Americas Honeywell Users Group 2013

Sustain.Ability.

CORROSION SOLUTIONS
Honeywell Corrosion Solutions

Modeling Applications

Joint Industry Programs

Real Time Monitoring

Laboratory Testing
Corrosion Software Models

- Socrates 9.0 – selection of corrosion resistant materials
  - Oil & Gas production / transmission
- Predict 6.0 – predict corrosion rates in carbon steel
  - Oil & Gas production / transmission and limited Refining
- PredictPipe 3.0 – assessment of corrosion rates in normally dry gas transmission lines
  - Oil & Gas
- Predict-SW 3.0 – corrosion prediction for sour water systems
  - Refining
- Predict-Amine 2.0 – corrosion prediction for amine units
  - Refining
- Predict-Crude 2.0 – Prediction and Assessment of Corrosivity of Crude oils and Crude Fractions
- Strategy A 4.0 – evaluation of steels in wet H\textsubscript{2}S service environments in sour pipelines (Upstream)
- Strategy B 4.0 – evaluation of steels in wet H\textsubscript{2}S refinery service environments (Downstream)

Go to Demo Software
## Target Markets and Applications

<table>
<thead>
<tr>
<th>Software Application</th>
<th>Oil &amp; Gas</th>
<th>Refining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predict 6.0</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>PredictPipe 3.0</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Socrates 9.0</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Strategy-A 4.0</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Strategy-B 4.0</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Predict-Amine 2.0</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Predict-SW 3.0</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Predict-Crude 1.0</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

Corrosion models are specialized and targeted towards certain industries and applications
Typical customers include O&G operating companies such as Chevron, Shell, Aramco, Petrobras, CNPC, ONGC and Engineering companies such as IMV Projects, KBR, WorleyParsons, Fluor, Black & Veatch
Predicted Time to Failure

Indicates effect of predicted corrosion rate on life of pipe
Corrosion Distribution Profile in Predict 6.0
Multi-Point Analysis in Predict 6.0

- This tool provides the ability to import multiple cases into Predict 6.0 using MS Excel.
Sensitivity Analysis in Predict 6.0

- This tool provides the ability to perform single parameter sensitivity studies
Expert – Multipoint Sensitivity Analysis in Predict 6.0

- Helps visualize predicted corrosion rates for an operating envelope
Socrates® 9.0

- Evaluates over 160 commonly used corrosion resistant alloys (CRAs) for resistance to corrosion and cracking in acidic environments
- Based on real lab and field data
- CRA Selection Guidelines
  - Resistant to general corrosion
  - Resistant to localized corrosion (pitting and crevice attack)
  - Resistant to SSC, SCC and HIC
  - Designed to offer significant reduction in operating and maintenance costs in comparison to conventional steel/inhibitor completions
Socrates® 9.0 User Interface

Input Data
- Environmental Specifications:
  - H₂S and CO₂
  - Chloride
  - HCO₃
  - GOR, WGR
  - Temperature
- Calculated system pH

Results
- Environment Severity
- Required Pitting Index
- Carbon Steel Corrosion Rate

Results
- Selected Materials
Socrates® 9.0 Environment Analysis

Evaluate a set of materials for a set of environments on a single screen.

Typical users include materials suppliers (JFE, Sumitomo), operating companies (Chevron, Petrobras) and engineering companies (Fluor, IMV Projects, Black & Veatch).
• Only program with extensive data relating to ammonium bisulfide corrosion
• Based on JIP Funded Research Results ($8M Plus program)
• Corrosion Rate Prediction of 14 materials
• Quantifying corrosion provides a path forward for risk mitigation and failure prevention
• Very well accepted in the refining industry

Program currently used by about 20 sponsor companies. Application relevant to every refinery operation for corrosion mitigation and failure prevention.
Problem Areas in Refinery Sour Water Handling
Predict-SW: Industry recognition and acceptance

• Two papers presented at Corrosion/06 at San Diego
  - (one by Shell Global and the other by Flint Hills Resources) –
  - Paper Nos. 06576 and 06577)
  - Both papers attest to the value proposition the software brings through application of new technology and Honeywell IP

• Other papers presented at NACE
  - 09337 and 10349

• Key takeaway from papers:
  - Every refinery will benefit from having this system because it can prevent failures, and will offer substantial Cost Savings (material replacement, maintenance planning)
Predict-SW®-SW 3.0 Software Interface

- Easy to use
- Needs typical process data
- Provides instant results for corrosion rate prediction

