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ESTABLISHMENT OF OPTIMAL PHYSICAL ASSETS INSPECTION FREQUENCY BASED ON RISK PRINCIPLES

USTALANIE OPTYMALNEJ CZĘSTOTLIWOŚCI PRZEGLĄDÓW OBIEKTÓW TECHNICZNYCH W OPARCIU O ZASADY OCENY RYZYKA

Risk Based Inspection (RBI) is a risk methodology used as the basis for prioritizing and managing the efforts for an inspection program allowing the allocation of resources to provide a higher level of coverage on physical assets with higher risk. The main goal of RBI is to increase equipment availability while improving or maintaining the accepted level of risk. This paper presents the concept of risk, risk analysis and RBI methodology and shows an approach to determine the optimal inspection frequency for physical assets based on the potential risk and mainly on the quantification of the probability of failure. It makes use of some assumptions in a structured decision making process. The proposed methodology allows an optimization of inspection intervals deciding when the first inspection must be performed as well as the subsequent intervals of inspection. A demonstrative example is also presented to illustrate the application of the proposed methodology.

Keywords: *risk analysis, risk based inspection, inspection frequency.*

Risk Based Maintenance (RBI), to metody planowania inspekcji obiektów, w tym ustalania priorytetów i zarządzania czynnościami obsługowymi, wykorzystujące zasady oceny ryzyka. Pozwalają one na taką alokację zasobów, która zapewnia wyższy poziom zabezpieczenia obiektów technicznych obarczonych wyższym ryzykiem. Głównym celem RBI jest zwiększenie dostępności sprzętu przy jednoczesnym zwiększeniu lub utrzymaniu akceptowalnego poziomu ryzyka. W artykule omówiono pojęcie ryzyka i zasady analizy ryzyka oraz metodologię RBI, a także przedstawiono metodę pozwalającą na określenie optymalnej częstotliwości przeglądów obiektów technicznych na podstawie potencjalnego ryzyka, a przede wszystkim ilościowo określonego prawdopodobieństwa uszkodzenia. Podejście to wykorzystuje niektóre założenia stosowane w ustrukturyzowanym procesie podejmowania decyzji. Zaproponowana metodologia pozwala na optymalizację długości okresów między przeglądami,dając możliwość określenia czasu wykonania pierwszego oraz kolejnych przeglądów. Zastosowanie proponowanej metodologii zilustrowano przykładem numerycznym.

Słowa kluczowe: *analiza ryzyka, planowanie przeglądów warunkowane ryzykiem, częstość przeglądów.*

1. Introduction

In the last decades many strategies and methodologies were developed to help managers, engineers and technicians to make the best decisions in the maintenance field. Some of them are applicable for industry in general while others became a reference in a specific field or type of industry. In high risk industrial facilities there is a need for implementing a strategy that must combine safety and reliability with economy. Periodic inspections are usually performed as a maintenance activity to avoid unplanned plant shutdown, unsafe situations and consequent high costs due to unavailability.

To pursue this objective, in 1983 the American Petroleum Institute (API) initiated a project named Risk Based Inspection (RBI) as the result of a necessity to ensure acceptable levels of risk in the petrochemical facilities [3]. As a risk methodology, RBI can be used as the basis for prioritizing and managing the efforts of an inspection program. In the majority of industrial facilities a relatively high amount of risk is related with a small percentage of asset items. To apply maintenance efforts in a justified manner and inside a tolerable risk level, methodologies like RBI must be followed. A RBI program allows the allocation of resources for inspection activities to provide a higher level of coverage on the high risk items and an appropriate effort on the lower risk ones. The main goal of RBI is to increase equipment availability while improving or maintaining the accepted level of risk.

Usually the main difficulty is to determine the optimal inspection frequency. This is an important aspect once higher frequency corresponds to higher maintenance costs (but with lower risk) while lower frequency means an increasing risk although the inherent lower maintenance costs. To overcome this ambiguity it is necessary to create some kind of method to determine the appropriate asset inspection frequency.

The main objective of this paper is to present a methodology that can be used to determine and reach the optimal asset inspection frequency meaning that risk will be under a defined and desired level.

