Progress in Monitoring and Chemistry Control in Power Plants

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AECL EACL

Drivers for Improved Chemistry Performance

- Achieve design life (60 years) and maintain option for life extension
- New focus on Ageing Management requires more rigorous chemistry control and management
- Increasing expectations of the regulator – maintain safety margins as plant ages
- Higher standards for health, safety and the environment
- Increase reliability and reduce costs

Improving Chemistry Control in CANDU Plants

1. Review and update all chemistry specifications
   - Each chemistry specification linked to a specific requirement and supported by a sound rationale
2. Design for improved chemistry control in all stages of plant operation: commissioning, power operation, layup and startup following an outage
   - Feedback to designers based on OPEX and R&D program
3. Developed an advanced monitoring, diagnostic and analysis system to proactively manage plant chemistry at reduced O&M cost

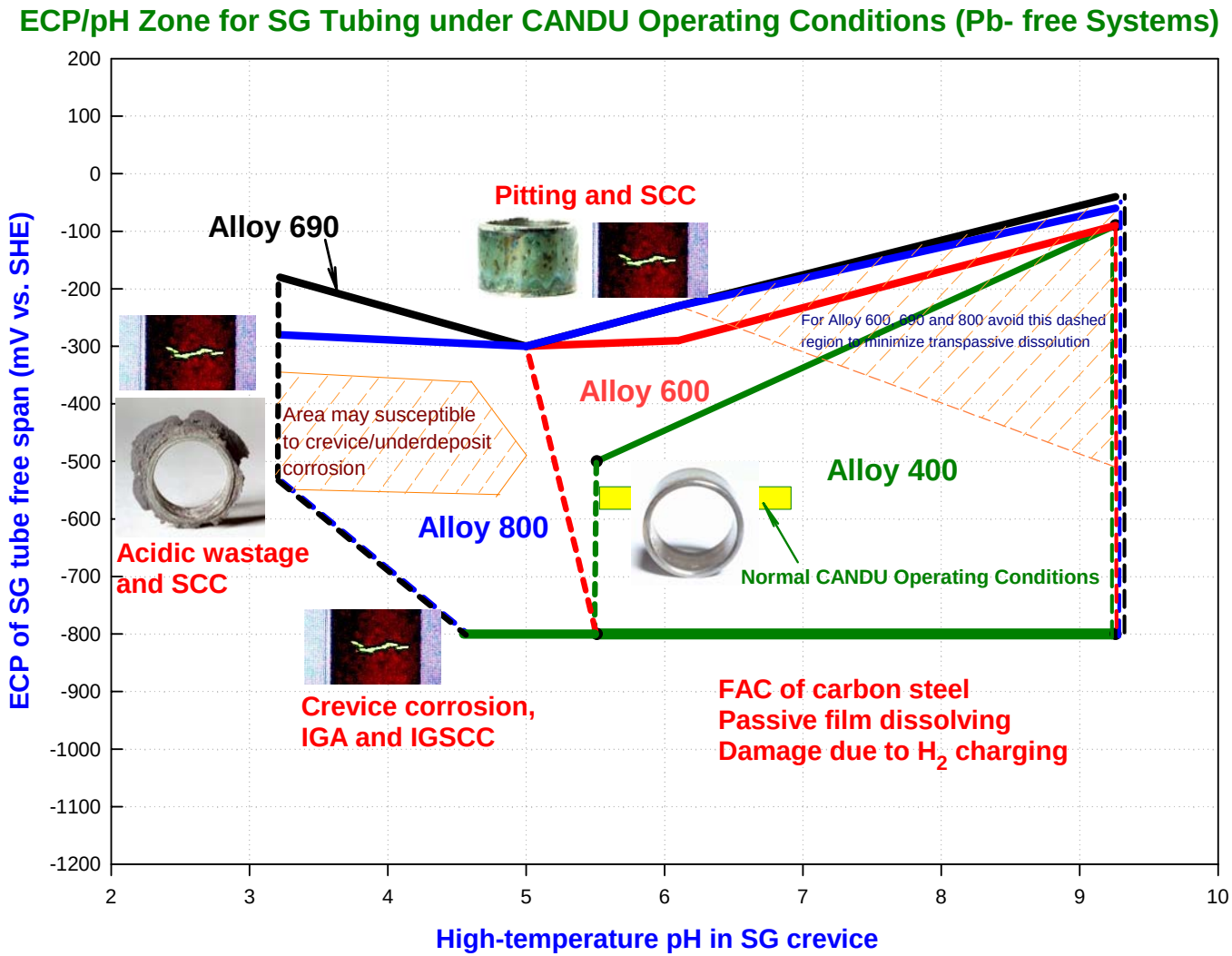
Outcomes from Review of Chemistry Specifications

- Chemistry Design Manual
  - Control parameters: protect system safety and integrity
  - Diagnostic parameters: assist in the interpretation of system chemistry
  - All parameters linked to specific requirement and rationale
  - On-line vs. grab, sampling system design
- Switched from pH to Li^+ for alkalinity control in primary coolant system (power operation)
  - CO_2 pickup gives unreliable results
  - Li^+ more directly related to OH^- (OD^-) concentration
- Reduced upper limits for impurities in primary coolant
  - mitigate risk of cracking of stainless steels (Cl^- < 10 μg/kg)
  - mitigate risk of cracking of carbon steel (SO_4^{2-} < 20 μg/kg)

