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Opportunities and Threats of Risk Based Inspections: the new Italian Legislation on Pressure Equipment Inspection

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Risk based inspection (RBI) is recognized an effective method to reduce risk and raise the level of safety in many industries. Whilst in traditional deterministic approach the inspection frequencies and modes are fixed, in RBI for each item of equipment, the inspection interval depends on the risk level. RBI ensures a higher safety level without increasing the costs; however it has many degrees of freedom and a misuse is possible, by companies that are not safety. For this reason many national Legislation are very cautious with RBI. This is the case of Italy, where, the deterministic approach has been saved in the new regulation on pressure equipment. RBI implementation at a plant must be authorized case by case and operators must demonstrate its equivalence to the deterministic frequencies. The paper presents a method to demonstrate that alternative inspection intervals, resulting from RBI, entail risk levels lower or equal than deterministic inspection intervals. The proposed method fits the requirements of Italian Authorities for RBI exception. Method is also suitable to be exported to other Countries where the legislation is RBI - skeptic.

1. Introduction

In the past century, in most European countries, including Italy, the inspections for the pressure equipment, were ruled by a very sound, stable and effective system. It was based on "command and control" or deterministic approach, with inspection modes and frequencies defined by law. This approach was questioned in the early Nineties. The first idea of Risk Based Inspections (RBI) has been introduced in 1991 by American society of mechanical engineers ASME to plan equipment inspections, aiming to reduce risk without affecting costs. The risk-based inspection and maintenance strategy have been better focused by national and international standardization bodies. At now the most popular RBI codes are: the API 581 code by the American Petroleum Institute (API, 2008), the RIMAP by the European Committee for Standardization (CEN, 2008) and the code by the American Society of Mechanical Engineers (ASME, 2008). The basic idea of RBI is the optimization of inspection intervals, instead of the fixed frequencies, required by the deterministic approach. In RBI, inspection times and modes are affected by the assessment of failure risk, assumed as the product of likelihood and consequences, as well as by the tolerable risk level and by the results of previous inspections. In the last decade over one hundred papers on RBI benefits have been published in the indexed scientific journals. The basic foundation of RBI may be found in an essential paper by Khan & Haddara (2003). The potential of RBI for optimizing plants in chemical industry has been widely discussed in a recent paper by Medina et al. (2011). Even though the benefits are widely recognized, a larger diffusion of RBI is hindered by a few open issues, which are briefly discussed here.

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1.1 Open Issues of RBI

For a decade RBI methods have been applied in the majority of oil refineries, major chemical installations and power stations, as surveyed by. Successful RBI implementation at major plants has been demonstrated by many authors in recent years, ... The application of RBI to the small sized enterprises SMEs is, instead, less successful. A limited budget could compromise the benefits of RBI because it takes considerable resources to develop, implement and maintain. There is a need of integrating RBI within the major management system, including the (regulatory and non regulatory) Safety management System SMS. In a recent paper Qingfeng (2011) has discussed the importance of integrating risk management with professional management, focusing on the PDCA cycle (Plan Do Check Act). This issue stresses again the importance of a sound organization for companies that decide to implement RBI method.

1.2 RBI and national legislations

In a few countries, occupational safety legislation has recognized RBI method as an adequate alternative to time based methods in mandatory inspections for pressure equipment, but many countries are still sceptic. There are many doubts about the RBI as it makes the controls by the regulatory bodies more difficult. The strengths of the RBI methods are more effective inspections and optimized costs. The weaknesses are the definition of the assessment method and the level of tolerable risk. A poor assessment method could jeopardize the inspection effectiveness, as well as a higher bearable risk level. The operators risk preferences (prone or adverse) are supposed to influence too much the length of inspection intervals. From the point of view of the regulator the question of accepting RBI is puzzling indeed. They should encourage the companies that perform well to adopt advanced method to reduce risk, without loosening the control on minor companies without adequate safety culture and commitment. The countries with a legislation pro- or con- RBI are shown in (RBI-ATLAS, 2011). In the countries pro-RBI there are Germany, Netherlands, France, Portugal, Finland and Latvia in the con-RBI there are Poland, Denmark Greece, Estonia and Sweden. There is also a third position: the RBI may be introduced for mandatory inspections just if a number of requirements are satisfied. Alternative inspection intervals, proposed by RBI, have to be authorized. This is the case of UK, Spain, Norway, Serbia, Ireland and Italy. Such differences in national laws are proof of how difficult the issue is.