The paper is organized into four sections. Section 2 gives a brief description about the concept and principles of risk analysis, presents the RBI methodology and points out some applications of it. In Section 3 a methodology to determine the optimal inspection frequency is proposed, a demonstrative example of the methodology is shown and some discussion is performed. Finally, in Section 4 some conclusions are stated about the subject of the study.

2. Risk analysis and RBI methodology

As equipment will not remain safe or reliable if not properly maintained, the general goal of a maintenance process is to make use of the knowledge of failures and accidents to achieve the possible and accepted safety level with the lowest possible cost [4]. To this scope, process industry is increasingly making use of risk analysis techniques to develop cost and/or safety optimal inspection plans [14]. Sometimes risk management is based on safety standards but, as stated by Abrahamsen et al. [1], it does not give always the expected effect on safety due to budget constraints once it implies that other important measures to reduce risk are not applied. Risk methodologies generally define the risk of operating physical assets as the combination of the consequence of failure (CoF) and the likelihood or probability of failure (PoF), where the previous is related with the potential effects of an undesirable event for people, business and/or environment and the later one refers to the probability of occurrence of such event (failure).

2.1. Risk analysis

Most of times risk analysis is a complex task because it is a function of several factors. The way to perform it must be carefully selected taking into account the purpose of the analysis and the desired precision of the results.

While some failures frequently occur without significant adverse consequences, others are potentially dangerous although their low probability of occurrence. Organizations must focus on these two elements (PoF and CoF) together in a way to observe the risk and its acceptability. Acceptance can be based on some criteria such as ALARP (As Low As Reasonably Practicable), MEM (Minimum Endogenous Mortality) or GAMAB (Globalement Au Moins Aussi Bon). The ALARP criterion is the most used in practice because it is a flexible approach where the risk area is divided in three zones, which should be defined before the risk analysis [23].

In other situations, it is common to present a risk matrix where the acceptance criteria are established showing acceptable and unacceptable regions according to the achieved value of risk. These criteria may be a consequence of legislation or regulations or may derive from corporate safety and financial policies and constraints. If a particular risk is unacceptable, then some mitigation actions shall be considered such as decommission, inspection or condition monitoring, consequence mitigation or probability mitigation.

When performing a risk analysis the analyst looks at the available data and failure information regarding some equipment as a way to determine the PoF, which is usually based on statistical data. Most of time, to know the PoF for each situation is a hard job because several deteriorating mechanisms and failure modes can be present in a particular item at the same time or failure data can be given from a mixed population representing several failure modes. If statistical data is aggregate it is difficult to perform an accurate analysis and achieve objective results that can lead to the implementation of an effective inspection plan. The likelihood or PoF is often established on generic failure rate estimations, sometimes based on a compilation of available asset failure historic data from various industries, as for example Offshore Reliability Data [20]. These database failure frequencies must then be affected by specific field adjustment factors. Tien et al. [27] refer that these adjustment factors can be divided into equipment and management system factors. Others attempt to quantify the PoF with less subjectivity and model failures based on operational and organizational errors showing that direct causes of all accidents are combinations of human errors, hardware failures and external events [9]. Papazoglou and Aneziris [21] assess the effects of organisational and management factors linking the results of a safety management audit with the frequencies of basic events based on a quantified risk assessment (QRA). They apply this methodology on a chemical installation showing that it allows a reflection of the deficiencies or strengths of the safety management system. Also, Milazzo et al. [18] studied the organizational and management factors as variables that must be incorporated into the process of assessment of the frequency of failures, giving the example of a loss of containment due to a failure in piping and how to link its causes with the measures adopted by the company to prevent it.

If we are considering critical physical assets in a process industry, the CoF usually refer to the impact on safety, business and environmental issues. Kim et al. [16] present a study focusing on the status of risk management activities conducted by petrochemical plants in Korea and on the global trends in the area. In this work some interesting tables are shown referring major accidents in a period (1999-2001), insured loss, property loss and loss due to business suspension. This information can then be used to assess the CoF in a similar facility.

Risk analysis is a decision-oriented process consisting of risk assessment, risk management, and risk communication. Fig. 1 illustrates a logical process of a risk analysis.