Predict-SW is licensed by leading refiners such as ExxonMobil, Shell, Marathon Oil, Flint Hill Resources, BP, Petrobras, Chevron, Tesoro, Axens, Citgo etc. and engineering companies such as Fluor
Sensitivity Analysis in Predict-SW 3.0
3-D Piping Model for Balanced Piping
Predict-SW: Functional Roles

- As a tool for corrosion quantification
- To support inspection planning, and allocation of resources towards situations that have potential for high corrosion
- To determine the right alloy or treatment choice (a more expensive material is not always better)
- To mitigate and minimize risk of failure (as a component in any RBI program)
- Applicable in various scenarios
  - Material selection for new equipments
  - Locating critical locations in existing plants
  - Determining inspection intervals
  - Evaluating materials or chemical treatment options
  - Optimizing Asset Integrity and Reliability programs
Predict-Amine 2.0

- Predict-Amine 2.0 focuses on Rich Amine Corrosion
- Incorporates
  - Large database of quantitative corrosion data developed by Amine JIP from simulated lab tests
  - Flow modeling calculations for wall shear stress
  - Algorithms/rule sets to address effect of the key variables that affect corrosion

- Predicts amine corrosion rate for five (5) commonly used materials in MEA, DEA and DGA services
- Provides tools for sensitivity and multipoint analysis
- Provides access to 3D Piping tools for modeling
- Provides secure access to all JIP data, presentations, trends and correction factors
Corrosion Problem Areas in Typical Amine Units

LEAN AMINE

TREATED GAS

RICH AMINE

CONTAC TOR ABSOR BER

FILTER S.

Lean To Rich Amine Heat Exch.

SOUR GAS FEED

STRIP P ER

Amine Make-up

ACID GASES
Predict-Amine Interface

- Easy to use Interface
- Simplified Inputs
- Extensive Functionality
- Units Flexibility
- Access to JIP Data
- Help system
- 3-D Piping Analysis
- XP/Vista/7 compatible
Sensitivity Analysis in Predict-Amine 2.0
3-D Piping Model for Amine Piping Circuits
Internal Corrosion of Pipelines

- Internal and external corrosion results in up to 50 percent of all pipeline leaks (upstream and midstream).
- For gas transmission lines, over 20 percent of pipeline leaks result from corrosion.
- Internal corrosion accounts for between 70 and 90 percent of corrosion failures.
PredictPipe Interface

- Comprehensive, in-depth ICDA for pipelines, with a number of modules
  - Import Pipe Geometry
  - Identify Critical Segments
  - Analyze Water phase behavior
  - Perform rigorous flow modeling
  - Generate Corrosion Prediction Profiles
  - Analyze Water Holdup
  - pH computation
  - Integrate analysis & data with other software systems
Honeywell’s Integrated Real-Time Solution

• Online Real Time Corrosion Management
  Assists in identification of critical processes that may cause damage
  Enables problem resolution through Boundary and Deviation management
  Corrosion quantified as it happens, providing operator / management ability to react quickly and appropriately

Ability to see ahead facilitates optimized functioning
Delivering Operational Excellence

PROBLEM: Operating Out of Range contributes to incidents

- ~80% of process upsets attributed to equipment failure / human error
- ~76% of equipment failure related to managing operations outside of “boundaries”

Source: ASM Consortium
Corrosion is a Key Part of Plant Risk & Safety

Building Blocks for Safety/Integrity: Honeywell Vision for Total Corrosion Management

- Corrosion data is a key requirement to ensuring safe operations
- DCS applications provide the operator the platform to reduce unexpected equipment failures.

Corrosion Modeling, Consulting and Corrosion Monitoring
Operating in The Design Envelope

Sources of Limits

- HazOp / PHA
- Safety Systems (Trip Settings)
- Safeguarding (Pressure Relief & Level Limits)

Risk Based Inspection

Reliability Centred Maint

Limit Monitoring

- Critical Hi
- Standard Hi
- Target Hi
- Target Lo
- Standard Lo
- Critical Lo

Limits

- Pressure
- Temperature
- Flow
- Corrosion
- Vibration
- Current
- Acceleration
- pH

Deviation Reporting

Alarms & Alerts

Real-Time Monitoring

- Corrosion

Manual Data

Process Data

Operator Rounds & Field Inspections

Console Operator

Management Reporting

Sources of Limits:

Know Your Limits – Stay within them - All the times!
Real Time Monitoring with SmartCET

Transmitter Assembly

Insertion probe body

Probe electrodes (consumable)
SmartCET with Super LPR Technology

• SuperLPR technology combines all three techniques into one measurement, using **one probe**.
  - Each measurement must be made on the same electrodes for the results to be accurate.

