Benefits of Risk Based Inspection to the Oil & Gas Industry

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ABSTRACT

A methodology for RISK BASED INSPECTION (RBI) has been developed by the American Petroleum Institute's (API) Committee on Refinery Equipment and Det Norske Veritas (DNV). This methodology has been documented in the "Base Resource Document for Risk Based Inspection" [1], which serves as the basis for the draft API recommended Practise RP 580 on application of RBI.

RBI combines knowledge of damage mechanisms and damage progression rates, inspection effectiveness with load and resistance models to determine the probability of failure causing leaks. It also combines the probability of failure with the consequence of failure to obtain the risk. Conventional risk assessment methodologies are used to assess the consequences of these leaks. A quantified ranking of process equipment and piping in terms of personnel and environmental risk, loss of production and damage cost, focuses the inspection towards high risk components and potential/active inspectable damage mechanisms for an optimal utilisation of inspection resources on key assets. In any plant a relatively large percentage of risk is usually associated with a small percentage of the equipment. A risk Based Inspection approach permits the shift of inspection and maintenance resources to provide a higher level of coverage on high-risk items and an appropriate effort on lower risk equipment.

In the refining and petrochemical industries, the use of risk analysis for inspection planning and as a decision making tool for cost benefit analysis (CBA) of inspection and maintenance activities is gaining industry acceptance. DNV has over the past three years conducted more than 100 RBI analyses of refinery units, petrochemical and chemical plants. This extensive experience shows that substantial cost savings can be achieved by optimisation of the inspection without compromising on safety.

This paper briefly presents the RBI methodology and gives examples from the industry that demonstrates the value of this novel technology.

1. INTRODUCTION

Recently the petrochemical and refinery sectors have been facing tougher safety and environmental regulations as well as challenges associated with need for cost reduction to improve competitiveness and ensure marginal returns in a situation of economic slowdown.

Under these circumstances management of operational risks, through utilizing of cost effective technology and best practises for inspection and maintenance planning is crucial.

RISK BASED INSPECTION (RBI) is the latest technology for cost effective maintenance and inspection. RBI prioritises these activities on the basis of risk. RBI should be considered in a wider perspective as a tool within the overall Risk Management. Leaks of flammable/hazardous material may originate from a variety of causes, and material related damage which is considered by RBI, is only one of these causes. Important other causes for leaks can directly or indirectly be associated with process upsets, failure of control systems, operator errors, incorrect operation, improper job training, lack of procedures for maintenance, bad weather conditions, etc. Inspection cannot prevent leaks associated with these causes however, statistics show that 40-50% of losses due to leaks in the Hydro Carbon industry can be attributed some form of mechanical failure, hence inspection is an important activity to prevent failure.

2. METHODOLOGY

Analysing all equipment items in a plant can be a time consuming effort; thus methods should be used to minimise the work and to focus on the high risk items. A screening of the plant systems in terms of risk is an efficient tool for this – the screening involves a qualitative RBI analysis. The systems 'screened out', i.e. systems with low risk will be candidates for corrective maintenance. The systems/items 'screened in' will be analysed in more detail using a quantitative technique. In this way time and effort are saved in the data gathering process for low risk items. For detailed inspection planning and in particular for cases where one wishes to extend the inspection intervals beyond code or statutory requirements, a detailed analysis approach, should be applied in combination with a more rigorous remaining life assessment i.e. refer to API 579, than ordinary code (API 510/570 or 653) calculations.

2.1 Qualitative Analysis

The screening process is done in close co-operation with the operating company and should involve experienced personnel from the plant (inspection, operation and materials) in addition to personnel with RBI assessment experience. This may be organised in structured working sessions.

The first step of the analysis is to determine a factor representing the ***probability of failure*** within the selected area, then a factor for ***the consequences of failure***. The two categories of factors are subsequently combined in the risk matrix to produce a risk rating for the unit.

The risk matrix results, see Figure 1, can be used to locate areas of potential concern and to decide which portions of the process unit need the most inspection attention or other measures of risk reduction. This approach shows at a glance the number of equipment items that are high or low risk, as well as whether the risk is dominated by likelihood of failure (a good candidate for inspection) or consequence of failure (a good candidate for mitigation), or both. Likewise components with low risk are identified and assigned a corrective maintenance strategy.

