REAL TIME PREDICTIVE ANALYTICS AND CORROSION MANAGEMENT WITH PREDICT®-RT
Speaker Bio

• Honeywell Connected Plant
  EMEA Customer Services Leader
  Honeywell Kft – Hungary

• Career Profile
  - Spent 15 years in the Automation Industry
  - Joined Honeywell in July, 2008 from GE Energy Optimization and Control Division
  - Career spans across the automation industry, holding various positions from Project Engineer, Lead Engineer, Project Manager, Senior Project Manager, Country Operation Manager, EMEA Advanced Solutions Engineering Services Operation Leader.
  - Graduated Industrial Process Automation engineer from the Budapest Technical College.
Outline

• Why is process corrosion management critical?
• What is Predict-RT?
• A paradigm shift: Making corrosion visible, relevant
• Predict-RT: Functionality, Overview
• Honeywell Connected: Real-Time Predictive Intelligence
• Conclusions
Honeywell Corrosion Solutions – Innovation Leader

Modeling Applications

THE NEW SOLUTION
REAL TIME PREDICTION

Joint Industry Programs

- Aggregated Funding ($2M to $4M)
- 2 to 3 Years Research Effort
- +30M$ IP developed

Solution Portfolio

Real Time Monitoring

- Predict®-Crude
- Predict®-SW
- Predict®-Amine
- Predict®-SA

Laboratory Testing

- Socrates™
- Predict®-Pipe
- Predict®-O&G
- Predict®-Amine

SmartCET® Technology

$25M facility for standardized and modified corrosion testing per ISO, ASTM, NACE, EFC, etc.
Corrosion…The *Cholesterol* in Process Applications

Need to reduce incidents, increase reliability, and extend equipment life

Pro-actively understand and correlate process to potential damage - critical to asset integrity
Corrosion is Expensive….

Conventional Reactive Corrosion Management Methods.. Don’t really work

**Inspection**
- Process corrosion quantification a complex task
- In Line Inspection (Smart Pigging) – Cost intensive
- Direct Assessment (Digging) – Cost intensive and loss of production

**“Fix it when it breaks”**
- Loss of production and fatalities when they can be avoided

**Chemical Injection**
- Inhibitor vendors driving the process “fox guarding the hen house” situation

**Corrosion Coupons**
- 90% of corrosion damage is caused during 10% of operational time!
- Corrosion is found after it happens
Real-Time Corrosion Prediction, Monitoring & Management

A real time software sensor
- Track damage and enforce appropriate limits
- **Identify** critical areas as operating conditions change
- Build a **complete** corrosion picture in combination with hardware
- **Adjust** your inspection schedule to address critical areas

“Mitigate before it can break”
- Predict **when** wall thicknesses will reach **critical** levels
- **Plan** your maintenance before it becomes an emergency

Minimize Chemical Costs
- **Visibility** means you can use chemicals effectively
- Optimal use translates into lower costs

Optimize process management with real time analytics
- Link corrosion and damage to relevant process parameters
- Know how you can optimize your process

Knowing where you are headed......predictive and proactive
Current Situation……..

Corrosion is “Invisible” to Operations
Making Corrosion Visible to Operations
Making Corrosion **Relevant** to Operations

Operate Plant → Present Corrosion Rate to Operators via Control System → Online Corrosion Rate Prediction → Real-time Corrosion Rate

Real-time Corrosion Rate → Correlate Corrosion Rates to process variables → Optimize operating variables to minimize Corrosion rates → Present Corrosion Rate to Operators via Control System → Online Corrosion Rate Prediction → Real-time Corrosion Rate

Operate Plant
Making Corrosion **Actionable** by Operations

- Operate Plant
- Online Corrosion Rate Prediction
- Generate Alarms & Alerts
- Present Corrosion Rate to Operators via Control System
- Correlate Corrosion Rates to process variables
- Optimize operating variables to minimize Corrosion rates
- Real-time Corrosion Rate
- Optimize operating variables to minimize Corrosion rates
- Generate Alarms & Alerts
- Present Corrosion Rate to Operators via Control System
- Correlate Corrosion Rates to process variables
- Real-time Corrosion Rate
- Optimize operating variables to minimize Corrosion rates
- Generate Alarms & Alerts
- Present Corrosion Rate to Operators via Control System
- Correlate Corrosion Rates to process variables
- Real-time Corrosion Rate
- Optimize operating variables to minimize Corrosion rates
- Generate Alarms & Alerts
- Present Corrosion Rate to Operators via Control System
- Correlate Corrosion Rates to process variables
- Rate OK?
Real-Time Prediction Solutions

Corrosion is now “visible” to everyone and “actionable” by operations / management
How Does It Work?
NOT GUESSING, IT IS SCIENCE!

