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The Frequency of Release from Piping: a Case-Study to Compare Approaches Quantifying Organizational and Managerial Factors

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The increasing public awareness about high risks associated with chemical and petrochemical installations determined a growing attention on the improvement of protective and preventing measures. To ensure higher levels of safety, designers and operators have focused their efforts to find innovative solutions combining safety and costs for safety. It has become crucial to manage risk through the use of best practices for inspection and maintenance planning. In order to achieve this aim, a useful tool, named "Inspection Manager", has recently been developed by ANTEA. It includes all functionalities for a easier data management concerning plant's inspection, furthermore the implementation of methods for the quantification of managerial and organizational factors gives it additional potentialities. This work has been focused on the comparison of two approaches for the quantification of organizational and managerial factors on the frequency of release from piping to be used to support risk-based decisions by means of the use of the "Inspection Manager" tool.

1. Introduction

In literature several methods for taking into account managerial and organizational factors in risk analysis are available. Concerning the chemical industry, the most important contributions are due to the following authors: Embrey (1992) incorporated management and organization factors into probabilistic safety assessment using the Model of Accident Causation using Hierarchical Influence Network; Davoudian et al. (1994) developed a method based on the analysis of work processes; Patè-Cornell and Murphy (1996) defined an approach based on observations; and, finally, Papazoglou et al. (1999) and Milazzo et al. (2010) quantified organizational and management factors through the definition of relationships between measures of risk prevention and causes of failure in piping. Recently Milazzo and Aven (2012) pointed also at the extension of the risk approach focusing on the concept of uncertainty.
Within this topic, currently, the most diffused methodology is the Risk Based Inspection (RBI). It is a framework for risk analysis and multi-attribute decision-making, which can be used in developing inspection and maintenance programs (API 580, 2009). It allows identifying critical equipments where an appropriate programme of inspections could provide the most benefit in reducing risks. The RBI analysis has recently been implemented in the "Inspection Manager" tool developed by ANTEA Company by Vianello et al. (2013) in order to help users to apply best practices for inspection and maintenance planning.
The aim of this paper is to compare the methodology RBI and the recent approach done by Milazzo et al. (2010) in quantifying the organizational and managerial factors on the frequency of release from piping. The first approach allows the calculation of the frequencies of breakage of pipes or other equipments using literature data before modifying it through a number of corrective factors. The second one is based on the Papazoglou method which quantifies organizational and management factors through the definition of

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relationships between measures of risk prevention and causes of failure in piping. The comparison between the approaches has been made by means of the Inspection Manager tool of ANTEA with the aim to verify its potentiality. To achieve this objective an application to a case-study has been necessary.

2. Methodologies

Before introducing the implementation of methodologies for the frequency estimation within the Inspection System Manager tool, we briefly describe its features.
ANTEA Inspection Manager is a software which encloses functionalities for an easier management of technical data required for a Plant's Inspection. The database acquires all the items found within the plant's P&ID, which are unequivocally loaded and connected with their card. Drawing and process data, specifications, reports and maintenance history are included. The main features of Inspection Manager (IM) are:

- Technical card consultation
- Corrosion management
- Maintenance and survey history
- Visualization and research of items both in the P&ID and the 3D view
- TML (Thickness Measurements Location) and welding visualization in the 3D model
- Document coordinating
- Deadline Log Book Management, this feature allows to manage all the expiry dates and to keep them updated
- Inspection budget management, this permits an economical view of the preservation activity

Figure 1 shows an example of a 3D view of an heat exchanger with the location of the points of thickness measurement. Data related to each element can be easily displayed.