• Measurement cycle consists of:
  - ECN – 300 seconds
  - LPR / HDA – 100 seconds
  - Solution Resistance – 30 seconds

• All calculations are performed in the transmitter
  - 4-20mA output is (LPR) general corrosion rate
  - Digital HART outputs are Pitting Factor, B value, CMI signals.
SmartCET Corrosion Monitoring – Summary

- **Four distinct corrosion monitoring models**
  1. Original 4-20 mA, HART compatible wired transmitter (CET5000M)
  2. Upgraded 4-20 mA, HART compatible wired transmitter (CET5500M)
  3. Stand-alone, self-powered data logger (CETW6000M-D)
  4. OneWireless corrosion transmitter (CETW6000M-W)

- **All four offerings feature the same corrosion rate and related variables**
  - The selection of which product then is mainly the manner to connect to the DCS (or not).
1. SmartCET CET5000 Series

- The original 4-20 mA, HART compatible corrosion transmitter
  - CET5000M – multivariable output. Four different corrosion measurements.

- Features
  - 430 seconds cycle time
  - CSA, FM and ATEX approval
  - Remote and direct probe connection options
  - Requires separate galvanic isolator
  - HART 5 compatible
2. SmartCET CET5500M

- The upgraded 4-20 mA, HART compatible corrosion transmitter
  - CET5500M – multivariable output. Four different corrosion measurements

- Features
  - 30 second cycle time
  - CSA approval
  - Built-in galvanic isolator
  - Local display of the four measurements
  - HART 6 compatible
3. SmartCET Corrosion Data Logger

- Model CETW6000M-D
  - Multivariable output. Four different corrosion measurements
  - Data is stored in local memory
  - Simple (optional) PDA device transfers data file Data Logger to PC
  - Lowest overall installed cost
- Features
  - 6, 10, 20 and 30 min logging option
  - Min / Max logging option
  - Excel compatible data file
  - CSA, FM and ATEX (pending) approvals
  - Local display of the four measurements
4. OneWireless SmartCET

- Model CETW6000M-W
  - Multivariable output. Four different corrosion measurements
- Works with OneWireless network
  - All other OneWireless options available
- Features
  - 30 second cycle time
  - CSA, FM and ATEX approvals
  - Remote-only probe connection
  - Local display of the four measurements
# Which SmartCET to Select?

<table>
<thead>
<tr>
<th>Customer Requirement</th>
<th>SmartCET CET5000M</th>
<th>SmartCET CET5500M</th>
<th>OneWireless SmartCET</th>
<th>SmartCET Data Logger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional wired connection to DCS</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connect to DCS but wiring costs are prohibitive</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>No power or communication wiring, no desire to connect to DCS</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Self-powered device</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Order in terms of lowest installed cost (lowest first)</td>
<td>3*</td>
<td>2</td>
<td>3*</td>
<td>1</td>
</tr>
<tr>
<td>Easiest (time and cost) for customer to evaluate SmartCET technology</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Approvals</td>
<td>CSA, FM, ATEX</td>
<td>CSA</td>
<td>CSA, FM, ATEX</td>
<td>CSA, FM, ATEX</td>
</tr>
</tbody>
</table>

* Cost would be dependent upon wiring costs versus network infrastructure. Second OneWireless transmitter would be less costly than wired.
Online, real-time corrosion monitoring….

A “Tachometer” for the plant operator!
## Corrosion Value Proposal: Why should You Care?

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure prevention/risk reduction</td>
<td>$10 to $35 million (CDU overhead)</td>
</tr>
<tr>
<td></td>
<td>$60 million each (sour water system)</td>
</tr>
<tr>
<td>Reduce lost production</td>
<td>~$100,000 per day</td>
</tr>
<tr>
<td>Steel/alloy upgrade</td>
<td>$1 to $10 million</td>
</tr>
<tr>
<td>Prioritize inspections</td>
<td>$1M+ to postpone smart-pig runs / 20% reduction in inspection costs</td>
</tr>
<tr>
<td>Reduce Unplanned Shutdown</td>
<td>&gt;$240,000 per day</td>
</tr>
<tr>
<td>Reduce Capital Materials</td>
<td>~$17 million per plant</td>
</tr>
<tr>
<td>Optimize Inhibitor Dosage</td>
<td>20-60% Savings on $250K to $2M contracts</td>
</tr>
</tbody>
</table>
Corrosion Modeling Services

• We can model any aqueous corroding system
• Incorporate corrosion predictions for most industry specific applications
• Help users
  - Identify and troubleshoot corrosion problems
  - Provide material selection recommendations
  - Analyze Corrosion Threat and help quantify risk
  - Design lab experiments to accurately simulate real life conditions
• Manage Joint Industry Research Programs
• Utilize our tools, industry know-how, consulting experience and technical advantage in providing customers the solutions they are looking for
Honeywell Corrosion Solutions – Laboratory services

