RISK ASSESSMENT AND RISK-BASED INSPECTION FOR PETROCHEMICAL UNIT: A PRACTICAL APPLICATION

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Contents

- Introduction
- What is RBI (Risk-Based Inspection)?
- Development of KGS-RBI™ program for petrochemical plant
- Application of KGS-RBI™ program on the NCC System in Petrochemical Plant
- Results and Discussion
- Conclusion
Introduction (1)

- Many refinery and petrochemical plants are being operated in Korea.
- Due to improvements of industrial technologies, the relevant equipment are getting complex to allow operation in higher temperature and pressure conditions.
- Thus continuous operation while sustaining their integrity through good maintenance practices becomes an important issue.

The examples of petrochemical facilities

The number of petrochemical plants in Korea
The possibilities of accidents owing to aging equipment have increased in refinery and petrochemical industries.

Unanticipated accidents may cause significant social and economic losses.

To reduce the possibility of such incidents, maintenance activities such as inspection, repair or replacement of aging equipment has to be carried out.

Thus, a risk-based inspection (RBI) methodology for refinery and petrochemical plants should be established.

The cause classification of major industrial accidents:
## Equipment Failure Category in Hydrocarbon-Chemical Industry

- **Piping systems**
- **Tanks**
- **Reactors**
- **Drums**
- **Pumps/Comp.**
- **H/E**
- **Towers**
- **Heaters/Boilers**
- **Others/Unknown**

![Bar Chart]

Over 80% of the Equipment - Caused by the Failure to Pressurized equipment


### Introduction (3)
• RBI is a method for using risk as a basis to prioritize and manage the efforts of an inspection activity.
  - Risk = LOF (likelihood of failure) × COF (consequence of failure)

• An effective risk based inspection activity results in reduced risk level for a given inspection level.
• In an operating plant, a relatively large percentage of the risk is usually associated with a small percentage of equipment.
• A RBI methodology permits the shift of inspection and maintenance resources to provide a higher level of coverage on the high risk items and an appropriate effort on lower risk equipment.

• For example, API 581 guideline
  - Level 1 (Qualitative RBI)
  - Level 2 (Semi-quantitative RBI)
  - Level 3 (Quantitative RBI)
Risk Evaluation Process based on API 581

Qualitative RBI

- Plant database
- Likelihood category
- Damage consequence category
- Health consequence category
- Choose the highest from two consequence categories
- Qualitative RBI
- Risk matrix

Semi-quantitative and Quantitative RBI processes

- Start
- Plant database
- Select a set of hole size
- Estimate likelihood of leak
- Estimate consequence
- Semi-quantitative RBI or Quantitative RBI
- Risk = LOF × COF
- Semi-quantitative RBI
- Convert to a risk matrix using likelihood category and consequence category
- Quantitative RBI
- Suggest each equipment risks after sum of all scenarios
• The 3-tier structure of proposed RBI program

- Presentation Layer
  - Visual Basic

- Application Layer
  - Window Environment
  - Visual C++, Visual Basic

- Database Layer
  - Microsoft Access 2000
List of input data for using the KGS-RBI™

- **Equipment Data**
  - Length (mm)
  - Diameter (mm)
  - Thickness (mm)
  - Operating Pressure (kg/cm²)
  - Operating Temp (C.)
  - Design Pressure (kg/cm²)
  - Design Temp (C)
  - Insulation (Y/N)
  - Lining Type
  - PWHT (Y/N)

- **Equipment Information**
  - P&ID No.
  - PFD No.
  - Stream No.
  - Inventory Group Name
  - Material
  - Service Start Date
  - Design Life (yr)

- **Likelihood Data**
  - No. of Valves
  - No. of Branches
  - No. of Injection Points
  - No. of Connections
  - No. of Nozzles
  - Construction Code
  - Vibration Monitoring
  - Planned Shutdown
  - Unplanned Shutdown
  - Stability Ranking
  - RV Maintenance
  - Fouling Tendency
  - Corrosive Service (Y/N)
  - Very Clean Service (Y/N)

- **Consequence Data**
  - Rep. Material
  - Initial fluid state
  - Toxic Material
  - Toxic Percent
  - Detection Rating
  - Isolation Rating
  - Mitigation Systems
  - Liquid Percent
  - Gas Density (kg/m³)
  - Inventory Input Type
  - Inventory (User input)

- **Financial Data**
  - Include Environmental Cleanup cost
  - % Released from Diked area
  - Release Type
  - Type of Foundation
  - Method of Detection
  - Detection Times

Input Data (Excel File)
Material management program
• Qualitative RBI module
Development of RBI program (6)

- Semi-Quantitative RBI module
Development of RBI program (7)

- Quantitative RBI module
To verify the applicability of the proposed RBI program, the proposed RBI program apply to Naphtha Cracking Center.

The NCC system in this study has been operated for 14 years since it started to produce in 1992.

The NCC process can largely be divided into four phases:

- In the NCC plant to construct RBI, assessment was made on 742 fixed equipments and 1,258 piping systems except utility unit.
Result of RBI for NCC plant (1)

- RISK Distribution of NCC Plant

NCC Plant Risk Distribution

- High 15%
- Medium 39%
- Medium 30%
- Low 16%

Likelihood of Failure

<table>
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<th>Consequence of Failure</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tr>
<td>B</td>
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<tr>
<td>C</td>
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</table>
• RISK Distribution for processes

A-(Cracking Heater) Process

- Medium: 36%
  - High: 3%
  - Low: 22%

B-(Quenching) Process

- Medium: 19%
  - High: 8%
  - Low: 57%

C-(Compressing) Process

- Medium: 54%
  - High: 4%
  - Low: 14%

D-(Distillation) Process

- Medium: 20%
  - High: 26%
  - Low: 5%
Result of RBI for NCC plant (3)

- RISK Distribution of NCC Plant

- **Column**
  - High: 6%
  - Medium: 34%
  - Low: 31%

- **Pipe**
  - High: 20%
  - Medium: 30%
  - Low: 5%

- **Drum**
  - High: 7%
  - Medium: 36%
  - Low: 38%

- **Heat Exchanger**
  - High: 8%
  - Medium: 35%
  - Low: 34%

- **Filter**
  - High: 0%
  - Medium: 23%
  - Low: 75%

- **Tank**
  - High: 0%
  - Medium: 33%
  - Low: 18%
Result of RBI for NCC plant (5)

- Analysis of damage factor for equipments and pipes by high risk
. Result of RBI for NCC plant (4)

- CoF & LoF Results with High Risk
### Result of RBI for NCC plant (5)

- **Inspection interval by Risk**

#### Inspection Interval

<table>
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<th>Inspection Interval (yr)</th>
<th>Total</th>
<th>(%)</th>
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<td>318</td>
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<td><strong>Total</strong></td>
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<td><strong>100.00</strong></td>
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![Bar chart showing inspection intervals]
Conclusion

• Based on risk ranking for the whole NCC plant, High Risk areas which need urgent risk-relieving measures formed about 15 percent, with piping system forming the largest part by equipments.
• Based on risk assessment for each unit process of the NCC plant, piping systems and the heat exchanger in the distillation process operated at low temperature showed remarkable brittle fracture and SCC, requiring special attention for them.
• Among equipments, risk was highest for pipe, followed by heat exchanger, drum, and column; in particular, the heat exchanger showed high risk due to significantly low inspection efficiency and inspection methodology in internal test.
• Based on management systems assessment from interviews with relevant workers, training, emergency response, and incident investigation got generally low scores in operating the NCC plant, which recommends complementary measures in the future.
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