

Development of a RBI Tool for Inspection Management in Chemical Plants

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1. Introduction

The increasing complexity of chemical and petrochemical installations and in of oil and gas operations, jointed with the growing sensibility to ensure higher levels of safety, have increased the sensibility of the designers and operators to find innovative solutions to ensure safe as well as economically viable operation. It has become crucial to manage operational risk through the use of effective technology and best practices for inspection and maintenance planning.

Literature shows several models and methods for taking into account managerial and organizational factor in risk analysis, as Integrates Safety Method (Modarres et al, 1992), WPAM – Work Process Analysis Model (Davoudian et al, 1994), Integrated Risk (Papazoglou et al, 2003), ARAMIS (Salvi and Debray, 2005) etc.

A new approach, described by Milazzo et al. (2010), is based on the influence of risk prevention measures on the frequency of failure. An innovative methodology recently proposed by Milazzo and Aven (2012), focuses the need for extending the risk's approach to the concept of uncertainty. The development of these innovating methodologies need of further studies and developments, but are very promising for future approach of this problems.

Actually, for risk assessment practice in the chemical plant, one of the highest benefit maintenance methodologies is Risk Based Inspection (RBI).

RBI is a framework for risk analysis and decision-making, which can be used in developing inspection and maintenance programs. RBI can be used to identify critical equipment where inspections will provide the most benefit in reducing the overall risk. The application of this methodology permits a significantly reduction of maintenance costs and simultaneously the increase of plant's reliability and availability. The result is an overall risk reduction and increase in plant safety and reliability while constraining costs. The guidelines for RBI analysis are proposed by American Petroleum Institute (API 580, 2009). In particular the RBI approach focuses attention specially on the more critical equipments where the associated deterioration mechanism represents the most risk to the facility.

2. RBI methodologies

The RBI analysis may be conducted at several levels: quantitatively, qualitatively and semi-quantitatively. The choice of approach is dependent on multiple variables such as: objective of the study, complexity of facility and processes, availability of data, time and human resources.

Figure 1 show a simplified block diagram of RBI process with essential elements of inspection's planning.

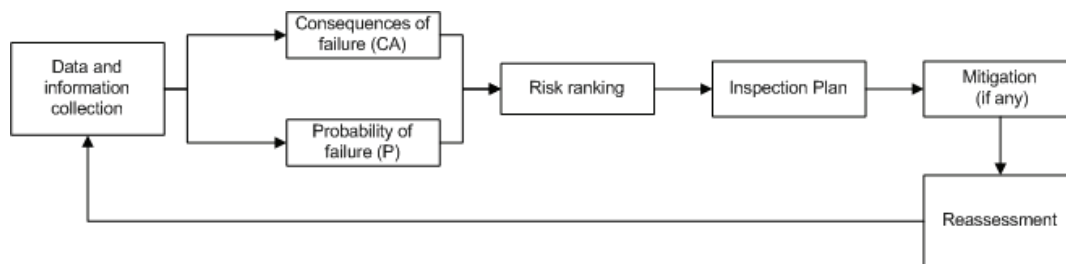


Figure 1: block diagram of RBI process

The approach reported in the document API 581 relevant the Risk Based Inspection (API 581, 2008) allows the calculation of the frequencies of breakage of the pipes, or other equipment, starting from frequency value of literature and correcting this values through the following factors: damage factor of equipments, which takes in account the complexity system, and an assessment factor of the system for the quantification of the efficiency managerial.

The API 581 methodology provides a generic value for the frequency of release for each equipments (type and size) and for different dimensions of the breakage. Assuming a log-normal distribution for the literature data for various chemical plants, the frequency of release can spans two orders of magnitude around its mean value. The generic frequency used is based on the mean value.

The determination of damage factor is very important because this identifies the damage's mechanism that affects the equipment.

The damage mechanisms can be divided into the following categories, as shown in Figure 2:

- Thinning damage, includes general corrosion, localized corrosion, pitting and other mechanism that cause loss of material from internal and external surface.
- Stress corrosion cracking, occurs when equipments are exposed to environments favorable to certain cracking mechanism such as caustic cracking, amine cracking etc.
- High temperature hydrogen attack, favors brittle fracture and external damage. Causes of these failure are varied but typically involve some forms of mechanical and/or physical property deterioration of the material due to exposure to the process environment.
- Mechanical fatigue, causes are various types and causes of mechanical deterioration.