HCS moved to a new, purpose-built facility in July 2009
- 17,500 sq. ft
- A fully-equipped corrosion and materials research and engineering laboratory
  - High-pressure, high-temperature vessels
  - Mechanical testing
  - Custom-built equipment
  - Electrochemical testing
H₂S Scrubber for Laboratory Air

- Laboratory has a dedicated scrubber that processes all air exiting the lab
  - Treats 20,000+ CFM of air
  - Design H₂S scrubbing efficiency exceeding 98%
Honeywell - Typical Laboratory Services

• Standardized and Modified Testing per ISO, ASTM, NACE, EFC, etc. Methodologies

• Upstream
• Downstream

• Corrosion Evaluations
• Environmental Cracking Evaluations
  - Hydrogen Induced Cracking
  - Sulfide Stress Cracking
  - Stress Corrosion Cracking
  - Slow Strain Rate Testing
  - Corrosion Fatigue

• Simulated Service Environments
  - High Temperature, High Pressure
    • Up to 700 F, 20,000 psi
  - Corrosive Media
    • Simulated with NaCl, H$_2$S, CO$_2$, etc.
    • Client supplied chemicals
• Alloy compatibility
  - Alloy compatibility determined for cracking and corrosion resistance to relevant upstream environments
  - TM0177 Methods used to evaluate upstream cracking resistance
    • Tensiles, C-rings, Bent Beams, Double Cantilever Beam Specimens (DCB)
  - Coupons or electrochemical methods used to evaluate general and localized corrosion resistance
  - TM0198 Method (SSRT) used to screen cracking resistance
- Sub-sea
  - Common concerns in sub-sea metallurgy are:
    - Corrosion of low alloy components in absence of cathodic protection
    - Hydrogen charging of alloys exposed to high levels of cathodic protection
    - Cracking of weldments exposed to CP, galvanic couples
• Autoclave Testing
  - General autoclave procedures for high pressure, high temperature can be found in ASTM G111
  - Honeywell Laboratory has many autoclaves (C276 wetted parts) for testing upstream environments:
    - (13) 5L capacity / 5 inch ID / 5,000 psig / 600 F
    - (12) 6L capacity / 4 inch ID / 1,000 psig / 600 F
    - (3) 2.7L capacity / 3 inch ID / 20,000 psig / 600 F
    - (8) 0.7L capacity / 1 inch ID / 10,000 psig / 550 F – “Rotoclave”
• **Crude Corrosivity**
  - Relevant in refinery systems like CDU and VDU
  - **High temperature sulfidation attack**
    - 400 F – 750 F
    - Reaction of sulfur species or \( \text{H}_2\text{S} \) with alloys to form \( \text{FeS, Fe}_x\text{Cr}_y\text{S}_z \)
  - **High temperature organic acid attack** ("naphthenic acid")
    - 400 F – 750 F
    - Reaction of organic acids with alloys to form soluble naphthenates
  - **Joint Industry Program examining corrosion rates**
• Amine Gas Treatment
  - Amine solutions used to scrub H₂S & CO₂ from gas streams
    - Often multiple amine treatment units in refineries
    - Also relevant for upstream (offshore carbon capture)
  - Multiple Joint Industry Programs examining corrosion rates
    - Rich Amine – high acid gas content in amine solutions
    - Lean Amine – low acid gas content in amine solutions
Downstream Laboratory / Consulting Services

• Sour Water Stripper
  - Water in refinery processes containing:
    ✷ H₂S
    ✷ NH₃
    ✷ Cyanides
    ✷ Etc.
  - Honeywell JIP (Phase III)

• Sulfuric Acid Alkylation
  - High concentrations of H₂SO₄ used as catalyst for alkylation
    ✷ 87%+ H₂SO₄
    ✷ Water and ASO
  - Honeywell JIP
Downstream Laboratory / Consulting Services

• High Temperature Gases
  - 1000 F +
  - Direct Oxidation
  - Carburization
  - Metal Dusting

• Corrosion under Insulation
  - External corrosion in refineries
  - ASTM G189 procedure
    - Wetted insulation
    - Wet / dry cycles
    - Elevated temperature (180 F+)
    - Electrochemical monitoring
Honeywell Corrosion Solutions

Improving Business Performance

Safety
- Predict and assess corrosion of plant assets, identify KPI and define IOW

Reliability
- Monitor corrosion real time as part of inspection and planning strategy

Efficiency
- Optimize process without increasing risk and maximizing asset life