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

• **Global Business Leader**
  *Corrosion Asset Integrity Solutions*
  *Honeywell International – USA*

• **Program Leader** – Joint Industry Projects related to refinery / oil & gas applications

• **Solution Architect** - Predict® and Predict-RT applications for refinery corrosion management

• **Author** - 100+ papers / book chapters related to corrosion, metallurgy, modeling and predictive data analytics

• **Board Member** – AFPM (American Fuel and Petrochemical Manufacturers)

• **Chairman** – STG62 (NACE committee on Corrosion Monitoring)

25+ years industry experience developing corrosion prediction and asset integrity management solutions
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
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

Like Driving with only a Rearview Mirror
Real-Time Corrosion Prediction & Management

| **A real-time software sensor** | - Track damage and enforce appropriate limits  
- **Identify** critical areas as operating conditions change  
- **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
Predict-RT: Solution in a Nut-Shell

Honeywell customers have a need to improve safety and reliability of processes *(Big Data to parse)*

- Corrosion Center of Excellence (CoE) creates *accurate laboratory simulations* to generate relevant, focused data
- CoE experts analyze data to provide ways to *correlate critical process parameters*
- Modeling team builds prediction models encapsulating *domain intelligence and data analytics*
- Models work with DCS/Historian to *automate safety and asset reliability/integrity*
Current Situation…….

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

- **Operate Plant**
- **Online Corrosion Rate Prediction**
- **Present Corrosion Rate to Operators via Control System**
- **Real-time Corrosion Rate**
Making Corrosion Relevant to Operations

Operate Plant

Present Corrosion Rate to Operators via Control System

Online Corrosion Rate Prediction

Real-time Corrosion Rate

Optimize operating variables to minimize Corrosion rates

Correlate Corrosion Rates to process variables
Making Corrosion Actionable by Operations

Operate Plant

Generate Alarms & Alerts

Present Corrosion Rate to Operators via Control System

Rate OK?

Online Corrosion Rate Prediction

Real-time Corrosion Rate

Optimize operating variables to minimize Corrosion rates

Correlate Corrosion Rates to process variables

Present Corrosion Rate to Operators via Control System

Generate Alarms & Alerts

Rate OK?
Real-Time Prediction Solutions

Corrosion is now “visible” to everyone and “actionable” by operations / management
…Through an On-line, Integrated Solution

<table>
<thead>
<tr>
<th>Accurate Prediction Models</th>
<th>Real-Time Corrosion Prediction</th>
<th>Process Data</th>
</tr>
</thead>
</table>
| • 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-Oil | • 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 available in plant historian via DCS  
  • Operating parameters  
  • Design Variables  
  • Material of Construction  
  • Service Life  
  • Laboratory Data (LIMS)  

**2017 Hydrocarbon Processing Innovation Award Winner**
Making the complex and invisible.....

1 – Sulfidation; 2 – Wet H2S Damage (Blistering/HIC/SOHIC/SSC; 3 – Creep / Stress Rupture; 5 – Polythionic Acid Corrosion; 6 – Naphthenic Acid Corrosion; 8 – Ammonium Chloride Corrosion; 9 – HCl Corrosion; 11 – Oxidation; 18 – Caustic Cracking; 20 – Erosion/Erosion Corrosion; 23 – Cl SCC; 30 – Short term Overheating / Stress Rupture; 33 – 885F Embrittlement; Dissimilar Metal Weld Cracking; 42 – CO2 Corrosion; 44 – Fuel Ash Corrosion; 48 – Ammonia Stress Corrosion Cracking; 52 – Liquid Metal Embrittlement; 66 – Organic Acid Corrosion
**Simple, Visible, Relevant**

**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 (mmpy)</th>
<th>Corrosion Rate (10) (mmpy)</th>
<th>Corrosion Rate (70) (mmpy)</th>
<th>Corrosion Rate (300) (mmpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>03CDUC02</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>03CDUAC04</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>
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<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>
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<tr>
<td>03CDUAC01</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>
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<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>
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<td>0.4186</td>
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<td>ATM Column Lights</td>
<td>3.8470</td>
<td>01-01-2020</td>
<td>1.3799</td>
<td>0.1721</td>
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<td>0.1619</td>
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<tr>
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<td>ATM Crude Furnace Outlet</td>
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<td>01-01-2020</td>
<td>1.3726</td>
<td>1.2144</td>
<td>1.1327</td>
<td>1.2239</td>
</tr>
<tr>
<td>03CDUAC03</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>
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<tr>
<td>03CDUAC02</td>
<td>VAC Column MVGO</td>
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<td>01-01-2020</td>
<td>1.3775</td>
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<td>03CDUATM04</td>
<td>ATM Column AGO</td>
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<td>0.6122</td>
<td>0.6193</td>
</tr>
</tbody>
</table>

