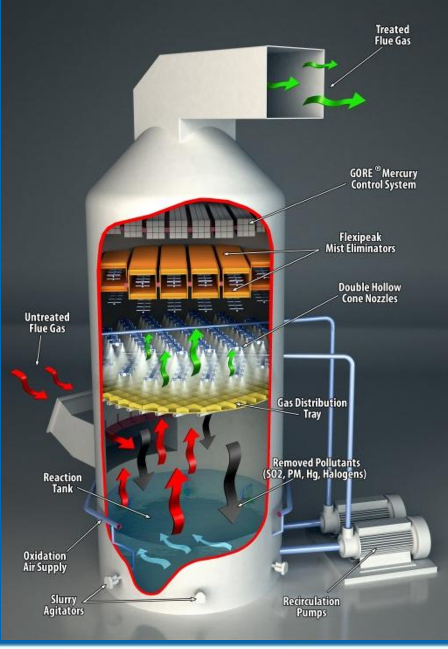

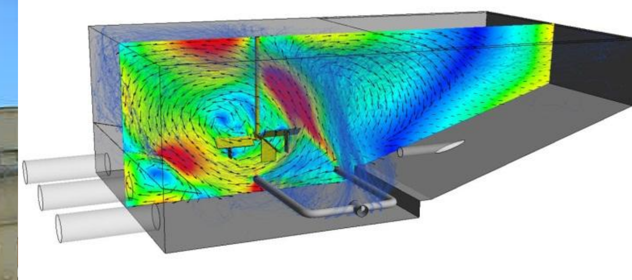

Methodology for Assessing FGD Corrosion Risk for Bromine-based Mercury Control Technologies

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Background

- LCRA was considering technologies for MATS Hg control compliance at the Fayette Power Project station
  - Three PRB-fired units, 450-610 gross MW, C-ESP, wet FGD
  - Native Hg oxidation ~50%
- Candidate technologies were tested at full scale in 2011:
  - Br addition with coal
  - **Injection of brominated powdered activated carbon (PAC)**
  - **Br addition with coal plus injection of non-Br PAC**

Balance-of-Plant Impact Concerns for Bromine-based Technologies

- Potential corrosion in bunkers, coal feeders
- Air heater basket corrosion
- **Increased pitting and/or crevice corrosion of wet FGD alloys of construction**
  - Station operates with zero liquid discharge
  - Units 1 and 2 FGD use mostly Stebbins Tile and C-276; some lesser alloys in wetted areas
    - Closed-loop water balance
  - Unit 3 FGD uses 316L with Potential Adjustment Protection, 317 LM, Alloy 2205
    - Relatively open-loop water balance
  - Large reclaim water system ties the FGD systems together
    - Cl^- purge water from Unit 3 used as makeup for Units 1 and 2

Technical Issue – How to Assess Increased Risk to FGD Alloys from Br-based Hg Controls

- Inventory of water at station and closed water loop on Units 1 and 2 FGD make testing for steady-state Br concentrations impractical
  - –Months of testing would be required
- Substantial industry experience with Cl^- and FGD alloys, but little experience with Cl^-/Br^- mixtures to determine safe limits