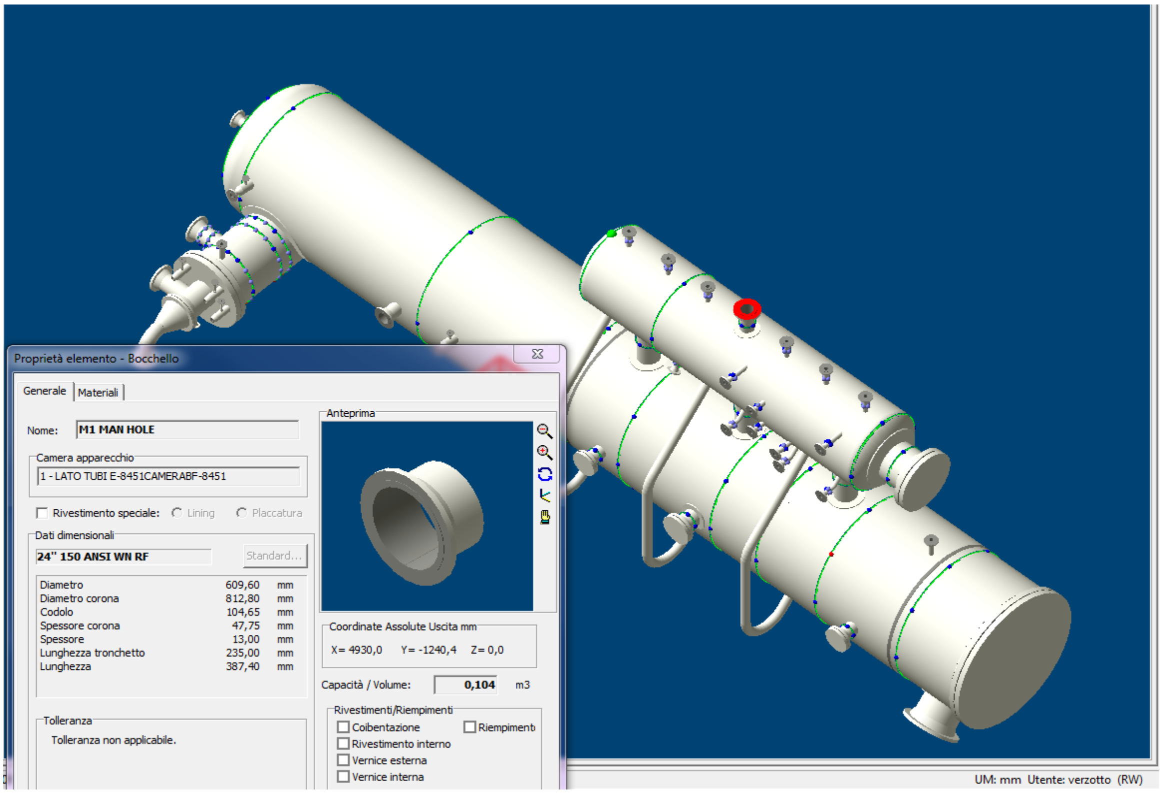

Figure 1: Example of 3D view with thickness Measurements Location

This system permits to quickly create an item's lists (piping, equipment, PSV, etc.) and to catalogue items according to specific criteria. Two approaches for the frequency estimation are briefly described in the following section, these are applied to a case-study and compared by means of the use of the Manager Inspection tool.

2.1 The RBI approach

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

The API 581 methodology provides a generic value for the frequency of release for each equipment and for different sizes of the breakage. The determination of the damage factor depends on the mechanism of damage affecting the equipment. These mechanisms, as shown in Figure 2, can be divided into the following categories (API 571, 2011):

- *Thinning damage*, this includes general corrosion, localized corrosion, pitting and other mechanism that cause loss of material from internal and external surface.
- *Stress corrosion cracking*, which occurs when equipments are exposed to environments favourable to certain cracking mechanism, such as caustic cracking, amine cracking etc.
- *High temperature hydrogen attack*, this phenomena favours brittle fracture and external damage. The 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* has various types and causes of mechanical deterioration.