*PREDICT-RT IS PATENT PENDING REAL TIME DATA MANAGEMENT TECHNOLOGY*
### Predict-RT: Real-Time Corrosion Prediction & Management

<table>
<thead>
<tr>
<th>Anticipate</th>
<th>Understand</th>
<th>Manage</th>
<th>Deliver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predict corrosion damage and avoid unplanned shut downs</td>
<td>Correlate process changes to potential corrosion consequences</td>
<td>Flexible operations means improved reliability without a corresponding increase in costs</td>
<td>Enhanced throughput and increased profits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scalability</th>
<th>Real-Time</th>
<th>Improved Margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor and expand corrosion visibility as needed</td>
<td>Visibility into your asset integrity program for better management of risk and inspection</td>
<td>Optimize feedstock selection and processing opportunity crudes for superior ROI</td>
</tr>
</tbody>
</table>

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

Preventing Corrosion Is Knowing When and Where It Occurs
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>• Four (4) additional DCO cargos/yr. processed safely</td>
</tr>
<tr>
<td>• $3/bbl incentive to the next heavy barrel alternative</td>
<td>• <strong>Annual saving of $7,200,000</strong></td>
</tr>
<tr>
<td>• Shipment incentive of $1,800,000/cargo</td>
<td>• Payout in less than 1 QTR</td>
</tr>
<tr>
<td></td>
<td>• Plans for solution rollout to additional refineries (900,000 bpd network capacity)</td>
</tr>
</tbody>
</table>

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

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

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

Predict corrosion suite enables accurate corrosion prediction and material selection for improved decision making.
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.
Predict-RT translates to extended asset life and better manage your asset integrity and corrosion costs.
**Smart Operations and Predict®-RT**

**Work Process Transformation**
Leveraging Operational Best Practices (API 584) and Domain Expertise (JIP Models) to transform work processes to maximize benefits from predictive data analytics and intelligence.

**Connecting the Enterprise to drive Smart Decisions**

**Enabling Enterprise Optimization through Connected Integration**

- Enterprise Decision Support System
- Evaluate Opportunities
- Prioritize / Execute
- Operating Assets
- Data Integration
- Predictive Analytics
- Reporting / Dashboards
- Process Data > Corrosion Knowledge > Intelligent Action
- Closing the Loop to Drive Efficiency, Safety, Reliability and Agility
Predictive Multi-Parametric Analyses means Dynamic IOWs

<table>
<thead>
<tr>
<th>Sour Water Flow Rate (gpm)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>15</td>
</tr>
<tr>
<td>Maximum</td>
<td>45</td>
</tr>
<tr>
<td>Operating Point</td>
<td>30</td>
</tr>
<tr>
<td>IOW Low</td>
<td>15</td>
</tr>
<tr>
<td>IOW High</td>
<td>32</td>
</tr>
</tbody>
</table>

Max allowable CR = 8mpy

Multi-parametric analysis includes:
- Temperature
- NH$_4$HS conc.
- H$_2$S, NH$_3$ conc.
- Vapour flow rate
- Liquid HC flow rate
- Total pressure

Max allowable CR = 8mpy

SW flow rate, gpm
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
- Prediction of current state of equipment
- Deviation Management and Reporting

Safety  Predictive Maintenance  Reliability  Profitability
Conclusions / Path Forward

