# Application of Risk Based Inspection to heat exchangers of a chemical plant for heavy water production

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## Keywords

Risk Management, Consequences, Likelihood, RBI, FSS

## 1. Introduction

Risk management is one of the main ways to optimize the activities of stakeholder's power equipment, chemical, petrochemical and other industrial equipment and facilities. Implementing an integrated risk management system leads to a better understanding of the risk consequences, an accurate risk classification in a likelihood-consequences matrix type and therefore to increased in-service safety of the equipments.

Risk can be defined as: an event or circumstance in the future that could significantly enhance or impede the ability of an organization to achieve its current or future business objectives. Risks facing organizations can have social, environmental, technological, financial, economical, consequences and can include social and cultural impacts and also may affect his candidacy and the measures of trade. To treat the risk, it must be clearly defined, identified, analyzed and quantified in terms of likelihood and consequences, evaluated according to certain predetermined risk criteria and monitored, once the specific treatment measures have been implementing.

Risk-based inspection and maintenance modern concepts was developed in the U.S. between 1995-2005, the first by API (American Petroleum Institute) in chemistry and petro chemistry, then by EPRI (Electrical Power Research Institute) for nuclear and thermal power plants and than in European Union by RIMAP project [1, 2] for every industry field. Recently, new standard in the field of risk management has been jointly developed by ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission [3, 4].

## 2. Industrial implementation of risk management system

As other types of management systems (project management, human resource management, quality management), risk management system performs managing of activities and processes, ensuring the appropriate risk management by integrating the new concepts on inspection and maintenance of equipment [5-8]: Fitness-For-Service (FFS), Risk Based Inspection (RBI), Reliability Centred Maintenance (RCM), in-service Inspection and monitoring the degradation state / failure of components. The new developments include:

- decision support tools, such as: hazard studies, failure modes and effects analyses and expert systems
- new maintenance techniques, such as condition monitoring
- designing equipment with a much greater emphasis on reliability and maintainability
- a major shift in organizational thinking towards participation, team-working and flexibility.

Implementation of risk management concepts in the industry is a current topic and it being approached by different authors [9-15]. Since most industrial units have already implemented a quality management system that works properly, the aspects regarding risk assessment is missing the link from the management system of industrial partners. Risk assessment is an essential component of risk management for a plant, which supplies a structured process to identify how their goals may be affected. This assessment is used in decisional process on risks treatment. After identifying risks, the management of the plant should ask themselves: "The risk is tolerable or acceptable? Requires a special treatment? "

The assessment procedure evaluates the remaining strength of the equipment in its current condition, which may be degraded from its original conditions. Common degradation mechanisms include corrosion, localized corrosion, pitting and crevice corrosion, hydrogen attack, embrittlement, fatigue, high-temperature creep, and mechanical distortion. Methods for evaluating the strength and remaining service life of equipment containing these types of degradation should be taken into account.

Risk management process must take place within the structured frame in industrial enterprises. Thus constituted body operating under the proper documentation is based on: Quality Risk Management System (RMQS) System Procedure (SP) that provides functionality of the system and Operational Procedure (OP), Work Instruction (WI) and Forms (F) specific activities within the technical units (working group – WG), for each risk type. The implementation of integrated risk management system should take into account various types of risk, such as technological risk, economic risk, the risk of environmental pollution, natural hazards. Risk management process is an integral part of plant management. Risk Management Planning process is done for each type of risk and objectives taken into account, according to the company needs. Context setting is made considering the relevant internal and external parameters for the organization as a whole which may affect the company objectives. Risk assessment is the overall process of risk identification, risk analysis and risk evaluation. Risk assessment is performed using specific tools (expert systems) and appropriate techniques (RBI, FFS, RCM, a.o.), which provides a better understanding of risk, causes, consequences and likelihood of events. Risk treatment involves selection of appropriate option for mitigating measure and their implementation. Monitoring and risk assessment processes is carried out continuously and include all aspects of risk management in order to:

- verify that the risk mitigating measures are effective and efficient;
- provide the additional information in order to improve risk assessment;
- analysis and accumulation of experience from previous events (including avoided);
- detect changes in internal and external context, including changes in the risk criteria that may request a review of priorities for risk treatment;
- identify emerging risks.