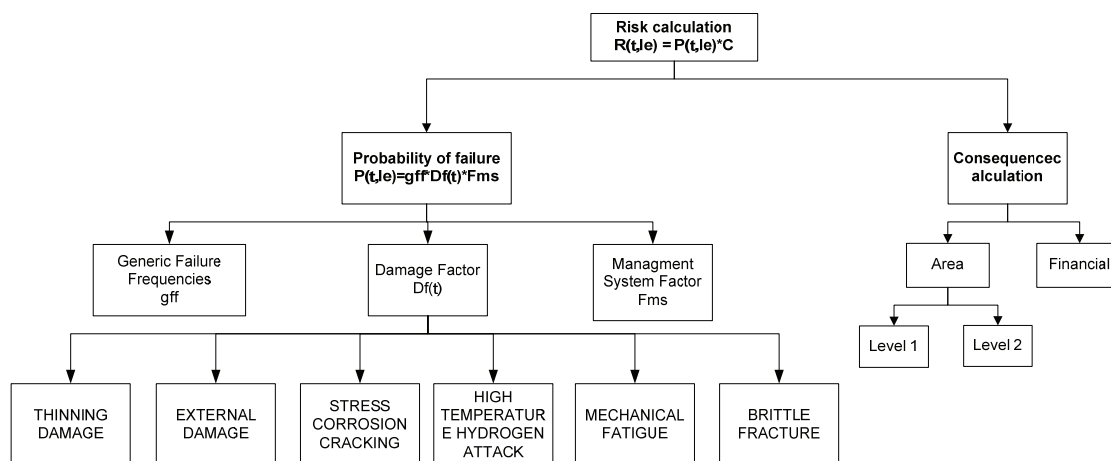


Figure 2: scheme of risk calculation for RBI methodology

Each damage factor is a representative group composed in turn by more specific damage's factors that are characterized by specific input data (API 571, 2011). As consequence, a critical point of RBI analysis is the management of a lot of information and data to carry out the analysis. For this reason, the analysis would be easier if associated with a software that permits to find these information, as the Inspection Manager tool. The API standard 581 is implemented in this software according to the flowchart of Figure 2. The result of the analysis is the calculation of risk in the form of matrices and the possibility to obtain a planning of inspections that can be carried out in years subsequent to analysis, (see Figure 3).

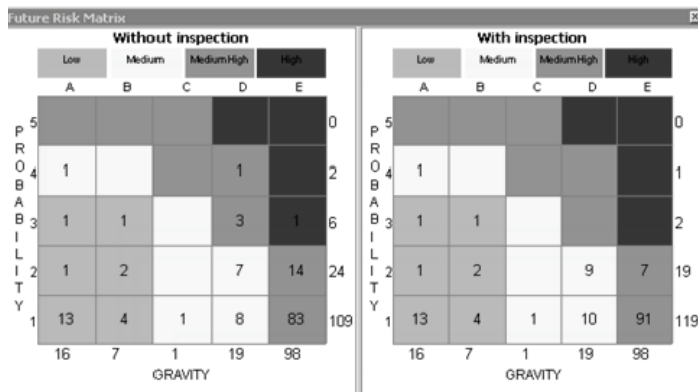


Figure 3: RBI risk matrices

3. Inspection manager

Critical points on RBI analysis could be the collection of initial data and plant's information and the storage of previous analysis of the equipments subjected at the analysis.

Both the collection of data and the retrieval of previous RBI analysis are expensive activities in terms of cost and time even if they are boundary operations of the RBI study.

In order to minimize the cost of these auxiliary activities it is necessary develop an integrated management system for all data of the plant.

ANTEA Inspection Manager is a software tool that encloses all functionalities for an easier management of of technical data for Plant's Inspection.

The database of Inspection Manager is based on the acquisition of the items found within the plant's P&ID that are unequivocally loaded and connected with their card. Drawing and process data, specifications, reports and maintenance history can be included (see Figure 4).

This process permits to create, in a very short time, an item's lists (piping, equipment, PSV, and others) and the catalog of items object of RBI study.

The useful features of Inspection Manager (IM) are :

- Technical card consultation : each item has a different technical datasheet that contains different information like chemical-physical properties, process design and operative conditions, construction information, normative, etc;
- Corrosion management : collection of all the memorized corrosion conditions and survey results to verify the integrity status of the items;
- Maintenance and survey history : for each item it is registered every operations and inspections that have been made previously. You can directly create a reports on these activities and store them inside the database.
- Display and research both in P&ID and 3D : each item could be located interactively in his process position (P&ID) and in his plant position through the representation in the in the 3D plant layout to have the complete view of the item function;
- TML (Thickness Measurements Location) : welding display in the 3D model. The inspections could be executed in precise positions to identify critical corrosion situations like fluid inlet/outlet, pipe elbow, welds, others;
- Document coordinating : for each item it is possible to consult immediately each typology of documentation like certificates, technical drawings, etc
- Deadline Log Book Management : this feature allows to manage all the expiry dates and keep them updated. This permits to manage all the correct RBI cycle.
- Inspection budget management : permits an economical view of the preservation activity.

