RISK BASED INSPECTION (RBI) IMPLEMENTATION EXPERIENCE AT STEEL INDUSTRY – STEP TOWARD RELIABILITY EXCELLENCE

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AUTHOR BIOGRAPHY

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Bachelor Degree in Applied Mechanical Engineering (2\textsuperscript{nd} Honor Grade)
KFUPM, January 2005

- Certified Reliability Leader (CRL)

Total of 10 years working experience in Saudi Iron and Steel Company (HADEED-SABIC)

Previous Position Held
- Engineer, Reliability (2005-2007)
- Engineer, Inspection (2007-2008)
- Team Leader, Inspection (2009-2011)

Senior Manager, Maintenance (March, 2015- till Now)
AGENDA

- Introduction
- Change Management
- Equipment Covered.
- RBI
- RBI Benefits
- Success Cases
RBI is very useful method for developing the strategies comparing to the conventional method (Time based) where it help in focusing the inspection resources. As well as the developing reliability driven strategies.

It is commonly used methodology in chemical plants and refineries and it prove its benefits, but it may need to be explore more in other manufacturing facility such as steel plant.

Next slides will go through RBI implementation experience at our steel plant (HADEED SABIC) and the gained benefits.
RBI (RISK BASED INSPECTION)

RBI is a systematic approach used to develop inspection strategies for the fixed assets based on their risk ranking.

**RISK = Probability of failure × Consequence of failure**

Focused on loss of containment due to material degradation.
RBI (RISK BASED INSPECTION)

RBI Reference Materials and Standards.

**API 580** – Outlines the Essential Elements of an RBI Program.

**API 581** - API Methodology that can be used to meet the Requirements of API 580.
RBI (RISK BASED INSPECTION)

Industrial Applications of RBI

- Refining and Petrochemicals
- Offshore platforms and pipelines
- Pulp and paper
- Cement & Metal
- Nuclear power
CHANGE MANAGEMENT

BEFORE RBI IN HADEED

All Fixed Equipment Inspections were carried out during turnaround mainly externally and thickness gauging. The scope of the work and coverage is generally based on inspector experience and judgment.

AFTER RBI IN HADEED

Fixed Equipment Inspections are scheduled based on their risk ranking (Consequence of failure and Likelihood of failure)
EQUIPMENT COVERED

1. Fired Equipment (Boilers Furnace, Reformers..etc)- Remain TB-SHE Critical.

2. Heat Exchangers.(Shell & Tubes, Cooler…etc)

3. Vessels (Columns, Rectors, Drums,…etc)

4. Tanks ( Dome Roof, General, …etc)

5. Piping (Utilities , Process..etc)
RBI AT SABIC; THE CHRONOLOGY

- **Initiate STRP4 project** (2007)
- **Reliability awareness sessions and RBI Methodology facilitation workshops started** (2008 - 2009)
- **Monitor RBI implementation** (2010)
- **100% completion of RBI analysis for equipment. Pipe circuit analysis is ongoing, to be completed in 1st quarter 2015.** (2012 - 2015)

**Evergreen Process**

As equipment condition changes and new history is obtained, RBI Assessment is re-evaluated and Inspection Plan is updated.

**It’s a continuous process of monitoring affiliates’ performance, quality check of RBI studies, and sharing best practices among affiliates.**
INTEGRATED & EVERGREEN WORKFLOW

Strategies Development

**Equipment (Asset) Coding**

- RBI Analysis
- Inspection Strategies

Recommendations & Strategy Re-Evaluations

- RCA
- Reliability Analysis
- Trending
- Condition Assessment

Evaluate

Execution

- Process Excursion Data (Process Historian)
- Inspection Event Data
- Maintenance Event Data (SAP)

Measure Strategy Effectiveness

KPI/Reevaluation Criteria
RBI BENEFITS

1. Failure early deduction (Reliability Driven Strategies)
2. Improving Assets Reliability thereby overall risk reduction
3. Manpower Focus and Resources Optimization
### SUCCESS CASES EXAMPLES