The Qualitative method [1] also gives guidance on the inspection interval for the various locations on the risk matrix as shown in Figure 2. It is recommended that detailed RBI should be performed for items where the likelihood category is Medium High or High.

2.2 Quantitative Analysis

The quantitative RBI approach commences with the extraction of process, equipment and other information from the plant management database, PFDs, P&IDs, material balance, inspection records. Then each equipment item within the area of interest is evaluated with regard to probability of failure, consequence of failure and remaining life. The consequence and probability for each scenario are combined to obtain the risk. Both current and future risk is estimated and based on the risk prioritisation the inspection efforts are focused, aiming at opportunities to reduce overall risk and cost.

2.2.1 Probability of Failure Analysis

The probability of failure analysis addresses the material degradation that may take place in the various components. This is done by considering the environment/material interaction, actual design data, operational history, experience with this or similar services, etc. Figure 3 illustrates the different elements of this analysis. The purpose of the analysis is to identify:

- potential damage mechanisms
- failure modes
- damage rates
- present condition of equipment
- damage tolerance
- remaining lifetime

This information is systematised and documented following the approach and methodology developed by the API Committee on Refinery Equipment. The methodology has been laid down in the API Base Resource Document on Risk Based Inspection (API 581) [1]. The information is analysed using different "Technical Modules" where the necessary conditions for failure are described as well as a procedure for calculation of the probability of failure. The most common failure mechanisms covered by the methodology are:

- External corrosion i.e. general or localised atmospheric corrosion, corrosion under insulation (CUI) etc.
- Internal corrosion i.e. general and localised corrosion in various environments (hydrocarbons containing water, sea water, water-injection systems, CO_2, Hydrochloric-, Sulphuric-, and Hydrofluoric acids, etc.)
- Stress corrosion cracking in various environments (Caustic, Amine, Chlorides, H_2S, etc.)
- High temperature phenomena (oxidation, hydrogen attack, thermal fatigue, creep, etc.)
- Fatigue caused by vibration and flow effects (slugging/choking)

New mechanisms can be added as required if the physical behaviour of the degradation can be described by a mathematical model.

The calculation method for probability of failure associated with the failure mechanisms is based on Structural Reliability Analysis (SRA) [2], where the stochastic uncertainty in the basic variables, in particular the uncertainty in the determination of the damage rate and the inspection effectiveness, are taken into account. An important feature of this theory is its ability to include both the prior damage estimates and the outcome from the inspections in the derivation of the updated posterior probability of failure (Bayes' Theorem).

The level of information gained from an inspection depends heavily on the quality and extent (coverage) of the inspection carried out. The inspection quality is modelled either by discrete probabilities for the inspection effectiveness (i.e. the probability that the inspection method will detect the ongoing damage) or by Probability of Detection (POD) curves [3] for the inspection method applied. The latter defines the probability of detecting existing degradation as a function of the characteristic dimension of the degradation.

2.2.2 Consequence Analysis

For a process plant, the most important consequence elements are the personnel safety and the financial loss due to shut-down or deferred production.

In the API BRD approach a simplified consequence modelling methodology is applied. The methodology is based on an event tree approach, similar to that applied for standard Quantitative Risk Assessments, with pre-simulated effect-scenarios. The five main consequence categories are (see Figure 4):

- Flammable events (fire/explosion)
- Toxic Releases
- Environmental Risks (cost of environmental clean-up)
- Business Interruption (lost/deferred production)
- Asset repair after failure

Cost data related to lost production, outage, asset repair, adjacent repair and environmental clean-up are used to calculate financial risks.

2.2.3 Risk Ranking

Risk is a function of probability and consequence of failure. Both consequence and probability of failure are categorised in 5 groups giving a total of 25 risk combinations. Iso-risk lines are set-up and categorised from "Very Low" to "Very High". The risk matrix allows comparison of components at a given point in time and helps prioritise the effort between different components.

The consequence of failure can be split into two main categories; one related to personnel safety and one related to economic losses. Some companies choose to combine the two risk categories into one, whereas others prefer to handle the two separately. For operations where the company and/or legislation sets safety requirements in terms of limits on Potential Loss of Life (*PLL*) or Fatal Accident Rate (*FAR*), the two risk categories should be separated. The overall safety requirement(s) can then be converted to an acceptance line in the safety risk matrix and used for inspection/maintenance planning as indicated in Figure 5. For components above the acceptance line, actions should be taken to reduce the risk. For components below and for all components with only financial risk, a cost optimisation scheme should be considered.