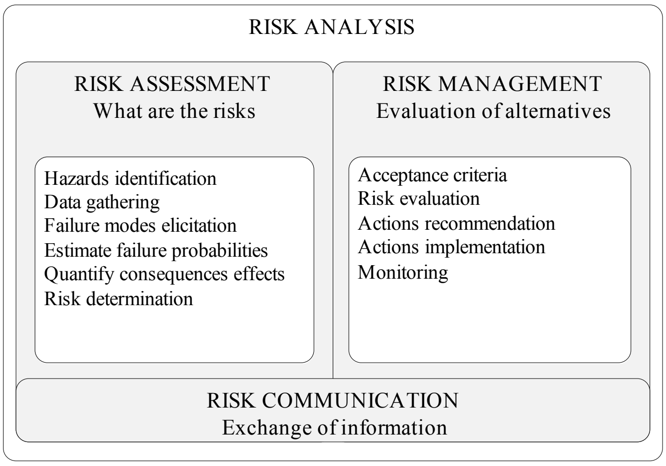

Fig. 1. Logical process of a risk analysis

From Fig. 1 it can be seen that a risk analysis process is a structured technique following a risk policy and ending on the implementation of actions leading to the reduction of the probability of failure and/or minimizing the effects of its consequences, if the achieved risk is considered as unacceptable. Risk analysis can be performed in a qualitative, semi-quantitative or in a quantitative way.

2.2. The RBI methodology

The main objective of RBI is basically to use the limited inspection and maintenance resources in coping with the really significant risks, once it is demonstrated and it is accepted that up to 20% of equipment items give rise to at least 80% of risk exposures [7]. Also, according to Lee and Teo [17] 10-20% of items give rise to 80-95% of equipment risk exposures. The same order of values is referred by Jovanovic [13] on his study about risk-based inspection and maintenance in power and process plants in Europe.

The purpose of RBI is to help the decision process, on prioritizing resources for inspection activities in a way to manage risk. Inspection does not directly reduce risk but it is a risk management activity that may lead to risk reduction. RBI complements other risk-based and safety initiatives such as RCM (Reliability Centred Maintenance), PHA (Preliminary Hazard Analysis), SIL (Safety Integrity Level), LOPA (Layer of Protection Analysis) or FMEA (Failure Mode and Effects Analysis).

An inspection strategy can be established taking into account the results of a risk assessment on the risk management process.

There are specific industrial areas where RBI methodology has been proposed in the last few years, which are basically referred to the oil and gas industry and nuclear power plants (NPP). In these industries the RBI methodology is usually focused on mechanical integrity of pressure equipment to minimize the risk of loss of containment due to deterioration. Pressure vessels, piping, storage tanks, rotating equipment, boilers and heaters or heat exchangers are examples of physical assets typically associated to a RBI process. The Section 2.3 shows some studies and examples of application of RBI methodology.

2.3. Typical applications of the RBI methodology

The current Section intends to demonstrate the potential capabilities of RBI methodology and the importance of inspection activity stating some examples of studies on different areas and involving distinct types of physical assets.

Singh and Markeset [26] tried to establish an RBI program for pipes, using a fuzzy logic framework estimating the rate of CO_2 corrosion in carbon steel pipes and taking into account the efficiency of inspection as a fuzzy variable where the goal is to estimate the rate of corrosion and use it to develop a risk-based inspection program.

Chang et al. [7] propose a RBI methodology aiming to optimize the inspection strategy of the piping at refinery and petrochemical plants in Taiwan. The goal of their work is to avoid under-inspection or over-inspection reducing risk and costs.

In the nuclear field, and still focusing in piping, a probabilistic failure analysis was done to find failures in piping segments, followed by a risk assessment [29]. At the end the risk levels corresponding to each pipe segment are ranked and an inspection program established.

A comparative study of two approaches was made by Simola et al. [25] to estimate pipe leak and rupture frequencies. The goal is to reduce inspection activities in some locations with low risk and concentrate efforts in higher risk zones. It is the risk-informed in-service inspection (RI-ISI). Some industrial applications of these approaches are referred in the paper.

Santosh et al. [22] refer a study where the goal is to obtain the failure probabilities for pipelines carrying H_2S (Hydrogen Sulphide) to establish a RBI program for heavy water plants. Corrosion due to H_2S is an important form of pipeline deterioration due to aggressive environments. It promotes metal loss reducing pipelines loading capacity.

In the same field Tien et al. [27] developed a risk based piping inspection guideline system built in accordance with international standards and local government regulations. The outcome of this work showed that most of the risk resulted from a small number of pipelines.