• Predict-RT is **NOT based on theoretical speculations**
• Predict-RT Database comprises **REAL corrosion data**
• Prediction algorithms are based on **+15 years research** data developed during Honeywell Joint Industry Programs
• Predict-RT represents the **most recent knowledge** about corrosion processes
• Unique Predict **IP worth +30$M** is available for our customers with support from Honeywell Corrosion Center of Excellence (CoE)
• **20+ major World-Refining** companies are using various Predict Models (off-line/on-line)
### Accurate Prediction Models
- Offline corrosion prediction and material selection models
  - Predict-SW 3.0
  - Predict-Amine 4.0
  - Predict-Crude 2.0
  - Predict-SA 2.0
  - Predict-CDU-OH

### Real-Time Corrosion Prediction
- Corrosion prediction in real-time is possible
- Immediate mitigation actions can be planned
- Immediate quantification of material damage is possible
- Enabled by **Predict-RT**

### Process Data
- Process data available in plant historian via DCS
- Operating parameters
- Design Variables
- Material of Construction
- Service Life
- Laboratory Data (LIMS)

---

2017 Hydrocarbon Processing Innovation Award Winner
Corrosion prediction – “dynamic” mode

Set of Parameters

Temperature
Flow rate
Pipe ID
Pipe configuration
MOC
TAN/NAT

Prediction Engine Level 3.5

KPI Dashboard

Level 4 Network

Level 3 Network

Level 2 Network

Inspection / RBI server
Lab server
Integrity server

Operator Console

Control Systems DCS

4-20mA / HART / Modbus

Super LPR
High Res ER
High Res UT

Temperature
Flow rate
Pipe ID
Pipe configuration
MOC
TAN/NAT
Simple, Visible, Connected

**PREDICT-RT IS THE INDUSTRY’S FIRST EVER SOFTWARE SENSOR FOR CORROSION**

<table>
<thead>
<tr>
<th>Point Name</th>
<th>Description</th>
<th>Remaining Corrosion Allowance (mm)</th>
<th>Next Replacement Date</th>
<th>Max Corrosion Rate (mm/yr)</th>
<th>Corrosion Rate (10Y) (mm/yr)</th>
<th>Corrosion Rate (70Y) (mm/yr)</th>
<th>Corrosion Rate (100Y) (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>03CDUCF02</td>
<td>VAC Crude Furnace Outlet</td>
<td>3.8246</td>
<td>01-01-2020</td>
<td>1.3719</td>
<td>1.4531</td>
<td>1.4229</td>
<td>1.3585</td>
</tr>
<tr>
<td>03CDUVAC04</td>
<td>VAC Column Residuals</td>
<td>3.8269</td>
<td>01-01-2020</td>
<td>1.3727</td>
<td>1.1308</td>
<td>1.1342</td>
<td>1.2029</td>
</tr>
<tr>
<td>03CDUATM02</td>
<td>ATM Column Naphtha</td>
<td>3.8447</td>
<td>01-01-2020</td>
<td>1.3791</td>
<td>0.3068</td>
<td>0.3132</td>
<td>0.3040</td>
</tr>
<tr>
<td>03CDUVAC01</td>
<td>VAC Column LVGO</td>
<td>3.8438</td>
<td>01-01-2020</td>
<td>1.3788</td>
<td>0.4546</td>
<td>0.4255</td>
<td>0.3762</td>
</tr>
<tr>
<td>03CDUATM03</td>
<td>ATM Column Diesel</td>
<td>3.8417</td>
<td>01-01-2020</td>
<td>1.3780</td>
<td>0.4878</td>
<td>0.4366</td>
<td>0.4186</td>
</tr>
<tr>
<td>03CDUATM01</td>
<td>ATM Column Lights</td>
<td>3.8470</td>
<td>01-01-2020</td>
<td>1.3799</td>
<td>0.1721</td>
<td>0.1742</td>
<td>0.1619</td>
</tr>
<tr>
<td>03CDUCF01</td>
<td>ATM Crude Furnace Outlet</td>
<td>3.8267</td>
<td>01-01-2020</td>
<td>1.3726</td>
<td>1.2144</td>
<td>1.1327</td>
<td>1.2239</td>
</tr>
<tr>
<td>03CDUVAC03</td>
<td>VAC Column HVGO</td>
<td>3.8332</td>
<td>01-01-2020</td>
<td>1.3750</td>
<td>0.6664</td>
<td>0.7904</td>
<td>0.9303</td>
</tr>
<tr>
<td>03CDUVAC02</td>
<td>VAC Column MGO</td>
<td>3.8401</td>
<td>01-01-2020</td>
<td>1.3775</td>
<td>0.5057</td>
<td>0.5360</td>
<td>0.5350</td>
</tr>
<tr>
<td>03CDUATM04</td>
<td>ATM Column AGO</td>
<td>3.8382</td>
<td>01-01-2020</td>
<td>1.3768</td>
<td>0.6274</td>
<td>0.6122</td>
<td>0.6193</td>
</tr>
<tr>
<td>03CDUATM05</td>
<td>ATM Column Reduced Crude</td>
<td>3.8344</td>
<td>01-01-2020</td>
<td>1.3754</td>
<td>0.7658</td>
<td>0.7517</td>
<td>0.8340</td>
</tr>
</tbody>
</table>
Real Time Analytics…Monitor Rates at Multiple Locations