Outcomes from Review of Chemistry Specifications

- Specific range for dissolved O_2 in condenser
  - Minimum 5 μg/kg to mitigate flow accelerated corrosion of carbon steel
  - Maximum 30 μg/kg to mitigate risk of cracking of carbon steel in the dearator
- Altered specification for N_2H_4 in steam cycle
  - Minimum N_2H_4 in feedwater is 5 x feedwater O_2
  - Recommended range in SG blowdown is 25 to 50 μg/kg
  - Higher concentrations not necessary during operation (except, perhaps, for Monel 400)
- Base SG impurity specifications on concept of Recommended ECP – pH_T Zones
  - Electrochemical Corrosion Potential (ECP)
  - pH_T is pH at temperature

ECP-pH Zone to Minimize Risk of Degradation of Tube Alloys



Design Changes to Improve Chemistry Control

- Filtration to Reduce Activity and SG Crud Burden
  - Sub-micron filtration of primary coolant to reduce source terms for activity transport. Applied effectively at some U.S. PWR and domestic CANDU plants
  - Filter feedwater during startup before feeding forward to SGs. Target crud concentration < 50 μg/kg
- Narrow-band pH Control
  - Two large IX columns not compatible with slow, well-controlled addition of Li^+ for narrow-band pH control
  - Add 3rd smaller column of cation resin for Li^+ removal, leaving large columns of lithiated-resin for Li^+ addition and removal of impurities

Design Changes to Improve Chemistry Control

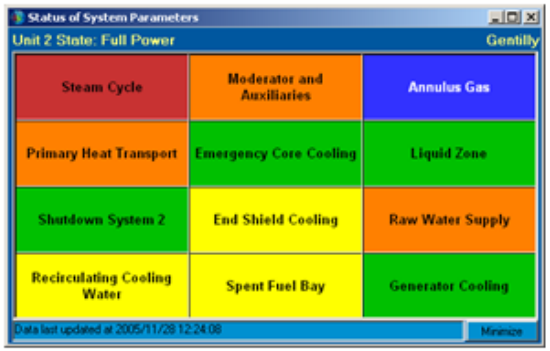
- **Dedicated SG Wet Layup Loop**
  - Wet layup loop with provision for chemical addition, sampling and purification to:
    - improve chemistry control,
    - reduce emissions of water-treatment chemicals, and,
    - reduce time to re-establish chemistry control on shutdown and startup
  - Establish layup chemistry within a few hours of shutdown
  - Target chemistry specifications:
    - Dissolved O_2 < 1 μg/kg (i.e., below limit of detection)
    - N_2H_4 =120 – 200 μg/kg

Design Changes to Improve Chemistry Control

- SG Blowdown Recycle
  - Heat recovery and blowdown purification; discharge to condenser hotwell
  - Electroionisation technology being evaluated for purification
  - Blowdown recycle facilitates consideration of alternative water treatment strategies to reduce SG fouling; dispersants, filming amines
- Other Design Changes
  - Provision for flushing piping systems following construction and maintenance
  - Elimination of dead legs: hard to flush; microbial activity
  - Improvements to chemical addition and sampling systems
  - Increased reliance on on-line analysers; computer interface to chem lab instruments to eliminate manual entry of data

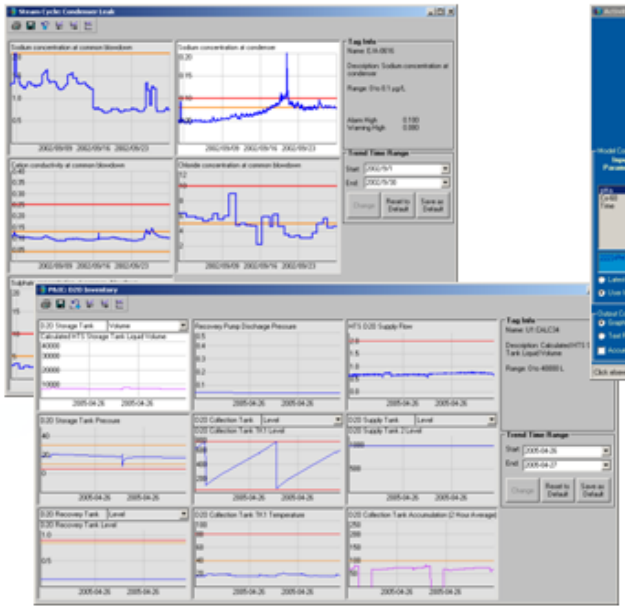
Advanced System for Monitoring, Diagnostics and Analysis - ChemAND