3. RISK BASED INSPECTION PLANNING

3.1 Risk Reduction by Inspection

The starting point to evaluate different inspection programs is to calculate the probability of failure for the different damage states, accounting for the previous inspection results and the maintenance history of the equipment.

The effectiveness of the inspection methods to detect the damage mechanisms is evaluated and characterised based on five inspection effectiveness categories: Highly effective, Usually effective, Fairly effective, Poorly effective and Ineffective.

Assignment of categories is based on professional judgement and expert opinion. One of the most important criteria is the capability of the inspection methods to detect the characteristics of the relevant damage mechanisms. The damage mechanisms considered cover:

1. Thinning (external corrosion, corrosion under insulation (CUI) and internal corrosion)
2. Surface-connected cracking
3. Subsurface cracking
4. Microfissuring/microvoid formation
5. Metallurgical changes
6. Dimensional changes
7. Blistering
8. Material property changes

3.2 Inspection Planning Techniques

The risk ranking is a method to prioritise the equipment. This prioritising has to be followed by specific actions to control the risk by inspection and condition monitoring. Ideally a cost optimisation should be performed for every item of equipment. For petrochemical plants and refineries where the API BRD and DNV methodology and software (API Level III or DNV's proprietary software ORBIT™2000) are applied for inspection planning, the inspection planning can be automated and performed item by item by the computer based on pre-defined risk reduction criteria. The number of inspections and the inspection interval is determined considering both the ***remaining life*** and the risk reduction which conveniently can be done by evaluating the effect of the inspection programme on reducing the ***Damage Factor.*** This distinguishes the API / DNV approach from other approaches for inspection planning which only consider the code calculated remaining life and the qualitative risk matrix. Such approach is not safe for high risk HC plants where multiple damage mechanisms are active. This is illustrated in Figure 6.

3.3 Risk Based Inspection Optimisation

The cost optimal level of inspection may be determined based upon cost-benefit analyses identifying which equipment item should get thorough inspection and which should get little or none. If the analysis reveals that high levels of inspection activity are required for some equipment, often the inspections can be "paid" for by the savings generated by reduced inspection activity on low risk equipment.

Inspection optimisation involves focusing the inspection efforts in order to reduce risk of failure and save cost. Hence, an essential part of the inspection optimisation is to establish the most cost-effective approach satisfying the failure acceptance or acceptable probability of failure criterion. The key to inspection optimisation is to use the method of probabilistic inspection updating, being a central part of the RBI concept. The methodology to establish the inspection interval is based on selected combinations of inspection methods i.e. inspection effectiveness, number of inspections and inspection intervals that can ensure that the risk (area or financial risk) is reduced by a certain factor depending on the location in the Qualitative risk Matrix, as shown in Figure 7.

For defects not acceptable based on code requirements, a Fitness-For-Service (*FFS*) option is included to assess the criticality of inspection findings, employing less conservative and more detailed assessment procedures than the generally conservative acceptance criteria of the design, inspection, repair, maintenance and alteration codes. *FFS* methodology is also applied to estimate remaining lives of equipment items less conservatively than that based on the methods specified in the codes.

Application of *FFS* contributes to further cost savings as expensive repair can be deferred or avoided and the useful life of the plant can be extended whilst maintaining risk at an acceptable level.

EXAMPLES OF RBI FOR PROCESS PLANTS

4.1 Types of process units analysed by DNV

The more than 100 RBI analyses performed by DNV to date cover a wide range of different process units, as shown in Table 1.

Table 1. Different types of process units subjected to RBI analysis by DNV.

Type of plant	Type of unit
Refinery	Crude and Sweet Crude units FCCU units and partial FCCU units

	Oleflex units Hydrofining units Hydrotreating units Hydrocracker units Naphtha Cracker units Heavy oil cracker units Coker units HF Alkylation units and Sulphuric Acid Alkylation units Paraxylene units Orthoxylene units Sulphur recovery units Gas oil treater units Gas treating units Butane isomerization units Toluene units
Gas processing plants	LNG units LPG units
Petrochemical and chemical plants	VAM units Ethylene units and Ethylene oxide units Paraformaldehyde units and weak formaldehyde units CO and MO-3 units VCM Chlorination units
Offshore topsides	Oil and gas processing units, FPSOs

In the following examples of some of the types of units that have been analysed by DNV are presented.