<table>
<thead>
<tr>
<th>Plant</th>
<th>Equipment</th>
<th>Problem</th>
<th>Recommendation</th>
<th>Status/ link</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR MODULE E</td>
<td>FLARE KNOCK OUT DRUM</td>
<td>About 2 mm pitting due to coating damage and scale formation at bottom dish area</td>
<td>To sand blast and recoat the internal surface of the vessel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All values are within acceptable limits after corrective action. Potential breakdown avoided.</td>
<td><img src="#" alt="LINK CASE STUDY 1" /></td>
</tr>
<tr>
<td>CMC - PPL</td>
<td>CONDENSATE TANK</td>
<td>Chloride stress corrosion cracking of (MOC: Stainless Steel 304) Condensate Tank was observed on the dish head.</td>
<td>Temporary repair was made by inserting a new plate on the damaged location, Permanent repair shall be made by changing the equipment with appropriate material and design.</td>
<td>All values are within acceptable limits after corrective action. Potential breakdown avoided. <img src="#" alt="LINK CASE STUDY 2" /></td>
</tr>
<tr>
<td>UTILITY (LP-I)</td>
<td>S &amp; B MULTI MEDIA FILTER NO.3</td>
<td>Internal pitting’s ≤ 6 mm were observed throughout the internal shell, dishes and internal piping, man hole, supports and Perforated plate of the filter. Through hole and erosion/corrosion was observed on the internal inlet pipe and supports</td>
<td>To rebuild the pitting’s and to recoat the internal surface with appropriate coating materials.</td>
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<td>DR MODULE C</td>
<td>REFORMER GAS COOLER</td>
<td>Coating damages for the shell, external surface of gas inlet and the inlet water spray nozzle was observed. The support for the grating was found cracked and fully detached from the shell.</td>
<td>To replace the corroded &amp; detached support for the grating. All Welding activities shall be carried out as per approved procedures and Standards. To sand blast and to recoat the shell as per the manufacture recommended coating in order to avoid further degradation.</td>
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<tr>
<td>SN.</td>
<td>Equipment Tag</td>
<td>Category</td>
<td>Class</td>
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<tr>
<td>01</td>
<td>TK 101</td>
<td>Tank</td>
<td>Dome Roof</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>V 502</td>
<td>Pressure Vessel</td>
<td>Drum</td>
<td></td>
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<tr>
<td>03</td>
<td>C 2012</td>
<td>Pressure Vessel</td>
<td>Cloume</td>
<td></td>
</tr>
</tbody>
</table>
RBI

Risk Ranking

**Risk** = **POF** x **COF**

**POF** = Probability of Failure
**COF** = Consequence of Failure

**COF** (Safety, Environment, Economic, Toxics…etc.)
**POF** (Degradation Mechanism Evaluation (Cracking, thinning, localized corrosion…etc))
INSPECTION STRATEGIES

**Specific, Risk, Failure Driven** Strategies (Scope, Frequency, Techniques).

Example:

80 % Thickness Gauging of the established TML for the shell every 4 Year.

60 Insulation Removal followed by through Visual Inspection, then Thickness gauging on the suspected areas every 10 Year.
INSPECTION EVENT DATA

Quality and clear recording for all the inspections, report should contain information such as.

1. Date of inspection
2. Equipment tag #
3. Instruments used with their serial number (ensure calibrated)
4. Name of inspector and approval SV
5. Finding and type of degradation mechanism observed (if any) with possible causes.
6. Type of finding (observation, small degradation, potential failure.. etc)
7. Recommendations with proper tracking
FAILRE EARLY DEDUCTION

Doing efficient inspection that resulted on failure mitigation

As the inspection strategies were generated based on detail analysis considering all the expected potential corrosion, Theses strategies helps to discover the following:

<table>
<thead>
<tr>
<th>Abnormalities Category</th>
<th>Total No. Discovered during inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion Degradation</td>
<td>516</td>
</tr>
<tr>
<td>Corrosion Potential Failure</td>
<td>97</td>
</tr>
</tbody>
</table>

**Corrosion Degradation:** Means some corrosion like thinning, erosion, bulging CUI.. etc started but still within acceptable limit as per codes but it could deteriorated further if not repaired (Failure early Predication).

**Corrosion Potential Failure:** Mean Corrosion exceed that acceptable limit and could lead to failure at any time.
A Reliability Growth Analysis is used to track changes in Mean Time Between Failure (MTBF) over a specified period of time to determine strategies or repairs necessary to increase the reliability of a product (i.e. element, system, or subsystem).

