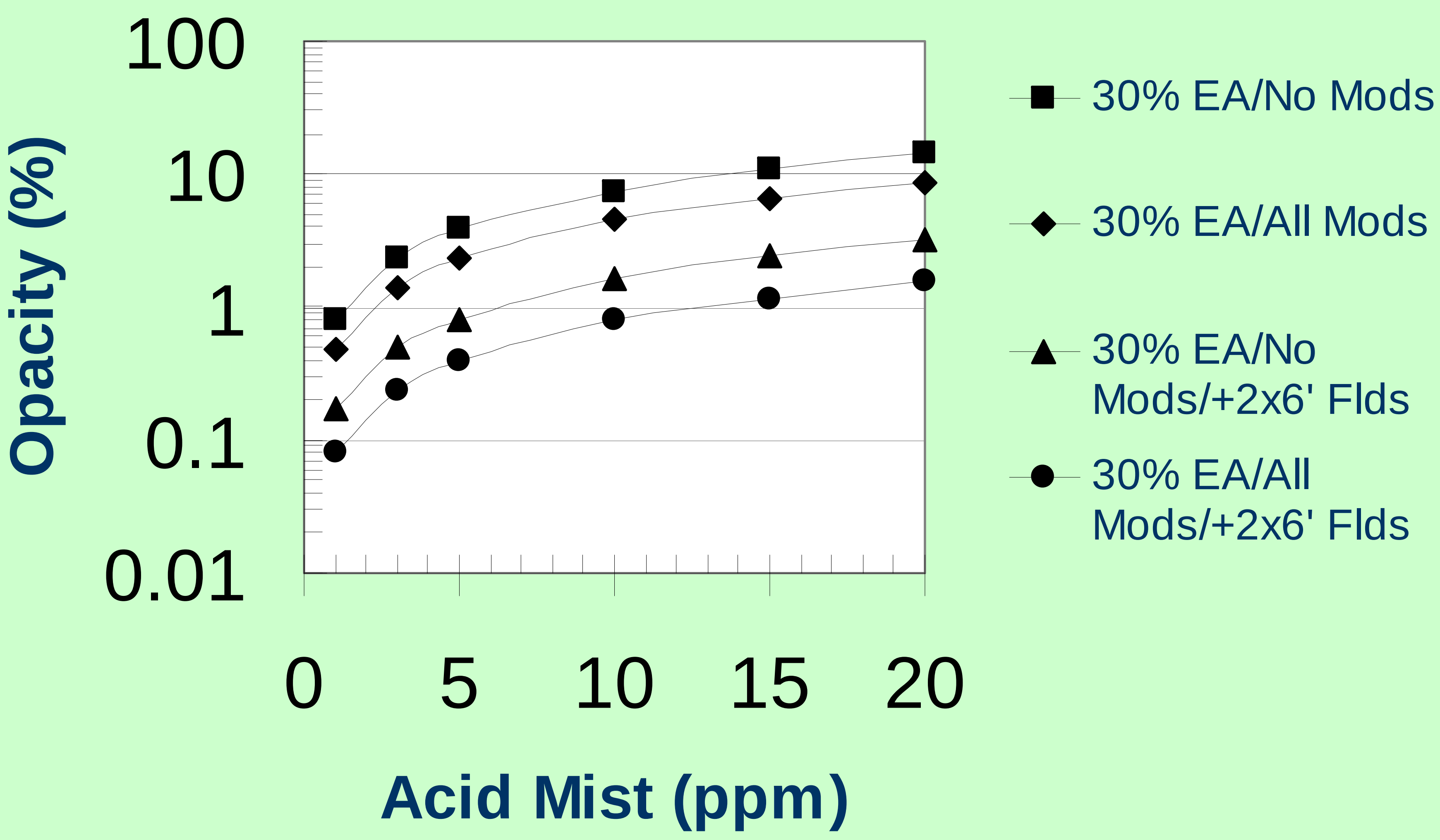


PLANT B: MODELING OF EFFECT OF ESP POWER INPUT ON OPACITY (Sg=0.25/S=0.14)



PLANT B: MODELING EFFECT OF ACID MIST UPSTREAM OF ESP (Sg=0.25,S=0.05)



PLANT B: MODELING EFFECT OF AMMONIUM SULFATE UPSTREAM OF ESP (Sg=0.25,S=0.05)