1.3 RBI in Italy

Legislation on equipment safety. According to the recent Italian legislation periodic inspections on pressure equipment are the following:

a. **Inspection during service**, aimed at verifying the correct use of the equipment and the efficiency of safety devices;
b. **Integrity inspection**; aimed at verifying the integrity of the equipment with respect to damage mechanism and corrosion allowance.

Frequency of the inspections “during service” varies from 1 to 5 years according to type and risk category of the equipment. On the contrary, integrity inspections are generally performed every 10 years of service. The Italian legislation is very cautious about RBI methods. Frequencies and modes of inspection are specified in detail, and RBI may be accepted just as an exception, if the employer is able to demonstrate that the residual risk level of his RBI implementation is lower than the risk that should come from conventional approach. According to the law INAIL (with local health agencies) is in charge for inspections, whilst the Ministry of Production is competent for exceptions.

RBI and Seveso. At the establishments where the Seveso directive on major accident hazard is enforced, the issue of RBI becomes more complicated, both for the inherent hazards of the plant and the interfering regulations. According to the Directive, at Seveso plants periodical mandatory inspections of the management system are organized by the Competent Authorities. In a recent paper Bragatto et al. (2009) discussed the feasibility and advantages of integrating the SMS and the equipment mechanical integrity program by exploiting mandatory inspections required by Seveso Legislation. This issue stresses again the need of shared tool for demonstrating to the Competent Authorities the adequateness of a RBI program. The challenge of a trustable method, sharable by all stakeholders is described in §2. In §3 the proposed method is discussed in detail and in §4 its applicability is demonstrated by an example. Potential of the method in chemical industry are discussed in §5.

2. Objectives

Regulators, in order to be equitable, have to meet two conflicting needs: 1) A tight control on small plants to avoid unsafe conditions; 2) A more flexible and smart control on major companies which are safety committed. Furthermore all decisions must be demonstrable to all stakeholders, in particular when RBI is applied at major accident hazard plants (Seveso Plants), which are often in the public eye.
The objectives of the present research are

i. To define minimal requirements for RBI acceptability by regulators
ii. To provide a measuring method for risk level
iii. To provide suggestion for RBI at Seveso plants.

To have yet another RBI method is definitely not objective of the research! RIMAP or API 581 may be used, depending on the operator’s preference. The method will be demonstrated suitable for all types of equipment, such as pressure safety valves (PSV), chemical reactors, piping and steam generators. Furthermore integration with regulatory Safety Management system has to be proved for Seveso establishments.

3. Proposed Method

A technical specification TS concerning the use of RBI methodology with pressure equipment has been developed by the Thermo-Technical Committee (CTI) of Italian Standard Organization (UNI), working group “Structural Integrity of Pressure Plants”. The TS has not yet been published and is undergoing the approval phase, with the code UNITS11325-8. It can be used for the definition of alternative inspection frequencies with respect to frequencies defined by national Decrees. It describes the RBI procedure, which has seven steps: analysis of plant data, analysis of equipment data; study of damage mechanisms; identification of the method of risk assessment; determination of the Likelihood of Failure LoF; determination of Consequences of Failure CoF and, finally, determination and assessment of risk. The procedure is very close to the API 581 procedure, and is featuring the “classical” RBI formulas and definitions. The risk R is the product of CoF and LoF. LoF, in turn is the product of the generic failure rate FR, the equipment modification factor EMf and the management system evaluation factor MSf.

$$LoF = FR \times EMf \times MSf \qquad (1)$$

In turn EMf is defined as a combination of damage factor Df, Complexity factor Cf and Inspection effectiveness factor IEf, which in turn depends on the inspection technique. Of course the effort is to affect LoF to lower risk level; so the inspection type and the frequency will be selected in order to achieve the desired risk level. The procedure uses a 5X5 risk matrix to define 4 risk categories, ranging from low to highs, as shown in figure 1.
An add-on of the proposed standard is the choice of the method for the risk assessment (qualitative, quantitative or semi-quantitative); it has been detailed, in order to help operators to comply with Italian regulation. It takes into account the requested time-extension (lower or higher 1 year), the inspection type (integrity or functionality), the equipment risk category.
The main achievement of the proposed method is the “analysis of the results”, which is aiming to evaluate the results of the RBI procedure, in order to extend inspection intervals.