The risk assessment process will highlight context and other factors that might be expected to vary over time and which could change or invalidate the risk assessment. These factors should be specifically identified for on-going monitoring and review, so that the risk assessment can be updated when necessary. Also, for proper functioning of the system, communication and consultation with internal and external stakeholders must take place during the risk management process. Risk treatment process runs according to the logic diagram presented in Figure 1.

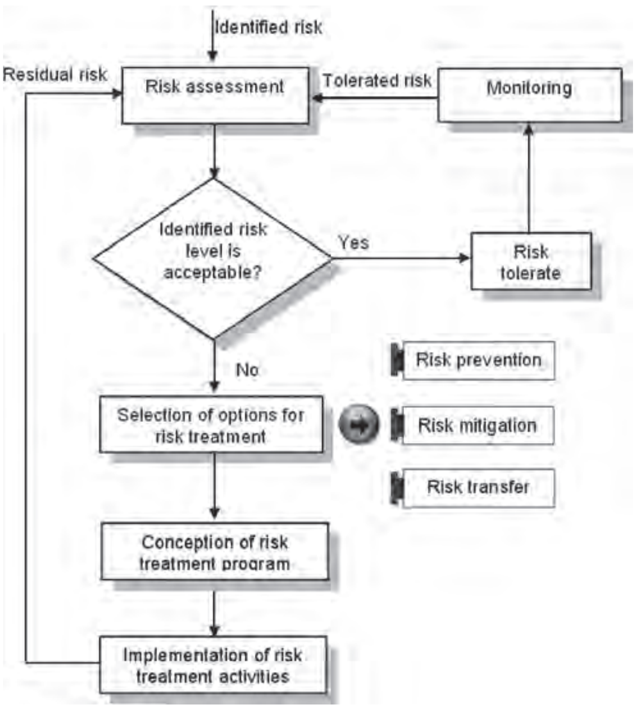


Figure 1. Logic diagram of the risk treatment process.

After identifying a potential risk within the organization, its treatment process takes place in the closed loop cycle, ether on branch of acceptable risk which must be monitored, either on branch of implementation of risk treatment actions, involving prevention, reduction or risk transfer.

The tolerated risk and residual risk resulting from implementation of risk treatment actions have to be reviewed regularly, the whole process of risk management been dynamic. The risk assessment criteria and tolerated risk levels can always be revised as a result of internal decisions or by changes in rules / regulations / standards in the field.

## 3. Case study

The following is an example of technological risk assessment of a chemical plant for heavy water production. Starting from the company target: risk classification of plant components in order to identify and implement a specific treatment for the components found in medium-high and high risk areas, in the frame of risk management process, automatic data analysis was performed for selected plant components, using the expert system ORBIT ONSHORE.

Analyzed isotopic exchange biterma installation belongs of heavy water production facility. In this installation, isotopic exchange occurs between water and hydrogen sulfide ($H_2O$ - $H_2S$). A biterma consists of a cold column and a hot column of isotopic exchange. Process water temperature at the entrance of the cold column is maintained at 30 - 32°C and temperature of the hot column is 125 - 130°C. In order to avoid environmental pollution and to reduce specific consumption of $H_2S$ a stripping column is used for recovery of dissolved H2S in the effluent. Effluent is stripped out at the bottom of stripping column, through heat exchangers shells where its heat flow, cooling is from 217°C to 67°C due to water coming from hot column and enters in the stripper, circulating through the heat exchangers tubes. The paper presents detailed analysis of eight heat exchangers and a release valve belongs of biterma installation for isotopic exchange.

For technological risk assessment all available data for these components were collected and processed by the expert system on the design, manufacture, putting into service, operation and previous inspections.