Noori and Price [19] present a risk approach to the management of boiler tube thinning based on inspection data, covering four boiler units of a power station over a period of five years. This data refers to the boiler regions where corrosion/erosion is the major cause of boiler tubes failure.

Chien et al. [8] propose a strategy for a semi-quantitative RBI applied to pressure safety valves installed in pressurized vessels. The authors present pressure safety valves characteristics from a practical point of view and its relationship to inspection and maintenance issues. Using statistical technique analysis the relationship of aging condition and some parameters was then performed and inspection intervals suggested.

Recently, the development of a two-stage inspection process for the assessment of deteriorating infrastructure was presented by Sheils et al. [24] based on the effect of the cost and quality of non-destructive testing tools to access the condition of infrastructure elements during their lifetime and where each stage of inspection is incorporated into a maintenance management model. According to the authors it was the first time that detection and sizing of an inspection were considered.

Bertolini et al. [6] present an application of a Risk Based Inspection and Maintenance process (RBI&M) which includes the work of a panel of experts composed by academic and refinery operators. The risk is analyzed assuming four impact categories (health and safety, environmental, economic and reputation). The results of such study reveal a clear necessity of improvement in maintenance quality indices.

RBI&M is also mentioned by Khan et al. [15] using in their work a fuzzy logic methodology to estimate risk by combining fuzzy likelihood of occurrence and its fuzzy consequence evaluation. The methodology is then based on aggregative risk analysis and multi attribute decision making.

Hulshof et al. [12] refer that RBI is an attractive method that had been applied at several Dutch power plants in the last ten years promoting a huge inspection interval extension.

Kallen and Noortwijk [14] present a decision making process using an adaptive Bayesian model to determine optimal inspection plans under uncertain deterioration corrosion damage mechanism. This model was exemplified for a pressurized steel vessel.

Another Bayesian approach is suggested by Giribone and Valette [11] computing the PoF assuming it as “the main driver for scheduling periodical inspections”. This article describes the theoretical principles yielding the calculation of the PoF prior to conduct an inspection and after performing it. In this work is referred the EU project RIMAP (Risk Based Inspection and Maintenance Procedure) which includes PoF determination.

RIMAP is also mentioned in a work produced by Bareib et al. [5] referring an European Guideline for optimized risk based maintenance and inspection planning of industrial plants. The authors also refer that RIMAP application in piping systems of power plants gives transparency to the decision making process.

RBI methodology has also promoted the development of various computer applications in order to facilitate their application in the field. For example Vianello et al. [28] presented a RBI software tool that encloses all functionalities for an easier management of the technical data, the Inspection Manager software. It allows to create in a short time an item’s list and the catalogue of items object of RBI study based on plant’s P&ID, process data, specifications, reports and maintenance historical data.

The above examples show that RBI has proved to be a very useful methodology for risk analysis in high risk industries, allowing controlling risks at relatively low costs. As it can be seen from the above literature review it has been applied to many industries, especially to static physical assets submitted to pressure and temperature and where lack of containment represents dangerous consequences and high failure costs. However, the methodology is increasingly being applied to other type of assets and fields with the appropriate adequacy.

2.4. The problem

Risk analysis is usually used to develop an effective inspection plan for facilities and their physical assets. These inspection plans include the inspection methods and technologies to be used, the extension of inspection, the inspection intervals and other risk mitigation activities.

Most of the situations described in the previous section have the objective to establish the referred inspection plans for the inherent assets under analysis. In these plans an important decision to take is the inspection interval. The majority of the studies presented determine a static inspection frequency, meaning that time between inspections is always constant. Some of them follow the American Petroleum Institute - Recommended Practice 580 [2], where the inspection frequency should be scheduled at the half remaining life or established on the basis of fluid content, depending whichever is shorter. However, this recommendation can lead to under-inspection of some high risk items or over-inspection with resources and cost waste on low risk items. In a recent study [10] referring the petroleum industry and regarding the determination of the frequency for testing safety instrumented systems (SIS) it was discussed whether the decision criteria of halving or doubling test intervals should be adopted for well barriers based on the comparison of the estimated failure rate and the failure rate in design. The authors suggested a new type of criterion incorporating the level of significance when deciding if the test interval should double or not.