_Predict-RT_ provides a real time quantified picture of unit and piping integrity; transforming your data into knowledge.
Correlate Rates with Operating Conditions

*Predict-RT* provides the ability to safely process opportunity crudes, better manage your corrosion costs and improve operating margins.
Evaluate Multiple Materials for Better Asset Life Assessment

*Predict-RT translates to extended asset life and better manage your asset integrity and corrosion costs.*
**Optimized Feedstock Selection**

**North American Independent Refinery (189,000 bpd capacity)**

*Predict-RT* implemented to monitor the 30 day rolling-average TAN envelope vs 30 day fixed TAN envelope – *providing visibility into the process* – allowing Refiner to purchase more economical Crudes for processing.

<table>
<thead>
<tr>
<th>Business Opportunity</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Process additional DCO cargo (600 kb/cargo)</td>
<td></td>
</tr>
<tr>
<td>• $3/bbl incentive to the next heavy barrel alternative</td>
<td></td>
</tr>
<tr>
<td>• Shipment incentive of $1,800,000/cargo</td>
<td></td>
</tr>
<tr>
<td>• Four (4) additional DCO cargos/yr. processed safely</td>
<td></td>
</tr>
<tr>
<td>• <strong>Annual saving of $7,200,000</strong></td>
<td></td>
</tr>
<tr>
<td>• Payout in less than 1 QTR</td>
<td></td>
</tr>
<tr>
<td>• Plans for solution rollout to additional refineries (900,000 bpd network capacity)</td>
<td></td>
</tr>
</tbody>
</table>

*Predict-RT* allows for crude slate flexibility while maintaining a robust mechanical integrity program for crude and other downstream units.
Predictive Analytics for Refinery Integrity Management

Leading North American Refiner & Distributor (1.1M bpd capacity)
Predict-Crude and Predict-SW implemented to support the largest US refinery’s integrity management program

<table>
<thead>
<tr>
<th>Business Opportunity</th>
<th>Solution</th>
</tr>
</thead>
</table>
| • Better manage corrosion rates for complex crude throughput  
• Provide crude corrosion prediction due to naphthenic acid and sulfidic corrosion  
• Provide accurate sour water prediction and modeling to ensure safe operations | • Predict software suite for refineries encapsulates comprehensive data from thousands of laboratory simulations  
• Refining industry’s first-of-its-kind predictive, analytical model designed to convert process data into predictive intelligence, facilitating enhanced safety and reliability while driving optimized unit operations |

Predict corrosion suite predictive analytics for enhanced reliability and integrity management.
Enhanced Refinery Safety and Productivity

Oil & Gas Industry leader and Member of Honeywell Refinery JIP

*Predict-SW* implemented across refineries worldwide to standardize corrosion prediction and material selection