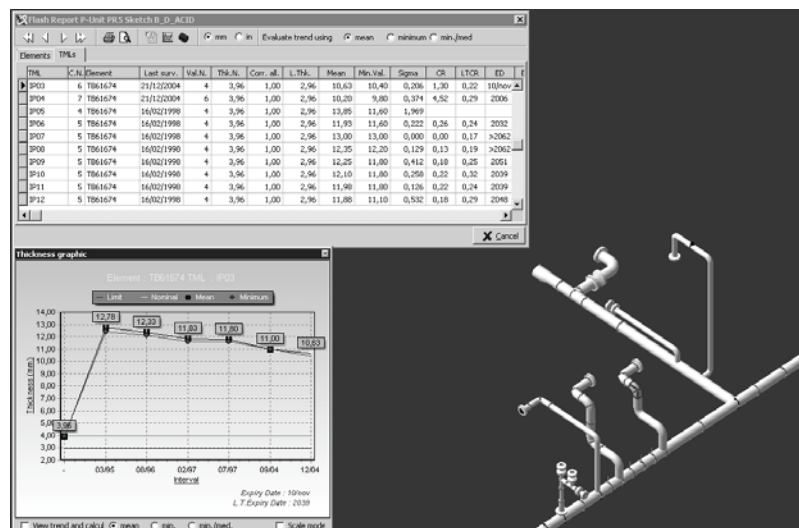


Figure 4: Result of database implemented in Inspection Manager

Actually the software manages all the RBI results, the objective of this study is to add a new module that allows technical expert users to carry out a RBI study compliant with API standards. All analyzed elements will be stored to minimize the inserting of repetitive data on the next RBI session. After the analysis, the inspection frequencies (results of RBI studies) will be updated directly on the deadline log book manager of Inspection Manager.

4. RBI Software

In order to calculate the main output parameters, the software performs the evaluation of a large number of inlet values. The overall process can be considered like a tree, where the root is a main output parameter (i.e. the probability of failure), its internal branches are various output values and the leaves are the input parameters.

After the insertion of input values, the software begins to evaluate all the output values that it can calculate. It is worth noticing that some times it is impossible to tell in advance which input parameters are required for the evaluation, for example, if you select a particular material some corrosion types will not occur and some of the input parameters will not be required any more.

After the user have inserted an input parameter value, the software performs the evaluation of all the output and it displays a warning, for instance it shows the next input parameter value that is not set, or an input parameter value that is not coherent with the value of another input parameter.

When the software running stops because an input value has not setted, this parameter will be yellow-highlighted and in bold face in the input grid. If the input parameter is required for a parameter that must be inserted or calculated (i.e. Fww) the software will tell you that you can insert directly that parameter.

Figure 5 shows two different areas:

1. The output parameters are listed in a tree, and the color of any row changes accordingly with the status of the parameter: if a parameter is not required for the evaluation of the main output parameter (i.e. Area Consequence), it is gray-highlighted, on the contrary, if it has been calculated, it is green-highlighted.
2. The input grid present a list of input parameters and a value for each parameter enabled should be chosen.
3. When a value for an input parameter is inserted, the software try to calculate all the output, and it stops when it found an input parameter not set. The assistant tells you the first input parameter required to go on with the evaluation.
4. During the evaluation of the output parameters, some warnings can be generated and listed in this grid.