4.2 Coker unit

This case study illustrates how RBI can be used to reduce risk and optimise the inspection budget for a coker unit [4].

The RBI study was performed to determine which equipment would require inspection over the next 4 years based on an established risk criteria. The analysis was performed in advance of a scheduled fall shutdown to evaluate the equipment needs for inspection to safely operate for the next four years and to evaluate the impact of the proposed inspection plan on cost and risk.

The deliverables of the study included:

1. Identification of the active damage mechanisms and susceptibility affecting the Coker unit equipment.
2. Qualification of the overall unit risk, likelihood of failure and consequence of failure for each equipment item.
3. Development of an inspection plan detailing the inspection methods and coverage for each equipment item based on the damage mechanisms and rate of damage expected.

The results of the study, refer to Figure 8, showed that the future financial risk after the targeted four year run could be reduced by 87.7% by conducting optimised inspection at the start of the period

By redirecting the inspection resources to the high risk items, 43 pieces of low risk equipment were removed from the T/A intrusive inspection worklist and 13 were added, showing a net total of 30 equipment items being removed from the intrusive inspection worklist. The overall maintenance and inspection budget savings amounted to $ 225,000 at an investment level of $ 50,000 for the RBI study giving a Cost Benefit of $ 175.000 and corresponding to a return on investment ROI ratio of 3.5:1.

The 13 equipment items added to the worklist represented unacceptable risk due to active damage mechanisms not previously identified in the unit. These equipment were inspected for wet H_2S cracking and blistering based on the corrosion and materials engineering review performed during the RBI study. Inspection later revealed one drum with significant wet H_2S damage that had gone undetected by previous inspections.

Table 2. Scope of RBI study of coker unit.

Type of equipment	**Number of items**	**% of Total**
Drums and Towers	66	10
Heat exchangers	51	7
Piping segments	571	83
TOTAL	688	100

4.3 Naphtha hydrotreater unit

A common industry practise involves inspection of the equipment at fixed inspection intervals, seldom taking into account of 20-30 year design life, past inspections, operating and maintenance experiences for similar equipment operating in same type of service [4].

The inspection intervals for those equipment was set at four years. Since the unit was originally commissioned in 1994, the operator used RBI methodology to study the impact of postponing the scheduled shutdown for 2 additional years.

The RBI study included 116 equipment items covering reactors, heat exchangers, drums and piping. Likelihood of failure, consequence of failure (loss of containment/leaks) and risk were calculated in terms of injury to employees, production loss, equipment damage and overall financial risk exposure.

Current (1998) risk values were calculated and compared to the corresponding risk for a two year look-ahead before and after optimised inspection. The current and projected future risks are presented in Table 3.

Table 3. Current and future risk projections before and after inspection for Naphta hydrotreater unit

	Year 4 (1998)		Year 6 (2000) Before inspection		Year 6 (2000) After inspection	
Risk Rankings	**Items**	**% of Total**	**Pieces**	**% of Total**	**Items**	**% of Total**
High	15	12.93	17	14.66	8	6.90
Medium High	58	50.0	56	48.28	62	53.45
Medium	43	37.07	43	37.07	46	39.66
Low	0	0	0	0	0	0
Equipment Total	116		116		116	

Only 16% (19 pieces) of the 116 covered by the study required inspection to satisfy the risk criteria established for this unit. This involved equipment classified as "High" and "Medium High" risk due to susceptibility to thinning (localised and general), sulphide stress cracking and wet H_2S damage. The detailed inspection plans developed on basis of the RBI guideline involved visual inspection, ultrasonics, radiography, automated ultrasonics, magnetic particle and eddy current testing. Inspections were recommended as on-line inspections prior to the 2000 scheduled shutdown and as intrusive inspection during the T/A shutdown.

As a result seen in Table 3, the "High risk" equipment will be reduced from 12.93% in 1998 to 6.90% in year 2000.

The inspection related Cost Benefits associated with this unit study were reduced by a conservative $ 108,334 per year. The overall T/A related costs averaged per year based on inspections at 4 and 6 years, are shown in Table 4.

Table 4. Turnaround costs, averaged inspection costs at 4 and 6 years inspection frequencies and annual cost savings assuming 6 years inspection frequency.