## 4. Results and discussion

The risk analysis was made on two stages:

– Qualitative risk analysis (screening);

– Quantitative risk analysis (detailed analysis).

In the first stage, screening analysis was performed on 112 components of the plant. The screening results, presents in Figure 2, shows 98 components (approx. 88%) placed in medium - high risk areas. For these components detail analysis are recommended. Of the 98 components 8 heat exchangers and one release valve were selected for detailed risk assessment as these components working with a toxic fluid at high temperatures.

In order to do the detailed analyze, each heat exchanger was divided in its elementary components (shell, tube bundle, movable lid, external lid and chamber) and depending on operating conditions, materials and other specific collected information, for each component of the heat exchangers, the feasible failure mechanisms were established and the likelihood of failure was evaluated.

Figure 3 shows the overall risk analysis results by detailed analysis for all 41 elementary components. The detailed analysis shows 33 components (approx. 80%) were placed in medium risk areas and 8 components (approx. 20%) in low risk zone. Although the overall risk is medium, risk analysis will be detailed based on consequences and likelihood of failure of the plant components (financial loss due to business interruption, population and environmental injure, spoil the company image). The detailed analysis for toxicity consequence (Figure 4) shows 8 components (approx. 20%) were placed in high risk areas, 25 components (60%) in medium - high risk level which all requires special treatment and 8 components (approx. 20 %) in low risk area.

The detailed analysis for fatality consequence (Figure 5) shows 25 components (60%) in medium - high risk level which all requires special treatment and 16 components (approx. 40%) in low risk area.

According to risk criteria all influent risk found by analysis requires specific treatment. In order to treat components placed in high and medium-high risk level, has developed a detailed inspection program and were taken specific measure to risk mitigation by on-line monitoring of critical parameters.

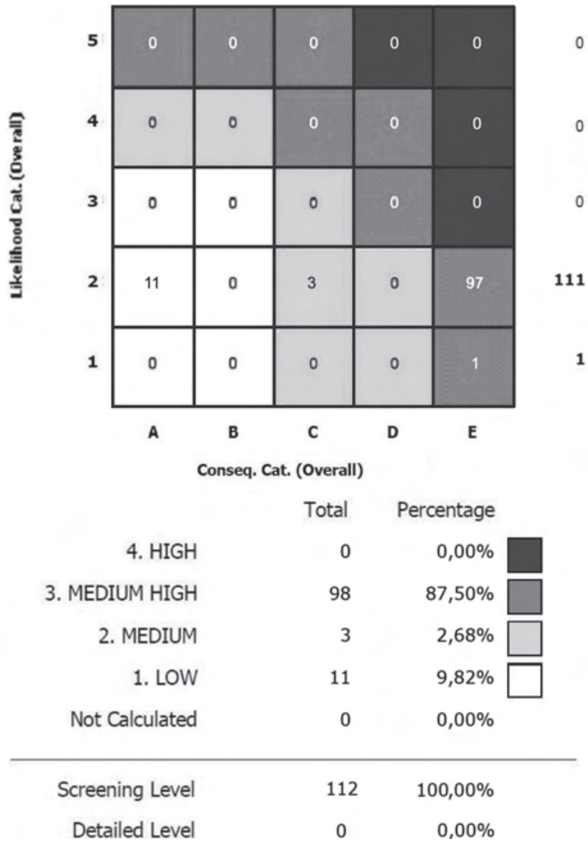


Figure 2. Risk matrix for all analyzed components, (screening, according to API 581).