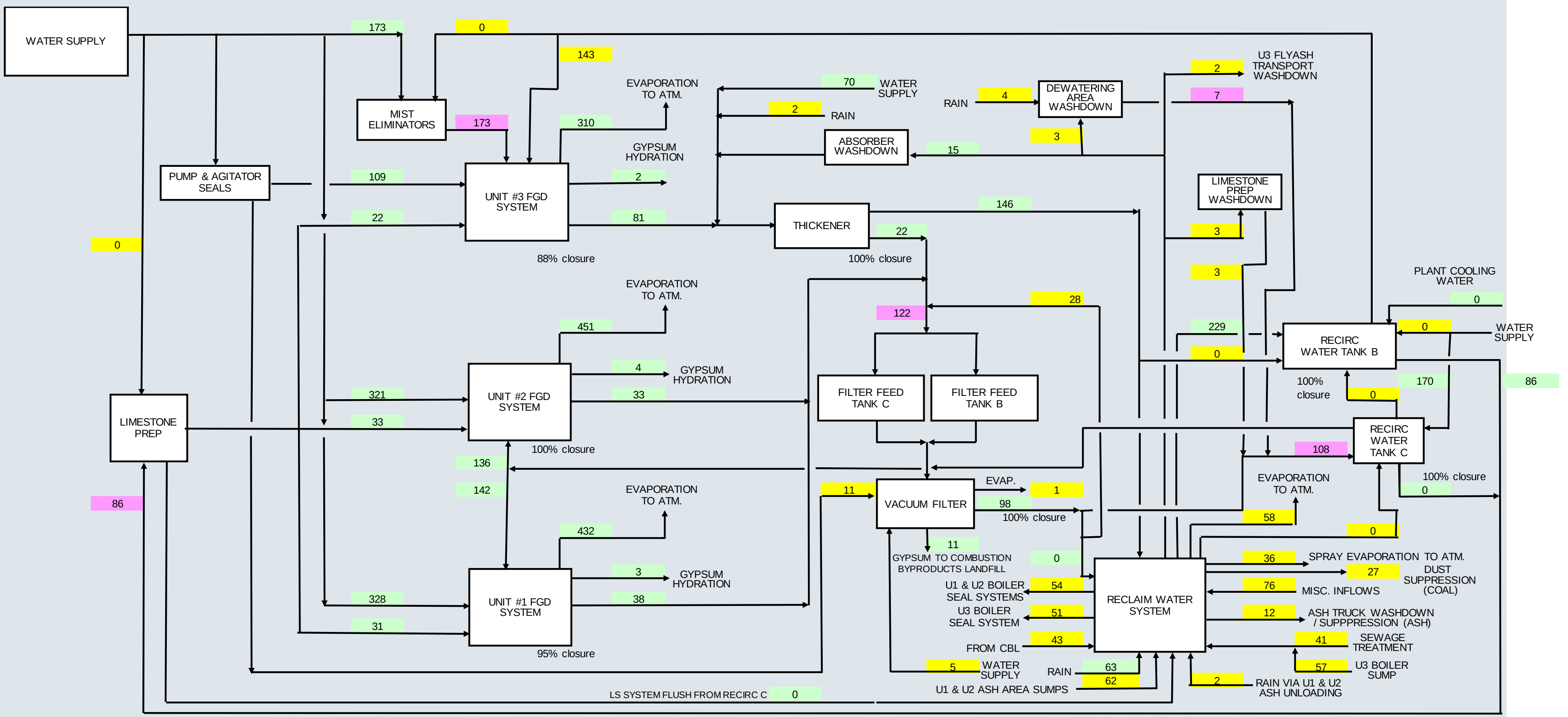
Technical Approach – FGD Water/Halide Mass Balance + Metallurgical Evaluation

- Developed spreadsheet-based mass balance tool
  - Process flow diagrams, water balance, Cl and Br balances
- LCRA data available to develop tool:
  - Multiple years of coal data
  - Existing station-wide water balance
    - But represented annual averages; not tied to specific coal, or unit operating conditions
  - Measurements of Br in FGD inlet flue gas during 2011 Hg control option testing
  - Process water Cl^- and Br^- concentration data collected over several months (summertime drought conditions)
  - However, did not have Br in coal or makeup water