Reality shows that risk is dynamic and thus inspection frequency must also be dynamic. This characteristic and premise is based on the constant change of the PoF once almost physical assets and their items had an increasingly probability of occurrence in time.

Therefore, the problem of establishing an inspection plan is to find a method to promote an adequacy of inspection intervals to the changing reality. Section 3 shows a methodology to determine the optimal physical assets inspection frequency based on risk principles.

3. Proposed methodology

The proposed methodology differentiates the period of time to first inspection (TTFI) from the subsequent inspection periods taking into account pre-established targets for PoF and tolerable or acceptable risk. This relatively new approach supports the main objective of the proposed methodology. Fig. 2 shows in a schematic way the framework of the proposal.

The main difficulty in risk analysis is concerned with the determination of each individual PoF. In this methodology the cumulative

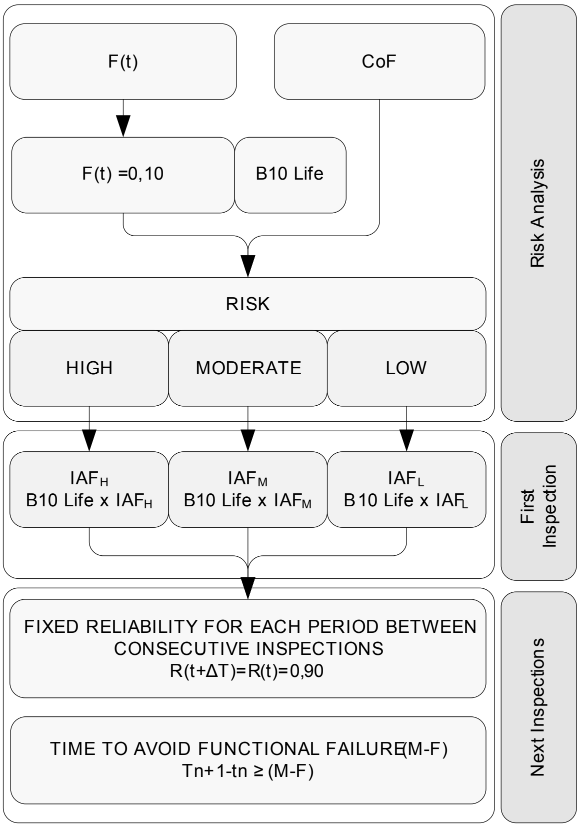

Fig. 2. Proposed methodology framework

failure probability function [F(t)] for each item is assumed to be calculated on reliability studies (life data analysis) or using generic failure frequency (GFF) from a reliable database, affected by modification factors, such as management factor, actual age, damage mechanism, environmental stress or inspection effectiveness.

After knowing the inherent F(t), a maximum value of probability of failure is then established. In this methodology it was stated a 10% maximum probability of failure, corresponding to the so-called B10 Life (the term was initially used to refer 10% of Bearings (B) life and later extended to other reliability studies, although remaining with the "B"). Then, calculating the severity of the consequence of failure (CoF) in a pre-defined scale (monetary, category or other qualitative measure) it is possible to localize the risk in a specific risk matrix.

The establishment of the acceptance criteria follows the API recommended practice 581 [3] where three regions are identified in the proposed risk matrix, namely:

- High risk zone;
- Moderate risk zone;
- Low risk zone.

Time to first inspection (TTFI) is applied to new items (for example after replacement or overall activities) and is established in accordance with risk category. In this case an Inspection Adjustment Factor (IAF) is applied to B10 Life distinguishing the potential risk from High (H), Moderate (M) and Low (L). In this methodology the IAF values were adopted as shown in Table 1. Each organisation is allowed to establish different IAF according to specific objectives.