<table>
<thead>
<tr>
<th>Business Opportunity</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Deploy a global standardize solution to support NH4HS corrosion programs</td>
<td>• Predict-SW is the only solution that can help guarantee against NH4HS corrosion in refinery operations</td>
</tr>
<tr>
<td>• Increase engineering productivity across corrosion and integrity management programs</td>
<td>• Over 60 global users of the solution across different locations and continents</td>
</tr>
</tbody>
</table>

Predict corrosion suite enables accurate corrosion prediction and material selection for improved decision making.
Predict-RT in Real-Time Corrosion Prediction & Management

**Anticipate**
Predict corrosion damage and avoid unplanned shut downs

**Understand**
Correlate process changes to potential corrosion consequences

**Manage**
Flexible operations means improved reliability without a corresponding increase in costs

**Deliver**
Enhanced throughput and increased profits

**Scalability**
Monitor and expand corrosion visibility as needed

**Real-Time**
Visibility into your asset integrity program for better management of risk and inspection

**Improved Margins**
Optimize feedstock selection and processing opportunity crudes for superior ROI

---

*Transforming* Process Data into Corrosion *Intelligence* for Enhanced Profitability and Reliability

Preventing Corrosion Is Knowing When and Where It Occurs
Asset Integrity - Predictive Maintenance/Reliability Framework

Data Collaboration
Asset Integrity Dashboard

- Corrosion damage quantification & ID of critical zones
- Real-time monitoring of static & rotating equipment
- Dynamic IOW Management
- Deviation Management and Reporting
- Prediction of current state of equipment

Safety → Predictive Maintenance → Reliability → Profitability
Conclusions / Path Forward

- Real Time Corrosion Management is a complex task
  - Want more details? Please contact Honeywell Corrosion CoE
    predict@Honeywell.com
- Predict-RT facilitates throughput flexibility, process optimization and enhanced safety / reliability
  - Request a demo download to see how Predict-RT makes the invisible visible
- Wish to implement the first ever predictive software sensor for corrosion?
  - Please contact your Honeywell Account Manager
Joint Industry Programs (JIP)

- **Typical Sponsors**
  - Operating Companies
  - Chemicals Providers
  - Service Providers
  - Engineering & Design Companies
- **Aggregated Funding ($2M to $4M)**
- **2 to 3 Years Research Effort**
- **Refinery JIP**
  - $21M+ Funding
  - 20+ Sponsor Companies

**Specialized corrosion engineering and research services**

**Ongoing Programs:**
- CDU Overhead
- Nap Acid Corrosion Phase II
- H₂S Limits for 13 Cr

**In preparation**
- CUI JIP
- Raman JIP
JIPs since 2000

Refinery Joint Industry Programs

- Crude Corrosivity Phase I JIP
- Crude Corrosivity Phase II JIP
- Crude Distillation Overhead Phase I JIP
- Hydrogen Induced Cracking (HIC) & SSC JIP – Steels
- Lean Amine JIP
- Rich Amine Phase I JIP
- Rich Amine Phase II JIP
- Sour Water Phase I JIP
- Sour Water Phase II JIP
- Sour Water Phase III JIP
- Sulfuric Acid Alkylation JIP

O&G Production Joint Industry Programs

- 13Cr MSS JIP
- CO₂/H₂S Corrosivity JIP – Carbon Steel
- Sulfide Stress Cracking (SSC) JIP – CRAs
- Titanium Alloy JIP

+30MUSD DATA DEVELOPED DURING JIP PROGRAM
### Sponsors for selected JIPs

#### CDU Overhead JIP Phase 1
- Crude Corrosivity JIP Phase 1&2
  - Corrosion in OVHD system
  - Nap acids and HT sulfidation
  - (2011-now)
  - (2006 – now/ongoing Phase 2)