**Segment No. 1: Pre RBI**
- Period 2007 to 2011
- MTBF is decreasing (644.06 Days)
- Failure-based strategy
- Some of RBI equipment were not covered in the Inspection program
- No. of Failures: 9

**Segment No. 2: Post RBI**
- Period 2012 to 2014 (Nov.)
- MTBF is increasing (7,323.71 Days)
  - RBI task implementation started
  - All RBI equipment are under Inspection program
- No. of Failures: 4
GROWTH ANALYSIS OF RBI EQUIPMENT IN HADEED (EXTRAPOLATED)
BENEFIT USING EXTRAPOLATION

Observation: After RBI Implementation an estimated **298 failures** are expected to be prevented.
PRE & POST RBI TASK DISTRIBUTIONS (%) - HADEED

Pre-RBI

- LOW
  - 0-5: 667
  - 11-15: 0
  - 16-20: 0
  - 6-10: 0

- MEDIUM
  - 0-5: 708
  - 11-15: 0
  - 16-20: 0
  - 6-10: 0

- MEDIUM HIGH
  - 0-5: 690
  - 11-15: 0
  - 16-20: 0
  - 6-10: 0

- HIGH
  - 0-5: 296
  - 11-15: 0
  - 16-20: 0
  - 6-10: 0

Post-RBI

- LOW
  - 0-5: 467
  - 11-15: 22
  - 16-20: 22
  - 6-10: 83

- MEDIUM
  - 0-5: 431
  - 11-15: 260
  - 16-20: 13
  - 6-10: 4

- MEDIUM HIGH
  - 0-5: 658
  - 11-15: 26
  - 16-20: 0
  - 6-10: 0

- HIGH
  - 0-5: 287
  - 11-15: 9
  - 16-20: 0
  - 6-10: 0

**Remarks:**
- Focus was not guided.
- Inspection strategy not as per the standard
- Better focus
- Inspection strategy get improved.
- PM optimization
INSPECTION INTERVAL CHANGE AFTER RBI - HADEED

<table>
<thead>
<tr>
<th>Component</th>
<th>Avg. Interval (Pre RBI)</th>
<th>Avg. Interval (Post RBI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Exchanger</td>
<td>2</td>
<td>8.6</td>
</tr>
<tr>
<td>Pipeline</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Pressure Vessel</td>
<td>2.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Tanks</td>
<td>5</td>
<td>6.47</td>
</tr>
</tbody>
</table>
CASE STUDY 1: DR MODULE E FLARE KNOCK OUT DRUM

Observations: About 2 mm pitting due to coating damage and scale formation at bottom dish area.

Recommendation: To sand blast and recoat the internal surface of the vessel

Feedback Results: All values are within acceptable limits after corrective action.

Breakdown avoided and thereby Potential business impact of 6.94 MSAR savings
CASE STUDY 2: CMC- PPL CONDENSATE TANK

Observations: Chloride stress corrosion cracking of (MOC: - Stainless Steel 304) Condensate Tank was observed on the dish head.

Recommendation: Temporary repair was made by inserting a new plate on the damaged location, Permanent repair shall be made by changing the equipment with appropriate material and design.

Feedback Results: All values are within acceptable limits after corrective action.
CASE STUDY 3: UTILITY - S & B MULTI MEDIA FILTER NO. 3

Observations: Internal pitting’s ≤ 6 mm were observed throughout the internal shell, dishes and internal piping, man hole, supports and Perforated plate of the filter. Through hole and erosion /corrosion was observed on the internal inlet pipe and supports

Recommendation: To rebuild the pitting’s and to recoat the internal surface with appropriate coating materials.
CASE STUDY 4: DRC - REFORMER GAS COOLER

Observations: Coating damages for the shell, external surface of gas inlet and the inlet water spray nozzle was observed. The support for the grating was found cracked and fully detached from the shell.

Recommendation: To replace the corroded & detached support for the grating. All Welding activities shall be carried out as per approved procedures and Standards. To sand blast and to recoat the shell as per the manufacture recommended coating inorder to avoid further degradation.
THANK YOU