Once determined the TTFI the following inspections should vary according to the potential failure mode under observation. The decision criteria used in the proposed methodology is based upon the principle that a constant conditional reliability should be maintained between two consecutive inspections and with a pre-defined value. Using this assumption and taking in consideration the conditional reliability expression

Table 1. Values adopted for Inspection Adjustment Factor (IAF)

Risk	Inspection Adjustment Factor (IAF)	Time To First Inspection (TTFI)
High	0.80	B10 Life x 0,80
Moderate	1.00	B10 Life x 1,00
Low	1.20	B10 Life x 1,20

$$R(\Delta t \mid T) = \frac{R(T+\Delta t)}{R(T)} \quad (1)$$

it can be stated that

$$R(T+\Delta t) = R(T) \quad (2)$$

This result can now be combined with any failure probability distribution based on available data. For example, due to its wide range of applicability on practical cases, if it is assumed a bi-parametric Weibull distribution with a probability density function expressed by:

$$f(t) = \frac{\beta}{\eta}.\left(\frac{t}{\eta}\right)^{\beta-1}.e^{-\left(\frac{t}{\eta}\right)^{\beta}} \quad (3)$$

Where β represents the shape parameter and η represents the characteristic life or scale parameter of Weibull distribution.

Reliability is given by:

$$R(t) = e^{-\left(\frac{t}{\eta}\right)^{\beta}} \quad (4)$$

In these circumstances the time for the n^{th} inspection can be expressed by:

$$t_n = \eta.\left[-\ln\left(R(t)\right)^n\right]^{\frac{1}{\beta}} \quad (5)$$

In this scope, three scenarios can be presented:

- If β < 1, which means a decreasing failure rate, $(t_{n+1}-t_n) < (t_{n+2}-t_{n+1})$;
- If β = 1, which means a constant failure rate, $(t_{n+1}-t_n) = (t_{n+2}-t_{n+1})$;
- If β > 1, which means a increasing failure rate, $(t_{n+1}-t_n) > (t_{n+2}-t_{n+1})$;

3.1. Demonstrative example

In an industrial facility an important item presents two distinct failure modes (FM#1 and FM#2) which failure probabilities can be represented by Weibull function with the following parameters:

Table 2. Weibull parameters

Failure Mode	β (Shape parameter)	η (Scale parameter) [h]	h(t) (Hazard rate)
FM#1	0.50	1500	Decreasing
FM#2	1.50	1500	Increasing

In accordance to the proposed methodology and with a maximum acceptable cumulative probability of failure of 0.1 between consecutive inspections a preliminary inspection schedule can now be established for each failure mode.

Table 3. Inspection schedule for FM#1

Inspection (n)	$R(t)^n$	Inspection Moment (t_n)	Inspection Period [t_n-(t_{n-1})]	F(t)	Hazard Rate [h(t)]	$R(t_n+\Delta t\|t_n)$
1	0.9000	16.65	16.65	0.1000	0.003164	-
2	0.8100	66.61	49.95	0.1900	0.001582	0.9000
3	0.7290	149.86	83.26	0.2710	0.001055	0.9000
4	0.6561	266.42	116.56	0.3439	0.000791	0.9000
5	0.5905	416.28	149.86	0.4095	0.000633	0.9000
6	0.5314	599.45	183.16	0.4686	0.000527	0.9000
7	0.4783	815.91	216.47	0.5217	0.000452	0.9000
8	0.4305	1065.68	249.77	0.5695	0.000395	0.9000
9	0.3874	1348.75	283.07	0.6126	0.000352	0.9000
10	0.3487	1665.13	316.37	0.6513	0.000316	0.9000

Table 4. Inspection schedule for FM#2

Inspection (n)	$R(t)^n$	Inspection Moment (t_n)	Inspection Period [t_n-(t_{n-1})]	F(t)	Hazard Rate [h(t)]	$R(t_n+\Delta t\|t_n)$
1	0.9000	334.61	334.61	0.1000	0.000472	-
2	0.8100	531.17	196.55	0.1900	0.000595	0.9000
3	0.7290	696.02	164.86	0.2710	0.000681	0.9000
4	0.6561	843.17	147.15	0.3439	0.000750	0.9000
5	0.5905	978.42	135.24	0.4095	0.000808	0.9000
6	0.5314	1104.87	126.45	0.4686	0.000858	0.9000
7	0.4783	1224.45	119.58	0.5217	0.000903	0.9000
8	0.4305	1338.45	114.00	0.5695	0.000945	0.9000
9	0.3874	1447.79	109.33	0.6126	0.000982	0.9000
10	0.3487	1553.14	105.35	0.6513	0.001018	0.9000

The results show in a clear way the influence of failure mode in inspection intervals and it is also noticeable that:

- When failure rate decreases, inspection intervals increase;
- When failure rate increases, inspection intervals decrease.