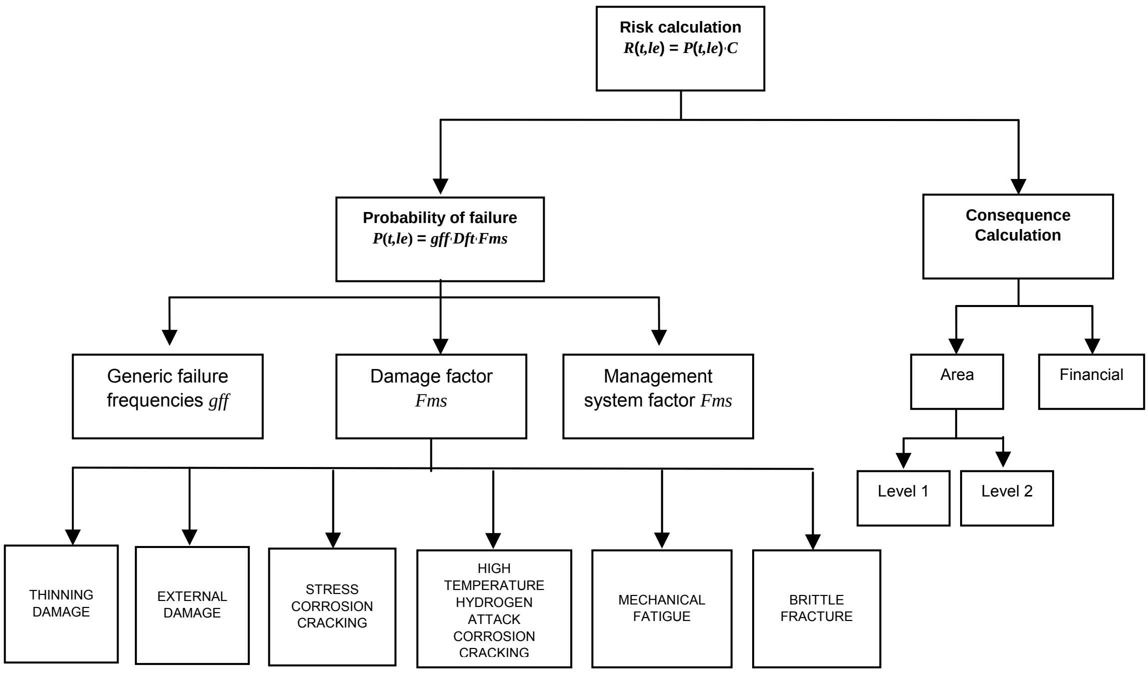

Figure 2: Block diagram for risk calculation through the RBI methodology

2.2 The approach of Milazzo et al.

The method of Milazzo et al. (2010) is based on an examination of the whole plant and the definition of how the measures of risk prevention influence the frequency of pipe rupture. A detailed identification of the potential causes of failure and measures for prevention is necessary. The use of the percentages of the failure causes related to the establishment allows to incorporate in the analysis specific information for the establishment, this is fundamental for the application of the method. This is needed to quantify the relationships between measures of risk prevention and causes of failure in piping.

The method modifies the frequency using the equation (1) (Papazoglou et al., 1999), whose application depends on the definition of the weight coefficients a_i:

$$log\ f_{mod} = log\ f_m + \sum_i a_i \cdot x_i / 100 \tag{1}$$

f_{mod} is the modified frequency, f_m is the mean frequency of failure based on world-wide experience, a_i is the percentage of the causes of failure and x_i the parameter indicating the judgement of the measure (it assume the value -1 if the plant is judged GOOD, 0 if the plant is judged AVERAGE and +1 if the plant is judged POOR). In order to identify the preventive measures and their effectiveness, an audit is necessary. The score x_i for the influence of the measures of risk prevention was defined in agreement the plant management of the establishment.