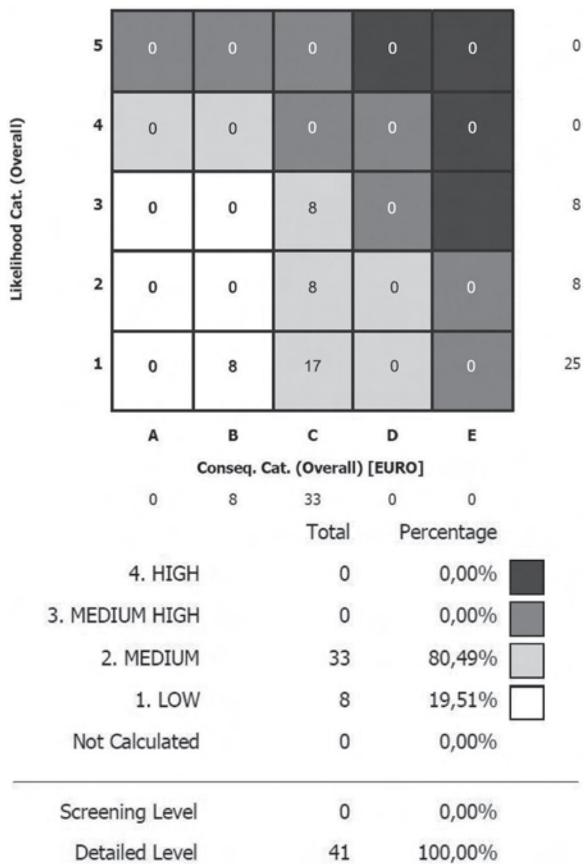


Figure 3. Risk matrix for 41 analyzed components, (detail overall evaluation, according to API 581).

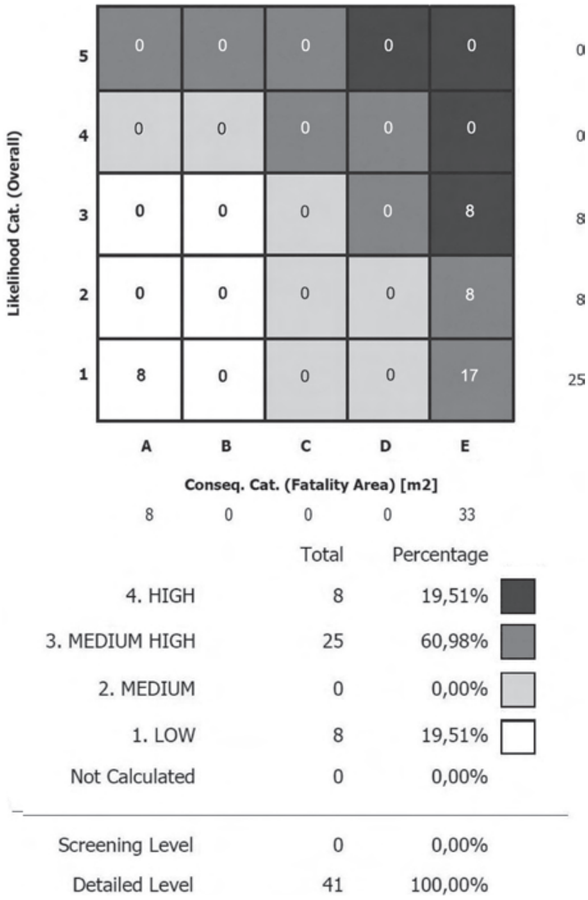


Figure 4. Risk matrix for 41 analyzed components, (detail analysis – toxicity consequence).