3.2. Discussion

If there is a lead time to failure (P-F interval) between potential failure (P) and functional failure (F), the establishment of inspection intervals should also take this information into account. Usually technicians adopt a constant interval for inspections with a frequency of half period between "P" and "F".

However, if we assume that between these two points there is an instant "M" that will be the ultimate time to detect a failure progression and provide measures to avoid the occurrence of a functional failure at "F", its detection must be obtained between "P" and "M". The proposed methodology should be followed while $(t_{n+1}-t_n) \geq (M-F)$. If this condition is not fulfilled then all inspections should be done in periods not less than (M−F).

Taking into account the demonstrative example of FM#2 for a high risk zone and assuming 100 hours as the necessary time act in a way to avoid functional failure, the inspection schedule can be determined as shown in Table 5.

For the above reasons, it can be seen that from the 6^{th} inspection on the inspection intervals cannot be less than 100 hours. Chronologically inspection schedule can be represented as shown in Fig. 3, where the white zone corresponds to (M−F) period and the darker one the remaining time or clearance between inspections.

However, if one follows this inspection schedule, it must be remembered that from the 6^{th} inspection (where the frequency is maintained at a constant value of 100 hours) our initial premise of having a constant conditional reliability of 90% in each period between inspections will not be fulfilled, meaning a higher probability of failure and an inherent higher risk.

Based on this reflection it is then recommended to act preventively when $(t_{n+1}-t_n) \leq (M-F)$, avoiding the functional failure due to the increased probability of failure.

Considering the above example (FM#2) when the item reaches approximately 884 operating hours an overall must be performed and from that a new inspection schedule must be implemented and followed.

Table 5. Inspection intervals

Inspection (n)	Initial Inspection Moment	Inspection Period (IP)	IP X IAF	**New Inspection Moment**
1	335	335	268	**268**
2	531	197	157	**425**
3	696	165	132	**557**
4	843	147	118	**675**
5	978	135	108	**783**
6	1105	126	101	**884**
7	1224	120	96 – 100	**984**
8	1338	114	91 – 100	**1084**
9	1448	109	87 – 100	**1184**
10	1553	105	84 – 100	**1284**

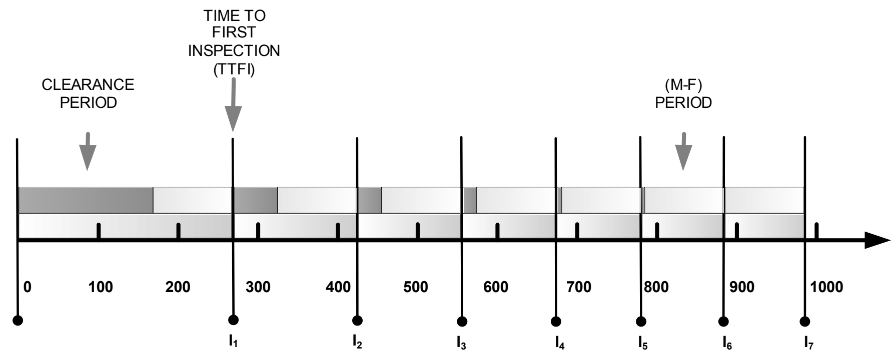

Fig. 3. Inspection schedule

4. Conclusions

Risk based inspection (RBI) methodology had been increasingly used in the last decade in risk assessment with great emphasis at petrochemical industry, power plants and nuclear plants. In this paper its importance was showed and some applications were referred. It is a method to manage risk reducing maintenance costs at the same time.

The great advantage of RBI methodology is based on the capability to determine different levels of risk in an installation and concentrate major efforts in inspection of items in accordance to these risks.

In this paper was proposed a methodology that accomplishes the API recommended practices and allows the establishment of different inspection periods taking into account an assumed constant probability of failure and putting emphasis on the separation of the first inspection and the subsequent ones. The methodology takes also into account the time period necessary to avoid a functional failure after an inspection.

Using this methodology one can create an inspection programme for each item or each failure mode and make decisions about preventive maintenance activities based on risk with an economic balance behind.

This methodology is flexible enough, being possible to change some values as the assumed probability of failure, the Inspection Adjustment Factor or the determination of subsequent times to inspect.

Future work will be focused on the harmonization of inspection programme with other maintenance activities and the evaluation of inherent costs.

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