Turn-Around Costs	Cost/Year @ 4 Year frequency	Cost/Year @ 6 Year frequency	Annual Savings	Cost of RBI Study
$2,500,000	$625,000	$416,666	$108,334	$30,000

4.4 Crude unit

In general refineries have increased the corrosivity of crude slates over the last 10 years. In the continuing drive to improve profitability, one refinery requested DNV to evaluate the impact of increasing sulphur and naphtenic acid crude content on equipment life, inspection requirements and operating cost projections for a sweet crude facility [4].

The refinery typically runs at 0.1% sulphur with naphtenic acid 0.15 TAN. The refinery unit has experienced few corrosion problems over the past 30 years of service. DNV conducted a study to evaluate the impact of increasing crude sulphur and naphtenic acid composition with the objectives to:

1. Identify equipment that would experience significantly increased corrosion as a result of the crude slate changes.
2. Quantify the impact of the test crude slates on unit risk compared to the current operation.
3. Quantify potential inspection and maintenance cost increases when compared to the current inspection programme.
4. Provide guidelines and recommendations to manage equipment risk in the future.

A quantitative RBI study was conducted and a computerised model of the plant was established that could be used to evaluate impact on operational risk of changes to input parameters, such as changes to the feed corrosivity. The plan period selected for this study was 10 years with start of the period in 1998. Three representative crude slate characteristics were analysed:

- 0.1% Sulphur and 0.15 TAN
- 0.5% Sulphur and 0.28 TAN
- 0.8% Sulphur and 0.67 TAN

No changes in the operational conditions or velocities were assumed associated with the compositional changes [4].

The results of the analysis with regards to changes to risk categories associated with the feed changes, have been summarised in Table 5.

Table 5. Risk ranking at the end of the 10 year plan period for the different crude slates evaluated [4].

	Equipment Count (10 Year Plan)			
Risk Ranking	**Current**	**0.1% S; 0.15 TAN**	**0.5% S; 0.28 TAN**	**0.8% S; 0.67 TAN**
High	3	4	7	14
Medium High	25	51	63	61

Medium	337	314	303	298
Low	125	121	117	117

The impact of processing the different corrosivity crude through the crude unit can be analysed on the basis of financial risk for each feed. As shown in Figure 9, the financial risk of processing 0.5% and 0.28 TAN would be 19% higher than for processing 0.1% and 0.15 TAN crude over the 10 year plan period. If we compare the financial risks of processing the 0.8% sulphur and 0.67 TAN crude versus the 0.1% sulphur and 0.15 TAN crude we find that the financial risk is increased by 77%. The annual inspection costs would increase by a factor of three assuming the above financial risk per year per equipment item is kept at the same level as for the 0.1% sulphur 0.15 TAN crude, this is illustrated in Figure 10.

4.5 Cost Benefit of RBI and shift in inspection focus

To further illustrate the benefit of RBI it is also referred to Figure 11 where the investment for the RBI analysis, the maintenance and inspection cost savings are compared to the actual and potential cost savings for a chemical plant, two refinery units and a gas processing plant unit.

For some units it has been found necessary to undertake significant changes to the inspection and maintenance routines. A typical example is from a refinery in USA where the RBI analysis of 5 plant units identified potential H_2S blistering and HIC/SOHIC which had not been addressed effectively by the existing inspection programme. For some of the other units it was found that the current inspection was not necessary and that for other units the inspection could be performed on-line rather than as intrusive inspection. The shift in inspection and maintenance cost spendings before and after implementation of the inspection/maintenance programme specified based on the RBI analysis, is shown in Figure 12. The overall savings for this particular project amounted to US $ 1,571,204 at investment of US $ 207,050 which corresponds to a ROI 8:1. The average risk reduction achieved for the five units was 72%.

The refinery unit example discussed above illustrates that RBI in some cases can lead to higher inspection costs for some plant units or individual equipment items but that the overall savings may still be significant and that a substantial risk reduction can be achieved by implementing the recommendations from the RBI analysis.

CONCLUSIONS

- Risk Based Inspection gives management the tools needed to make cost/benefit decisions regarding inspection and related maintenance activities; hence RBI is a subset of Risk Based Management, using risk as the criterion for action or inaction for any activity affecting safety or reliability of equipment.