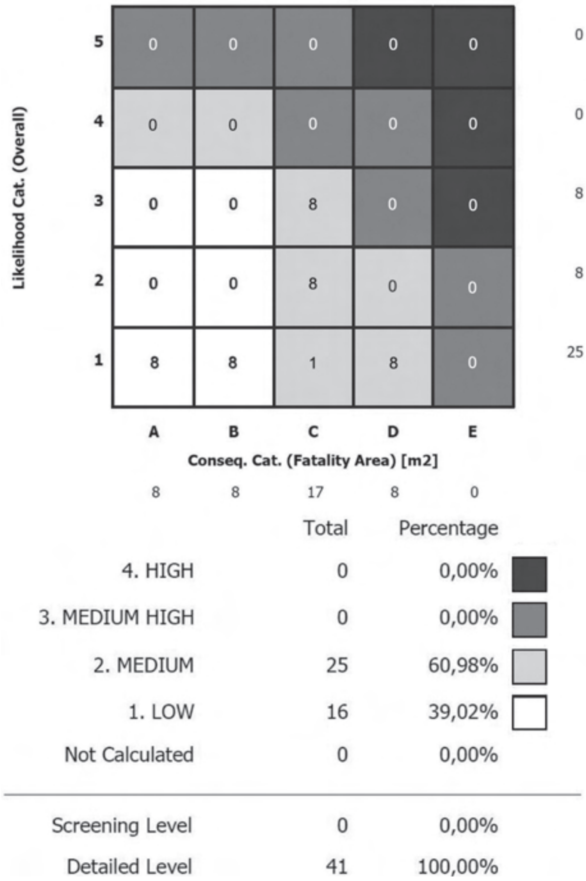


Figure 5. Risk matrix for 41 analyzed components, (detail analysis– fatality consequence).

In earlier period thickness measurement of the shell were performed regularly at every 6 months and visual examination were performed for all component to every annual review.

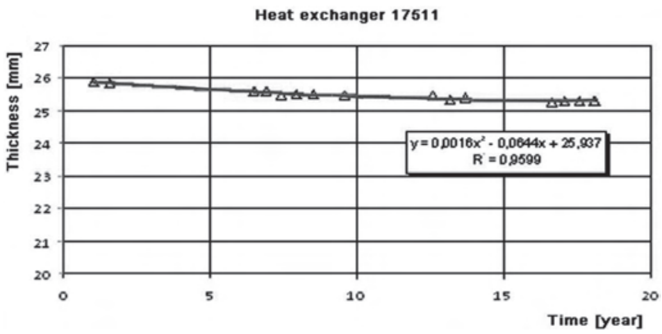


Figure 6. Corrosion rate of heat exchanger shell.

By detail analysis of operational parameters, materials and failure mechanisms for all components, using the expert system and Risk Based Inspection - RBI method, the corrosion rate is estimate (see Figure 6) and the interval between successive inspections is increase (see Table 1).

Table 1. Inspection program

| Component type | Likelihood category | Consequence category | Risk level | Inspection Type* | Inspection interval [years] |
|---|---|---|---|---|---|
| Chamber | 1 | C | 2. MEDIUM | TM - layer, PT-welds | 8 |
| | | | | VT | 3 |
| | | | | TM - base material | 15 |
| External Lid | 1 | B | 1. LOW | VT | 3 |
| | | | | TM - base material | 15 |
| Movable Lid | 1 | C | 2. MEDIUM | TM - layer, PT-welds | 8 |
| | | | | VT | 3 |
| | | | | TM - base material | 15 |
| Shell | 2 | C | 2. MEDIUM | PT-welds | 8 |
| | | | | VT | 3 |
| | | | | TM - base material | 8 |
| Tube Bundle | 3 | C | 2. MEDIUM | PT-welds, | 5 |
| | | | | VT | 3 |
| | | | | TM - base material | 5 |
| Release Valve | 1 | C | 2. MEDIUM | Test | 5 |

*TM – Thickness Measurement, PT – Penetrant Test, VT – Visual Test

The paper shows that through an assessment of risk in two stages (by screening and detailed) using risk based inspection concept the time limits between inspections can be extending, thus making significant financial savings.

## 5. Conclusions

The results obtained by implementing of integrated risk management system lead to a better understanding of risk consequences, accurate classification of the component in a consequence - probability matrix type and by default raise of business efficiency due to increase safety in operation.

Components of a plant can be ranked according to their operation risk level, with direct results on:

- increase safety in operation due to focus efforts in accurate evaluation of components identified as having high or very high risk level and developing an inspection plan according to the level of risk;

- financial return, reducing the costs of unnecessary inspections of low-risk components, reducing downtime losses and reducing costs of failure.

Based on risk assessment results can be developed a detailed inspection program for risk mitigation of critical components.

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