3. Case-study

To achieve the aim of this work, both the methodologies mentioned above were applied to a real chemical industry (confidential) in order to estimate the frequency of random events which can potentially occur. An event from the establishment's Safety Report was chosen based on the source of the piping leakage from the flammable and toxic liquid. Two dimensions of breakage have been assumed, 5 % (Rn 5) and 20 % (Rn 20) of the pipe diameter (Ø = 100 mm). Table 1 shows the main characteristics of the pipeline.

Table 1: Main characteristics of the pipeline

Parameters	Value
Diameter [mm]	100
Material	API 5L Grade A
Operating temperature [°C]	15
Pressure design [bar]	10
Fluid phase	Liquid
External coating	No
Time since last RBI analysis [age]	5
Component thickness [mm]	11.13
Velocity of fluid [m/s]	2

The analysis of many databases (HSE, 2012; NKS, 2002; J.-P. Heirman, 2009; API 581, 2008), containing initial frequencies of leakage and rupture, showed a great variability for these typologies of data. In this work an average value for the initial frequency of leakage was used, then, this value was modified taking into account the complexity of the system. Table 2 gives the values of the initial frequency of leakage (from literature) and the frequencies of leakage (modified using the damage factor) used for this application.

Table 2: Initial frequency of failure

Pipe leakage	Initial frequency of leakage (event/year)	Frequency of leakage (event/year)
Rn5	$4.8 \cdot 10^{-6}$	$1.93 \cdot 10^{-3}$
Rn20	$2.30 \cdot 10^{-7}$	$1.25 \cdot 10^{-4}$

3.1 Implementation of the Inspection Manager tool

The essential elements of the API 581 standard are shown in the block diagram of Figure 3, these have been implemented in the ANTEA Inspection Manager. The final version of the Inspection Manager tool, which is the result of a collaboration between the University of Padova and ANTEA (see Vianello et al., 2013), permits to elaborate the frequency of failure based on the history of the piping, thus, taking into account the plant specificities.

The software provides a risk ranking using a matrix showing the classes of frequency (ordinate axis) vs. the classes of consequence (abscise axis). The consequence categories are defined according to the extension of the impact area (A) as shown in Table 3. Therefore, according to the position of the event in the matrix, the risk is classified in four categories: low, medium, medium high and high.

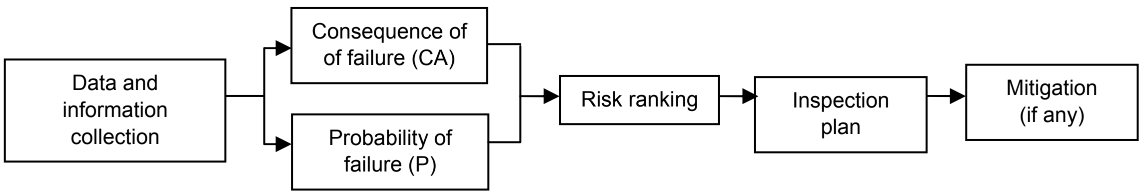

Figure 3: Block diagram of RBI process.

Table 3: Consequence category (CA)

Category	Range (m^2)
A	$A \le 9.29$
B	$9.29 < A \le 92.9$
C	$92.9 < A \le 279$
D	$279 < A \le 929$
E	$A > 929$

4. Results and discussion

Figure 4 shows the position in the matrix of both the dimensions of breakage. The results obtained using the frequencies of leakage of Table 2 are written in italics and those obtained using the factor for the quantification of the managerial efficiency defined in the API 581 document are in bold. An analogous matrix has been produced for the results of the approach proposed by Milazzo et al. (2010) (Figure 5).