- Risk is a good criterion for prioritising inspection efforts because :
  - Highest priority items are easily identified as the highest risk items
  - Risk can be measured as economic loss (or gain from reduction of risk)
  - Inspection and maintenance activities can be justified on a cost/benefit basis

- DNV's experience shows that application of RBI methodology can lead to substantial cost savings for the refineries and petrochemical industry in terms of reduced time required for turnaround inspection and by specification of optimised on-line inspection to replace intrusive inspection.

- However, the cost optimisation should not only be focused on reduction in the direct inspection costs, but on an overall risk cost reduction. This may in some cases lead to higher inspection costs for some plant units or individual equipment items.

REFERENCES

[1] API Committee on Refinery Equipment: *"Base Resource Document on Risk based Inspection"*. Prepared by DNV Industry Inc. Houston Texas January 1998.

[2] Madsen, H.O., Lind, N.C. and Krenk, S., *"Methods of Structural Safety"*, Prentice-Hall, Engelwood Cliffs, N.J. 1986

[3] Førli, Olav*: "Development and Optimization of NDT for Practical Use-Reliability of Radiography and Ultrasonic Testing*". 5th Nordic NDT Symposium, Esbo, Finland 1990, 26-28 August, NORDTEST

[4] Alvarado, Greg, Kaley, Lynne and Valbuena, Richardo R.: "Risk Based Inspection Demonstrating Value".

Paper Presented at NACE'99

[5] Mohamad Husni Wahid: "Risk Based Inspection – GPP experience"

Paper presented at Petronas Carigali (PCSB-KRO) RBI Workshop 17-19 May 1999, Kerteh, Malaysia

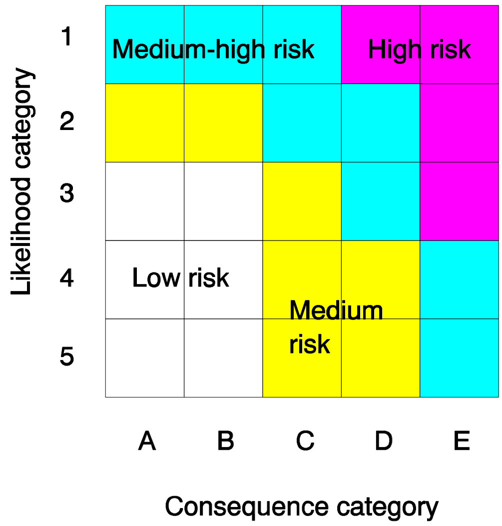


Figure 1. Qualitative Risk Matrix

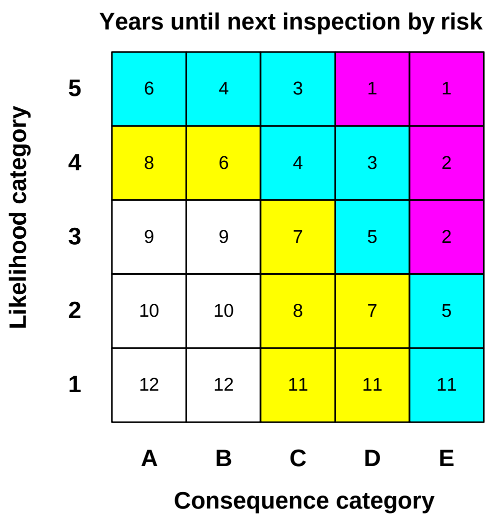


Figure 2. Qualitative inspection planning according to the API BRD [1].