3.1 Analysis of the results

In order to verify the possibility of extending the inspection interval from the base time interval (X years) to alternative time interval (Y years) the following procedure has been defined.

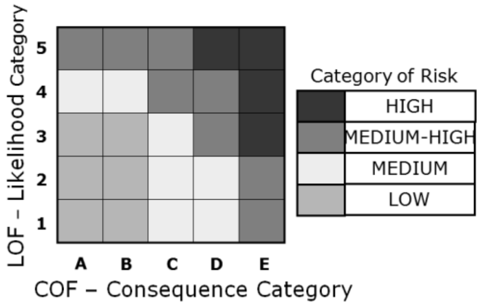

Figure 1: The 5x5 Risk Matrix, with relevant Risk Categories, as used in UNI TS 11325

i. Determination of risk (Rx). The value of risk corresponding to an interval between inspections equal to X years must be assessed. The value can be represented as a number or as a risk category.
ii. Determination of risk (Ry). The value of risk corresponding to an interval between inspections equal to Y years must be assessed. The value can be represented as a number or as a risk category.
iii. Comparing risk levels (Rx) and (Ry)

In order to evaluate the possibility of modification of the time interval between two following inspections, the risk levels at the two time frames must be compared.
For this purpose Likelihood of Failure (LOF) and Consecuence of Failure (COF) must be calculated. With reference to the risk matrix (figure 2) the following considerations can be made:

- The level of risk at time interval Y (Ry) falls in a low risk category: a modification of inspection interval is possible.
- The level of risk at time interval Y (Ry) falls in a high risk category: a modification of inspection interval is not acceptable.
- The level of risk at time interval Y (Ry) falls in a medium-high category of risk and the Probability of Failure is high: a modification of inspection interval requires a Fitness for Service procedure.
- In all other cases a modification of the inspection interval can only be possible if risk level at longer time (Ry) is not higher than the risk level at shorter time (Rx). To obtain this goal mitigation measures might be necessary (Figure 2). Please Note that, since the Consecuence of Failure does not depend on the inspection interval, only values of LoF at the two time frames (LoFx, LoFy) are to be compared.

In all cases, in order to extend the inspection interval, additional requirements need to be verified:

- Results of previous inspections should demonstrate the absence of critical situations for the integrity of the equipment.
- Value of risk at longer time interval (Ry) should be lower than tolerable risk. The definition of risk tolerability is under the responsibility of the User, according to applicable laws and regulations.
- Damage mechanisms should not be strongly time-dependant.

3.2 SEVESO

According to the EU Directives, the operators of Seveso establishments must implement a management system for the Accident Prevention, aiming to assure an adequate level of protection. The Seveso Competent Authorities must organize every 12 months a planned and systematic examination of the organizational and technical systems at the establishment. Each Member Country, including Italy, has regulations or codes to rule management systems and audits. According the Italian regulation, inspections are ruled by a check list, featuring hundreds of nested items, which have to be duly verified. In order to support Seveso activities the national standardization Institute has delivered a a guideline, named TS 11226, for inspections at major accident hazard establishments (UNI, 2007). It is aiming to address audits and It is close to the regulatory check list, but it has a few extra capabilities, including a trustable scoring system. For each inspection topic, there is a partial score, Si based on conformances and non conformances.

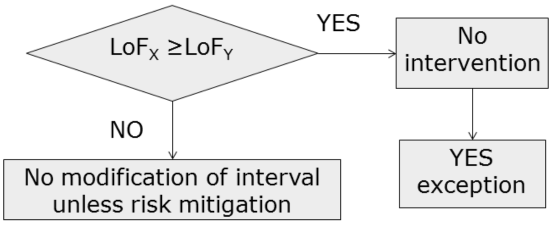

Figure 2: Comparing LoF at two time frames X (base interval), Y (alternative interval)