Status



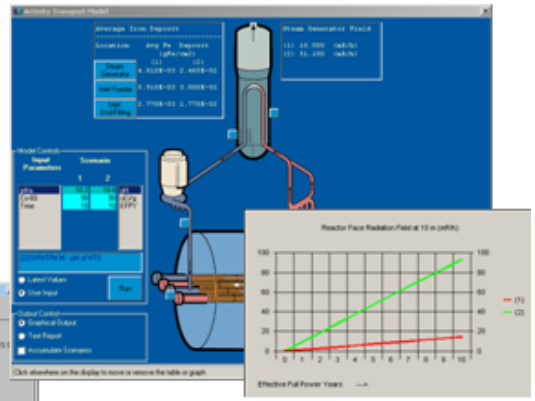
- Current value and trend of most recent values compared to user-defined limits
- Colour indicates status of all chemistry and process parameters on a system basis

Diagnostics



- Trends of correlated parameters facilitate diagnostics and support making proactive and informed decisions

Analysis



- Activity Transport
- SG Fouling
- Steam Cycle Chemistry

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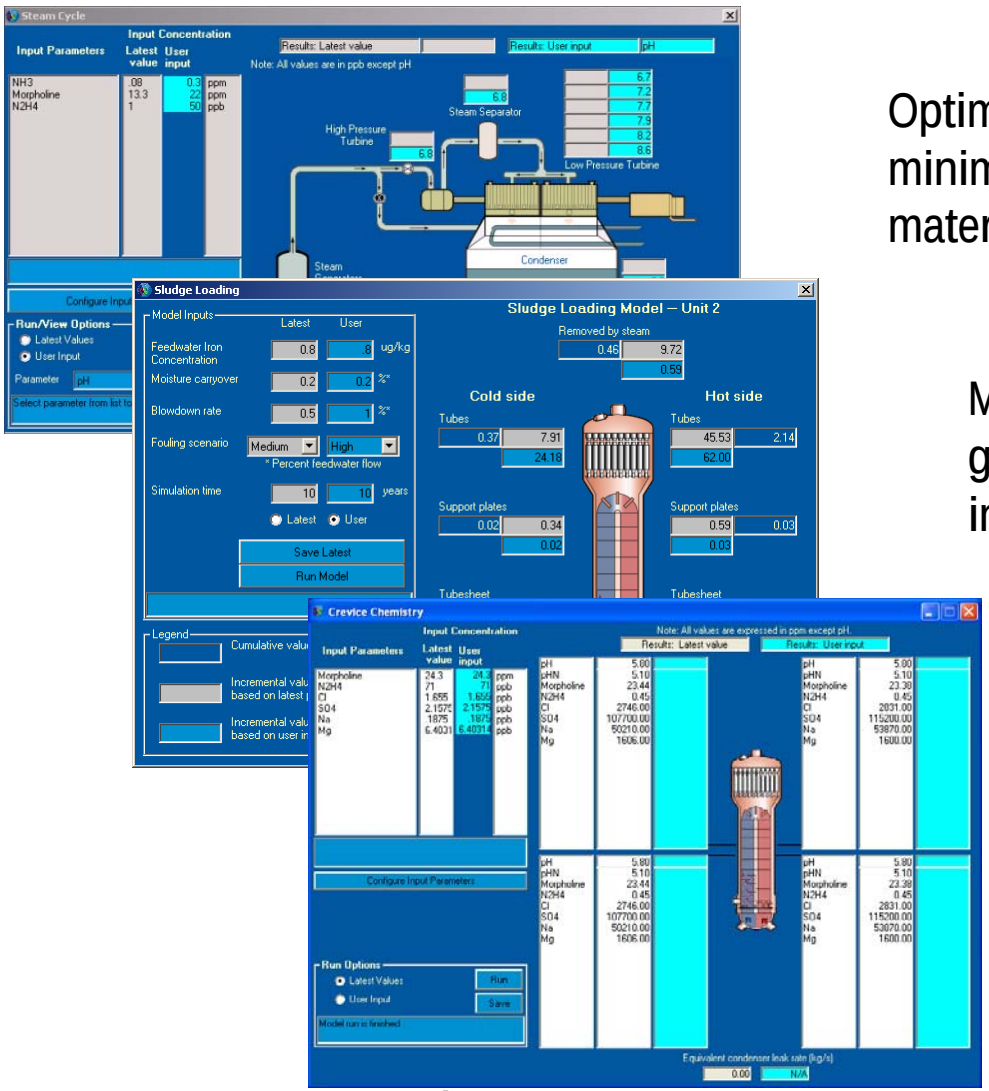
Advanced System for Monitoring, Diagnostics and Analysis



Optimize All Volatile Treatment to minimize corrosion of steam cycle materials; e.g., flow accelerated corrosion

Monitor deposit loading of steam generator to advise where to inspect and when to clean

Assess impact of chemistry transients on risk of steam generator tube degradation

Summary

- AECL has taken rigorous approach to reviewing and updating all aspects of chemistry control in CANDU
  - Updated chemistry specifications linked to specific requirements and backed by sound rationale
  - Design changes to improve chemistry control during operation, startup and layup
- AECL has developed an advanced monitoring, diagnostic and analysis system to:
  - Provide overview of plant chemistry and direct attention to where it is needed
  - Facilitate identification and resolution of problems related to chemistry control
  - Provide analysis to optimize operating conditions and assess impact of current conditions on future performance

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