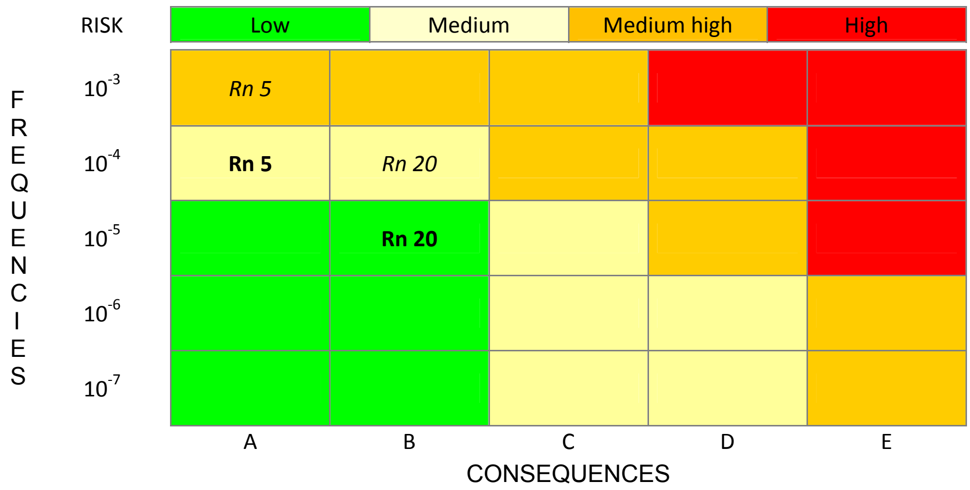

Figure 4: Risk quantification using the RBI approach (in italics frequency of leakage of Table 2 and in bold results quantifying the managerial efficiency).

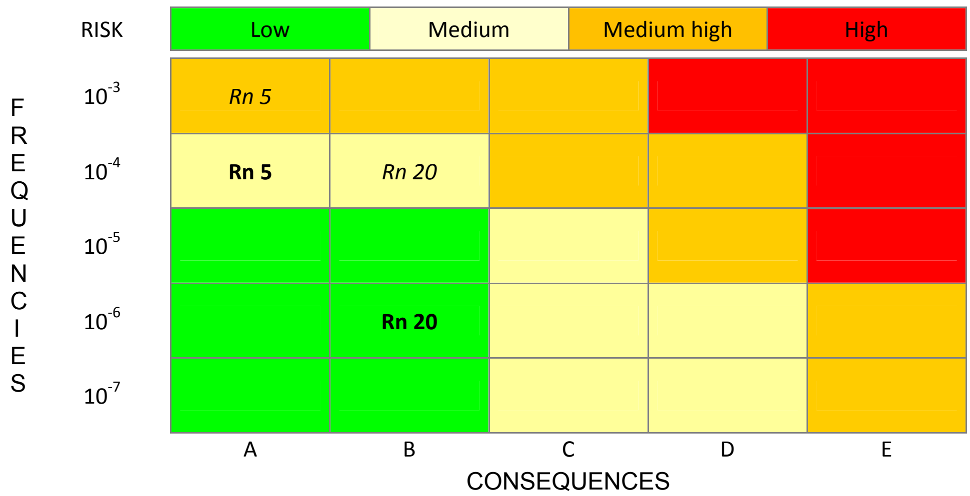

Figure 5: Risk quantification using the method of Milazzo et al. (in italics frequency of leakage of Table 2 and in bold results quantifying the managerial efficiency).

5. Conclusions

In this paper a comparison between two approaches for the quantification of organizational and managerial factors on the frequency of release from piping has been illustrated. The inclusion of the RBI approach within the software of ANTEA (as a result of a collaboration between the University of Padova and the ANTEA Company) allows elaborating the frequencies of leakage taking into account the complexity of the system (by means of a damage factor) and the history of the equipment (maintenance, welding, etc.). The final frequencies can be modified including the influence of the managerial efficiency.
The analysis of a case of piping's breakage showed that the RBI approach is more conservative in quantifying managerial efficiency because the factor used for its quantification is defined using generic literature data, however in the worldwide context this approach is the most diffused. The method of Milazzo et al. (2010) modifies literature data through an audit of the management system, taking into account also of plant specificities. In this framework, the implementation of the procedure RBI in the Inspection Manager software provided a useful tool to be used to support risk-based decisions by means also of the integration of different approaches.

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