<table>
<thead>
<tr>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevron Energy Technology Co.</td>
</tr>
<tr>
<td>BP</td>
</tr>
<tr>
<td>FHR</td>
</tr>
<tr>
<td>ECOPETROL</td>
</tr>
<tr>
<td>MARATHON OIL</td>
</tr>
<tr>
<td>REPSOL</td>
</tr>
<tr>
<td>Petrobras</td>
</tr>
<tr>
<td>Reliance</td>
</tr>
<tr>
<td>SK Innovation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker Petrolite (1)</td>
</tr>
<tr>
<td>BP (1&amp;2)</td>
</tr>
<tr>
<td>Chevron (1&amp;2)</td>
</tr>
<tr>
<td>ExxonMobil (1)</td>
</tr>
<tr>
<td>Flint Hills Resources (1&amp;2)</td>
</tr>
<tr>
<td>Idemitsu (1)</td>
</tr>
<tr>
<td>IOCL (1&amp;2)</td>
</tr>
<tr>
<td>Lyondell (1)</td>
</tr>
<tr>
<td>Marathon (1&amp;2)</td>
</tr>
<tr>
<td>Nalco (1)</td>
</tr>
<tr>
<td>Petrobras (1&amp;2)</td>
</tr>
<tr>
<td>Petronas (1)</td>
</tr>
<tr>
<td>Reliance (1&amp;2)</td>
</tr>
<tr>
<td>REPSOL (2)</td>
</tr>
<tr>
<td>Shell / SGS (1&amp;2)</td>
</tr>
<tr>
<td>StatoilHydro (1)</td>
</tr>
<tr>
<td>Syncrude (1)</td>
</tr>
<tr>
<td>TOTAL (2)</td>
</tr>
<tr>
<td>UOP (1)</td>
</tr>
</tbody>
</table>

#### Rich & Lean Amine JIP
- Corrosion in Amine Unit
- (2003-2011)

<table>
<thead>
<tr>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG – International (L1, R1&amp;2)</td>
</tr>
<tr>
<td>BP (R1&amp;2)</td>
</tr>
<tr>
<td>ExxonMobil Research and Engineering (L1, R1&amp;2)</td>
</tr>
<tr>
<td>Flint Hills Resources, LP (L1, R1&amp;2)</td>
</tr>
<tr>
<td>Fluor, Inc. (L1, R1&amp;2)</td>
</tr>
<tr>
<td>Idemitsu Kosan Co., Ltd. (L1, R2)</td>
</tr>
<tr>
<td>Marathon Petroleum Co. (L1, R2)</td>
</tr>
<tr>
<td>Chevron Energy Technology (L1, R1)</td>
</tr>
<tr>
<td>GASCO (L1)</td>
</tr>
<tr>
<td>Syncrude Canada Ltd (L1, R1)</td>
</tr>
<tr>
<td>ConocoPhillips, Inc (R1)</td>
</tr>
<tr>
<td>Huntsman Chemicals (R1)</td>
</tr>
<tr>
<td>Petrobras (R1)</td>
</tr>
<tr>
<td>Saudi Aramco (R1)</td>
</tr>
<tr>
<td>Shell Global Solutions (US) Inc. (R1)</td>
</tr>
</tbody>
</table>

Honeywell Proprietary - © 2017 by Honeywell International Inc. All rights reserved.
Predict Amine RT – display example

- **Real Time Corrosion Assessment** in key areas:
  - Reboiler loop
  - Hot Lean Amine
  - Stripper OVHD

- Number of additional locations where corrosion may be an issue

- Immediate corrosion picture on whole Amine Stripper Loop
# Predict Amine RT (real time) – KPI example

<table>
<thead>
<tr>
<th>KPI</th>
<th>30 Days (Corrosion Rate, mmyp)</th>
<th>Acq. Limit (mmyp)</th>
<th>Inst. CR (mmyp)</th>
<th>30 Days Avg. CR (mmyp)</th>
<th>Corrosion Sensor Reading (mmyp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet Air Cooler (Com. Header )</td>
<td>0.25</td>
<td>0.05</td>
<td>0.06</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Inlet Amine Stripper HS</td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td><strong>Inlet Stripper Rec. Elbow</strong></td>
<td>0.25</td>
<td><strong>0.36</strong></td>
<td>0.32</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Out Amine Stripper (Overhead )</td>
<td>0.25</td>
<td>0.07</td>
<td>0.06</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Outlet Air Cooler (CH)</td>
<td>0.25</td>
<td>0.21</td>
<td>0.20</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Outlet Reboiler - Elbow</td>
<td>0.25</td>
<td>0.03</td>
<td>0.06</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Outlet Reboiler - VS</td>
<td>0.25</td>
<td>0.03</td>
<td>0.06</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Outlet of Air Cooler VS</td>
<td>0.25</td>
<td>0.20</td>
<td>0.19</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Reducer Section</td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Rich-Lean Exch. Inlet</td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Rich-Lean Exch. Out. Elbow</td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Rich-Lean Exch. Out. VS</td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>
Predict-RT Amine Unit: Modeling Points (real case study)