- Real Time Corrosion Management is a complex task
  - Stop by Demo room for a Predict-RT functional demonstration
- 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
<table>
<thead>
<tr>
<th>KPI</th>
<th>30 Days(Corrosion Rate, m.mpy)</th>
<th>Accp. Limit(m.mpy)</th>
<th>Inst. CR(m.mpy)</th>
<th>30 Days Avg. CR(m.mpy)</th>
<th>Corrosion Sensor Reading(m.mpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FV077 Valve Down Elbow</td>
<td></td>
<td>0.25</td>
<td>0.38</td>
<td>0.38</td>
<td>0.28</td>
</tr>
<tr>
<td>FV086A Valve Down Elbow</td>
<td></td>
<td>0.25</td>
<td>0.41</td>
<td>0.40</td>
<td>NA</td>
</tr>
<tr>
<td>HVGO pumps (P20A/B) - HVGO...</td>
<td></td>
<td>0.25</td>
<td>0.38</td>
<td>0.38</td>
<td>NA</td>
</tr>
<tr>
<td>HVGO pumps (P20A/B) HVGO...</td>
<td></td>
<td>0.25</td>
<td>0.38</td>
<td>0.37</td>
<td>NA</td>
</tr>
<tr>
<td>HVGO pumps (P20A/B) to HV...</td>
<td></td>
<td>0.25</td>
<td>0.36</td>
<td>0.36</td>
<td>NA</td>
</tr>
<tr>
<td>HVGO pumps (P20A/B) to fl...</td>
<td></td>
<td>0.25</td>
<td>0.40</td>
<td>0.40</td>
<td>NA</td>
</tr>
<tr>
<td>Inlet of HVGO pump (P20A)...</td>
<td></td>
<td>0.25</td>
<td>0.43</td>
<td>0.43</td>
<td>NA</td>
</tr>
<tr>
<td>Old PV610 Loop Elbow u/p</td>
<td></td>
<td>0.25</td>
<td>0.38</td>
<td>0.38</td>
<td>NA</td>
</tr>
<tr>
<td>Outlet of HVGO pumps (P20...</td>
<td></td>
<td>0.25</td>
<td>0.39</td>
<td>0.39</td>
<td>NA</td>
</tr>
<tr>
<td>P20A Suction piping</td>
<td></td>
<td>0.25</td>
<td>0.36</td>
<td>0.36</td>
<td>NA</td>
</tr>
<tr>
<td>VC (C16) to HVGO pumps (P...</td>
<td></td>
<td>0.25</td>
<td>0.36</td>
<td>0.36</td>
<td>NA</td>
</tr>
<tr>
<td>VC (C16) to HVGO pumps (P...</td>
<td></td>
<td>0.25</td>
<td>0.36</td>
<td>0.36</td>
<td>NA</td>
</tr>
</tbody>
</table>
• RT corrosion rates in line with measured rate

• Ability to see remaining thickness and cumulative metal loss
# Real-Time Data on Dashboard

**KPI**

<table>
<thead>
<tr>
<th>KPI</th>
<th>30 Days (Corrosion Rate, mmpy)</th>
<th>Accp. Limit (mmpy)</th>
<th>Init. CR (mmpy)</th>
<th>30 Days Avg. CR (mmpy)</th>
<th>Corrosion Sensor Reading (mmpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet Air Cooler (Com. Header...)</td>
<td><img src="image1.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.05</td>
<td>0.06</td>
<td>NA</td>
</tr>
<tr>
<td>Inlet Amine Stripper HS</td>
<td><img src="image2.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Inlet Stripper Rec. Elbow</strong></td>
<td><img src="image3.png" alt="Graph" /></td>
<td>0.25</td>
<td><strong>0.36</strong></td>
<td>0.32</td>
<td>NA</td>
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<tr>
<td>Outlet Amine Stripr(Overhead...)</td>
<td><img src="image4.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.07</td>
<td>0.06</td>
<td>NA</td>
</tr>
<tr>
<td>Outlet Air Cooler (CH)</td>
<td><img src="image5.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.21</td>
<td>0.20</td>
<td>NA</td>
</tr>
<tr>
<td>Outlet Reboiler - Elbow</td>
<td><img src="image6.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.03</td>
<td>0.06</td>
<td>NA</td>
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<tr>
<td>Outlet Reboiler - VS</td>
<td><img src="image7.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.03</td>
<td>0.06</td>
<td>NA</td>
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<tr>
<td>Outlet of Air Cooler VS</td>
<td><img src="image8.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.20</td>
<td>0.19</td>
<td>NA</td>
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<tr>
<td>Reducer Section</td>
<td><img src="image9.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
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<tr>
<td>Rich-Lean Exch. Inlet</td>
<td><img src="image10.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
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<td>Rich-Lean Exch. Out. Elbo...</td>
<td><img src="image11.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
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<tr>
<td>Rich-Lean Exch. Out. VS</td>
<td><img src="image12.png" alt="Graph" /></td>
<td>0.25</td>
<td>0.03</td>
<td>0.03</td>
<td>NA</td>
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