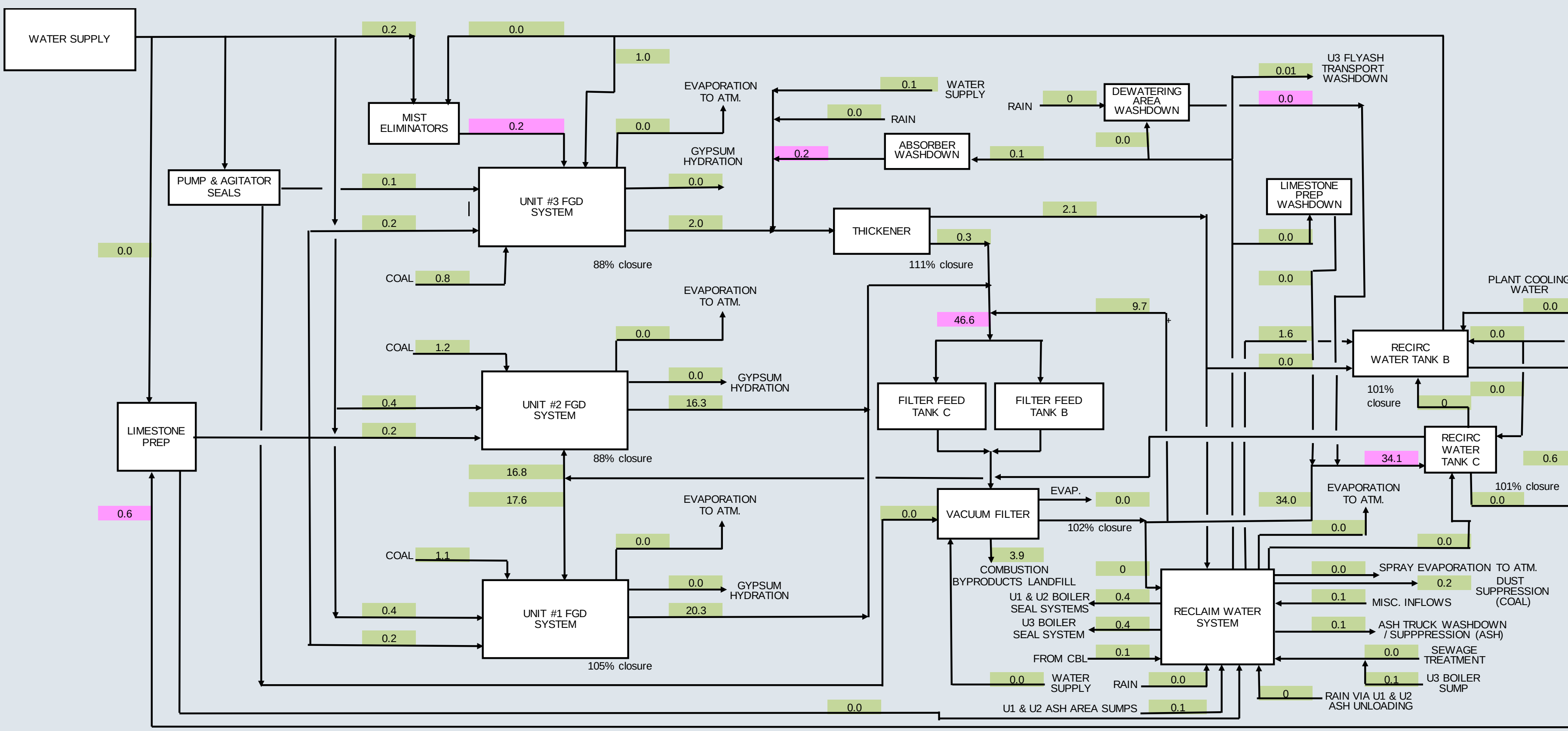
Part 1: Developing Balance Cases

- Established baseline:
  - Adapted station water balance to spreadsheet
  - Converted average flows to process-based rates where possible (based on unit load, coal S, etc.)
  - Used plant process water halide data to develop Cl^-, Br^- balances (educated guess on coal, makeup water Br^-)
  - Adjusted process flow diagram, flow rates to achieve good closures
- Developed predictive balances for Hg control conditions
  - Used 2011 Hg control test data for future Br^- input to FGD
  - Let mass balance spreadsheets predict steady-state Cl^-, Br^- in FGD systems

Example Water Balance Process Flow Diagram



Example Br Balance Process Flow Diagram



Part 2: Predicting Br^- Impacts on FGD Materials

- Established baseline
  - Materials of construction of all FGD components
  - Operating history (pH, Cl^- conc., etc.)
  - Current condition
    - Schedule did not allow for assessment inspections
  - Develop Cl^- limits for existing materials

- Estimated Br^- effects on materials
  - Limited data available for FGD conditions
  - Relative effects of Br^- vs. Cl^- are alloy specific
    - Steen, et al. (short-term pitting potential measurements)
    - Sherlyn (defined a critical temperature which impacts relative Br^- vs. Cl^- corrosivity, and which correlates with PREN values)

Part 2: Predicting Br^- Impacts on FGD Materials (continued)

- Developed alloy-specific halide relationships:

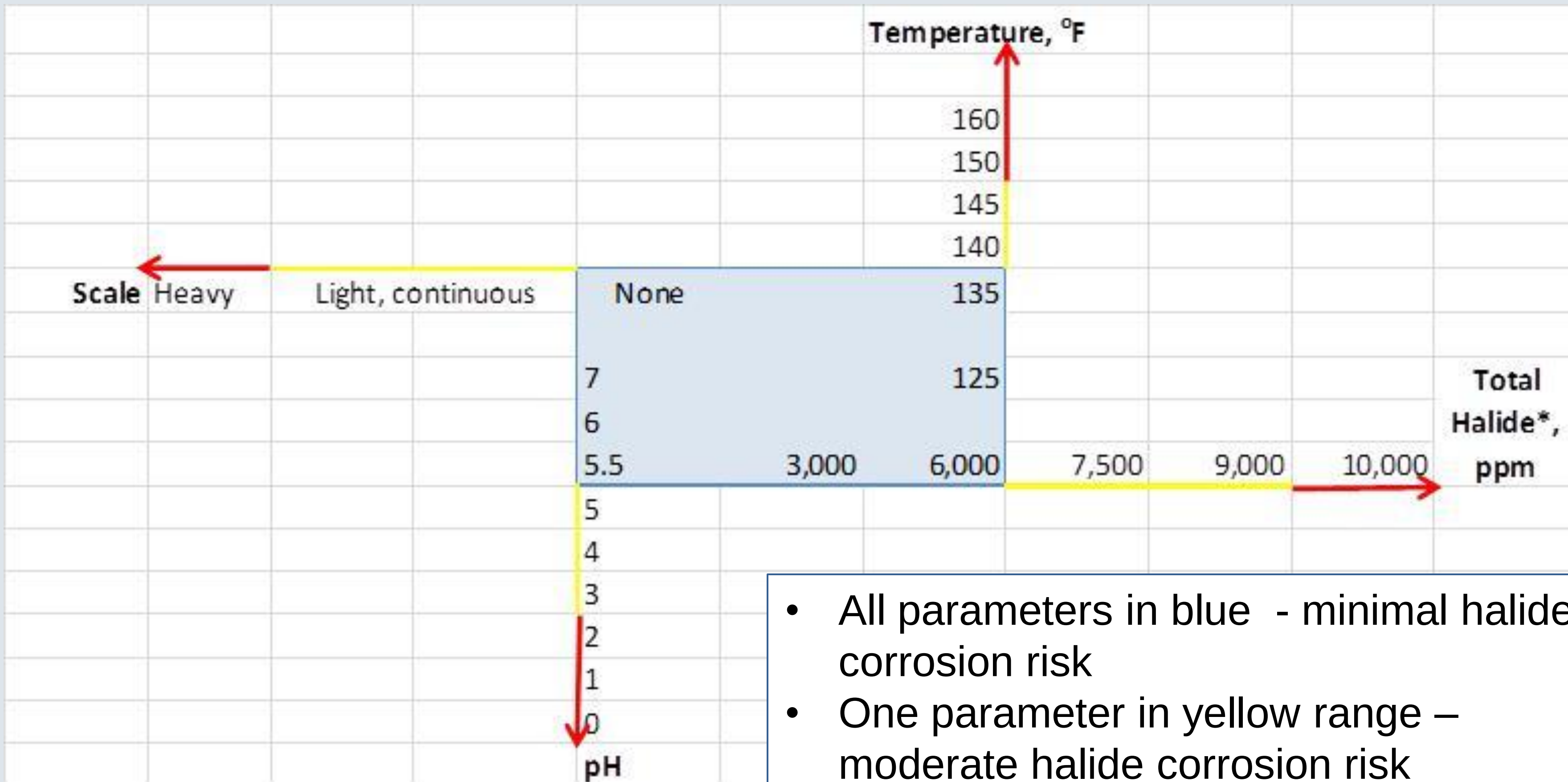
$$[\text{Total Halide}] = [Cl^-] + \mathbf{X} * [Br^-]$$

  - **X** establishes the relative weighting of Br^- versus Cl^- concentrations on potential for pitting and crevice corrosion
  - **X** can vary from alloy to alloy
  - Total Halide limits are then set using industry experience with Cl^- for each alloy
  - With limited data available, considerable **professional judgment** was required to establish **X** values

Part 2: Predicting Br^- Impacts on FGD Materials (continued)

- Total Halide limits **not** represented by single values
  - pH, temperature, presence of scale and duration of exposure all must be considered
  - All of these variables impact recommended time between component inspections
  - Must consider the probability of simultaneous excursions of multiple variables outside of "normal" range (e.g., high Total Halides and low pH)
- Total Halide limits must consider lowest alloy installed in FGD systems

Example pH, Temperature, Scaling and Total Halide Relationship



- All parameters in blue - minimal halide corrosion risk
- One parameter in yellow range – moderate halide corrosion risk
- One parameter in red or two or more in yellow – high risk of halide corrosion; inspect soon

Results

- Units 1 and 2 FGD systems are more sensitive to Hg control system selection in spite of higher alloys of construction
  - Closed-loop operation leads to elevated Total Halide concentrations (outside of “blue box”)
- Based on 2011 test data, brominated PAC poses less of a materials risk than Br addition with coal + non-Br PAC (@2011 addition rates)
  - Future testing with state-of-the-art PAC, optimized addition rates may change these results
  - Mass balances can predict steady-state Total Halogens at future addition rates

Recommendations

- Implement brominated PAC injection as a near-term MATS compliance technology
  - Determine optimal injection rates
  - Consider Br with coal plus non-Br PAC later
- Monitor halide concentrations in FGD systems on a bi-weekly frequency, use Cl^- and Br^- specific analytical methods to apply "**X**" factor
- Update FGD component inspection frequencies as needed
  - Use alloy-specific relationships, and
  - Actual experience for Total Halide concentration, pH, temperature, scaling and duration of exposure