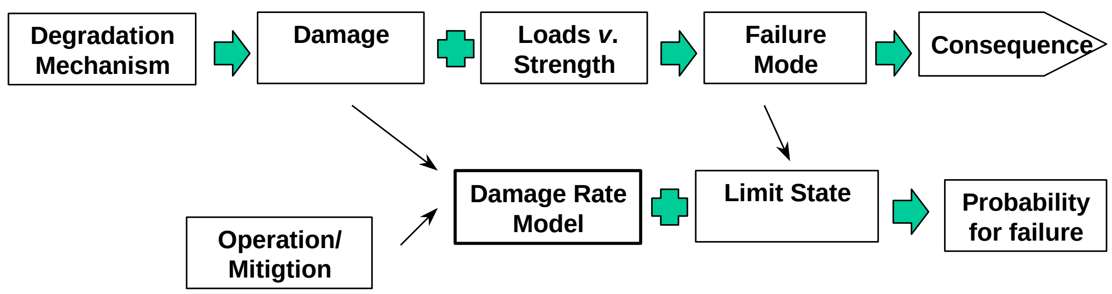


Figure 3. Elements in the Probability of Failure modelling

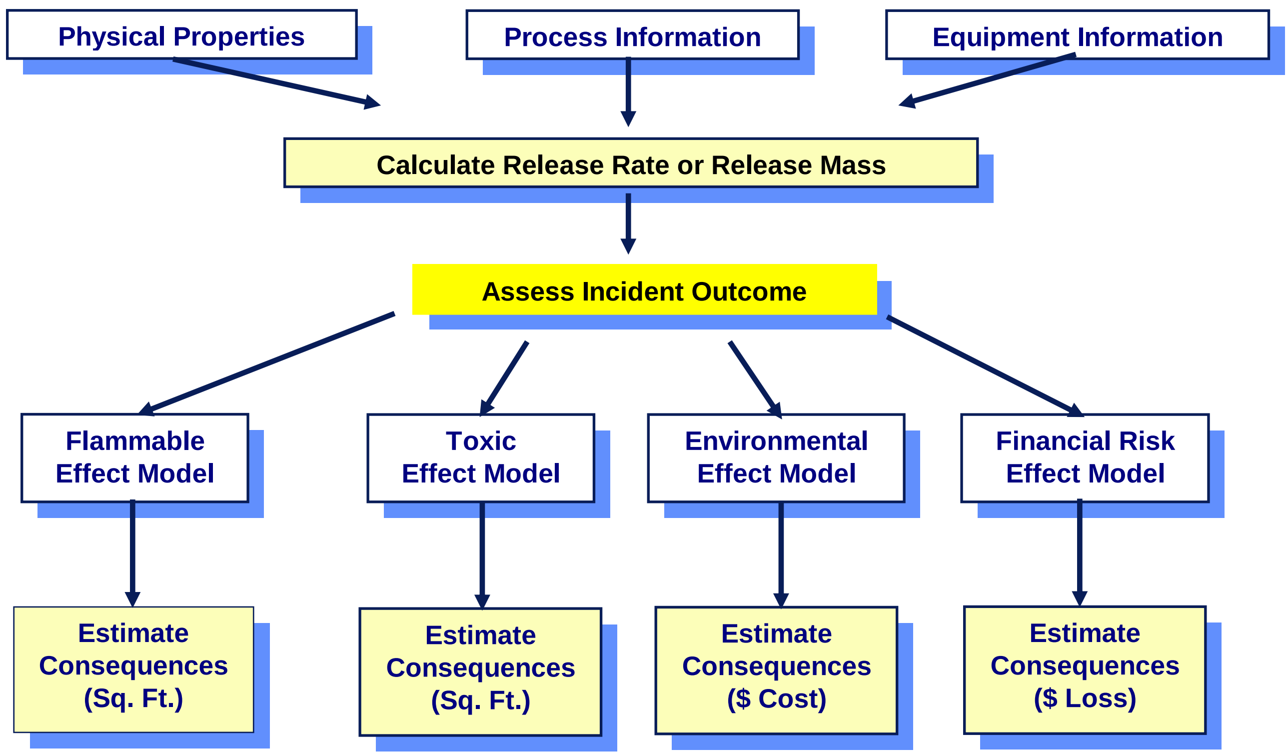
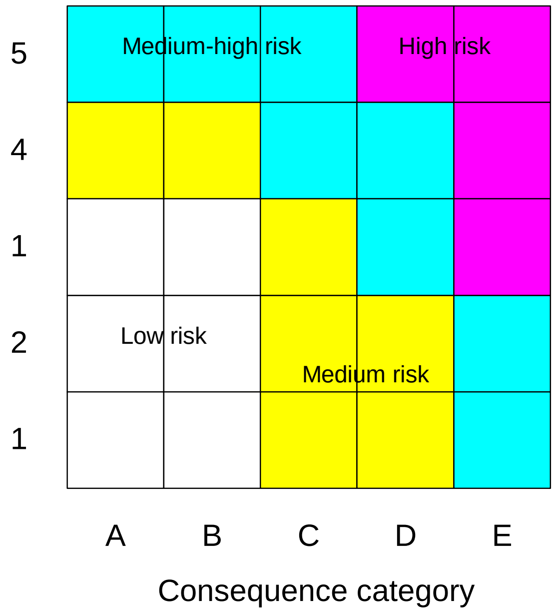


Figure 4. Consequence Calculation



Likelihood Category	Likelihood Factor	Consequence Category	Consequence Area (sq ft)
1	=<1	A	=< 10
2	>1-10	B	>10 – 100
3	>10 - 100	C	>100 –1000
4	>100 - 1000	D	>1000 – 10000
5	>1000	E	>10000

Figure 5. Quantitative risk ranking matrix.