The score ranges from excellent = 0.25 to inadequate = 1. Of course the lower the score is, the lower the failure probability is. In audit procedure the verification of the operating control procedures is a section of the check list. Of course the inspection planning is an essential item of this section. The proposed method for RBI demonstration is suitable also for Seveso purpose. The risk level measurement may be used to demonstrate to the inspector that the risk level is as low as possible. Unlike non-Seveso establishments, where RBI is considered acceptable just if the risk level is definitely lower than the risk level resulting by the fixed inspection frequencies. In such a way results of RBI evaluations may be imported in Seveso inspections. It is possible to have also the inverse link, I mean the results of Seveso audits may be exploited to improve RBI program. According to the Seveso audit code, the overall score is the weighted quadratic average of the partial scores Si. Weights Wi have to be provided by the auditor, considering both inherent risks and operation experiences.

$$P = \sqrt{\frac{\sum_i \left(S_i^{\,2} * W_i\right)}{\sum_i W_i}} \tag{2}$$

This formula may be used in UNI TS 11325 and namely P may be accounted as MSf in Eq. 1.

4. An example

A typical example regarding the determination of alternative frequencies for “integrity inspections” is illustrated below. Two reactors (R1 and R2) of a petrochemical plant are examined with respect to operating parameters, and service life (Table 1).

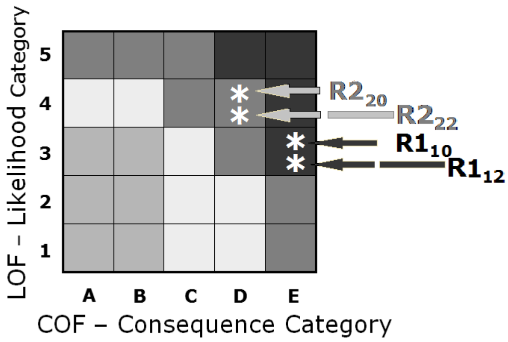

Figure 3: Risk level at different time frames for inspection. R1 (10 or 12 years) – R2 (20 or 22 years)

Damage mechanisms in both cases are High Temperature Hydrogen Attack (HTHA), H_2S corrosion (THINNING) and internal lining damage (LINING). Due to maintenance and process reasons the first “integrity” inspection normally performed after 10 years needs to be carried out after 12 years , for reactor R1. Similarly the second “integrity” inspection fixed by law after 20 operating years needs to be postponed after 22 operating years, for Reactor R2. Results at the two corresponding time frames are visible in the chart of Figure 3, where $R1_{10}$ represents the Risk Level after 10 years, with respect to inspection performed according to Italian regulation on pressure equipment inspection (only visual test and thickness measurements) and where $R1_{12}$ represents the Risk Level after 12 years, with respect to specific inspection performed according to Table 1. A similar notation was adopted for reactor R2. For both reactors a non-increment of risk level is shown. However in the case of reactor R1 both final outputs end up in a high risk region, which strongly suggests – according to UNI TS 11325 - not to change the periodicity of the inspection, with respect to the one fixed by regulation. On the contrary for reactor R2 both outputs fall in a medium-high risk area. The increment of 2 years in the inspection frequency will be accomplished by a higher efficacy of NDT.

Table 1- Operating parameters service life of vessel R1, R2; for both the partial H_2 pressure 20 ate.

	ReactorR1	ReactorR2
Base Material	16 Mo 5 UNI 5869	A 387 Gr11 Cl2
Lining Material	A240 Tp321	A240 Tp304L
Operating temp ; press	Top = 330 °C; Pop = 33 ate	Top = 327 °C; Pop = 29,5 ate
Operating time	T = 8 years	T = 18 years
NDT specific inspection for H_2 damage	2 AUBT Inspections performed	None
Inspection for lining	Visual Test Thick. measure (After 8 y. service life)	Visual Test Thick. measure (After 8 y. service life)

5. Conclusions

The discussed method does not change the RBI but set strict limits, which make RBI acceptable also for regulatory bodies. It is not yet another RBI but a bridge to connect RBI and conventional methods referred by national regulations. The method has been demonstrated suitable for Seveso plants too. The results of the Seveso audits may be used to tune the failure probability and consequently the risk level and then the times and modes of inspections. In such a way the well performing companies, as verified by Seveso competent authorities, may be awarded with a longer inspection interval. The proposed method is also suitable to be transferred to other countries, where regulators are RBI-skeptic.

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