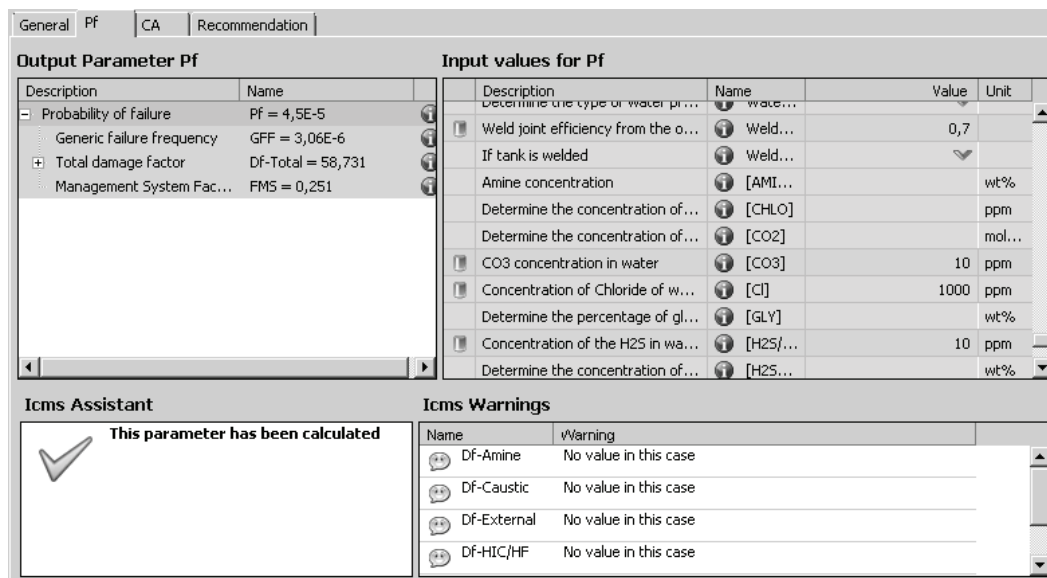


Figure 5: Window of software

5. Quantitative example

An example of an application of the code developed for the RBI quantitative analysis was been conducted by taking as reference a pipeline outgoing from a storage vessels of a petroleum refining plant. The pipeline has a diameter equal to 100 mm and the fluid inside is benzene with trace of hydrogen sulfide (H₂S). The table 1 shows the data needed to conduct the RBI analysis for this equipment.

Table 1: Information pipeline

Parameters	Value
Diameter [mm]	100
Material	API 5L Grade A
Operating temperature [°C]	40
Maximum operating temperature [°C]	80
Minimum operating temperature [°C]	-10
Pressure design [bar]	20
Fluid phase	Liquid
External coating	Yes
Time since last RBI analysis [age]	5
Component thickness [mm]	11.13
Velocity of fluid [m/s]	2

In the analysis the value of the management system evaluation factor (Fms), that has been considered, is equal to 0.251, that means the managements system score is of 80%.

The result of the probability of failure is equal to $4.5 \cdot 10^{-5}$. The damage factors identified in the analysis are stress corrosion cracking, mechanical fatigue and general thinning.

The impact area of consequences calculated by RBI methodology is equal to 183.213 m².

The result of the analysis shows that the risk associated with the pipeline is medium, as shown in Figure 6a. The ranges of risk matrix correspond to ranges proposed by API 581 (API 581, 2008).

The software allows us to consider the inspections activities carried out in the plant, inserting in the specific cell the number of inspections and the effectiveness of these actions is possible to calculate the probability in function of inspection activities. Whereas it has been carried out one inspection with highly effectiveness, the probability that is obtained is equal to $5 \cdot 10^{-6}$. As can be seen in Figure 6b, the probability is less than the first case.

Thank to the software it is possible to planning the inspection activities in function of risk category.

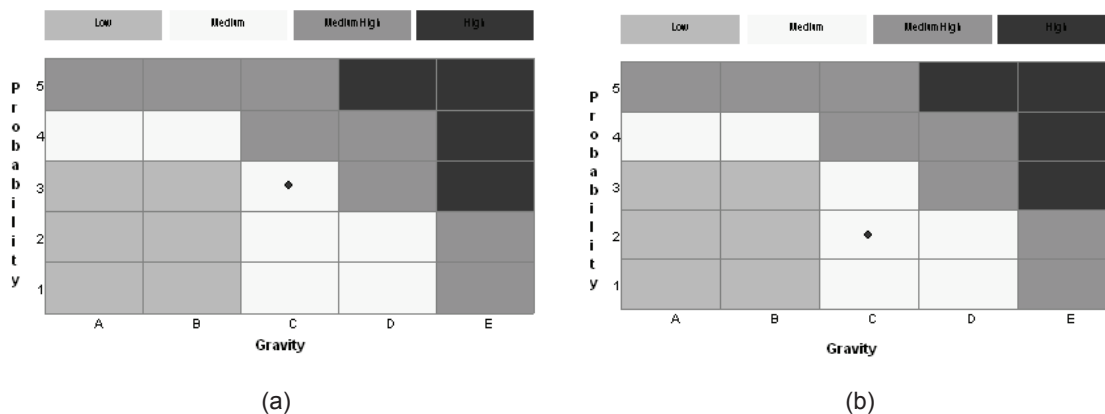


Figure 6: Risk matrix of pipeline: (a) no inspection; (b) 1 inspection with highly effectiveness.

6. Conclusion

The use of a RBI analysis is very important phase to plan the inspection activity.

The problem of collecting data that characterizes this analysis is overcome with the help of software inspection manager that encloses all functionalities for an easier management of technical data in the Plant's Inspection. The main target of this paper is to add a new software tool that allows expert technical users to proceed a RBI study compliant to the API standards.

The results of the new tool of Inspection Manager for RBI permits to carry out easier the inspection plan. The software permits a guided procedure for the insertion of the data necessary for the analysis, and then the analysis is easier and faster. The identification of risk derives from range proposed by API 581.

In the case of not standard operations, the operator can be update the data and, thanks to the saving of the previous analysis to minimize the inserting of repetitive data, the RBI session turns out to be simpler and faster.

Acknowledgements

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