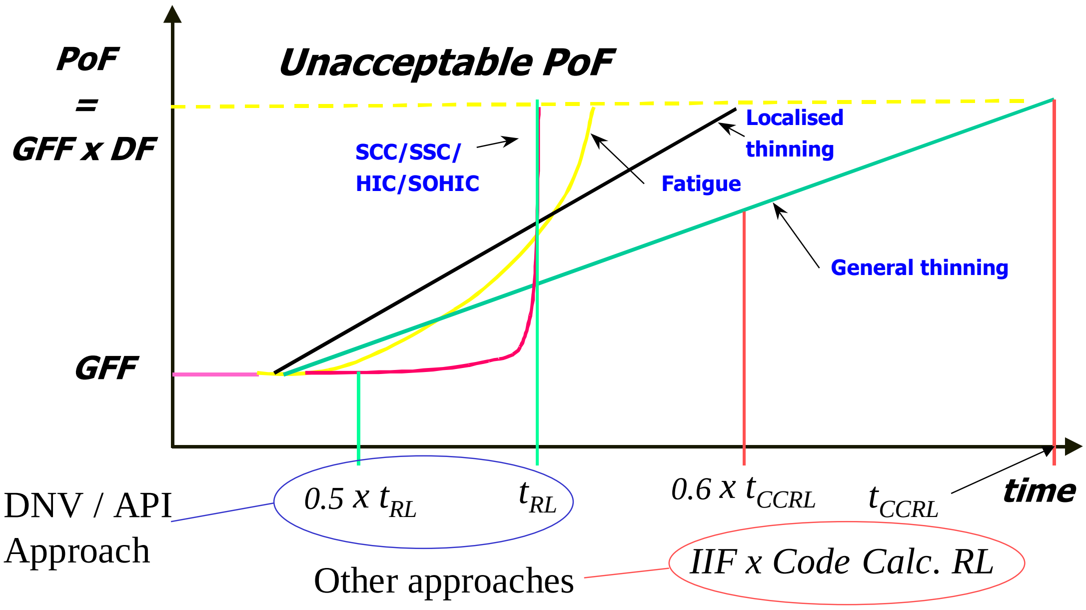


Figure 6. The difference between the API / DNV approach for determining safe inspection intervals and other approaches.

Risk reduction factor

Likelihood category	A	B	C	D	E
5	3	3	5	1	25
4	2	2	5	5	25
1	1	1	2	5	10
2	1	1	1	1	2
1	1	1	1	1	2

Consequence category

Figure 7. Risk reduction factors for establishing inspection effectiveness, number and frequency of inspection for the quantitative method

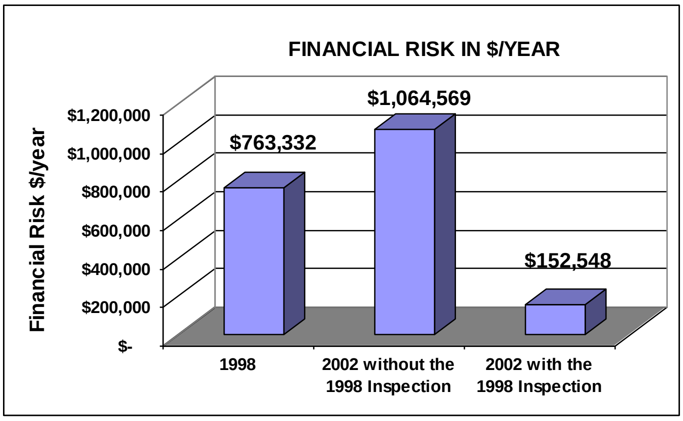


Figure 8. **Financial risk for Coker unit based on 1998 analysis and 2002 look-ahead without and with optimised 1998 inspection programme.**

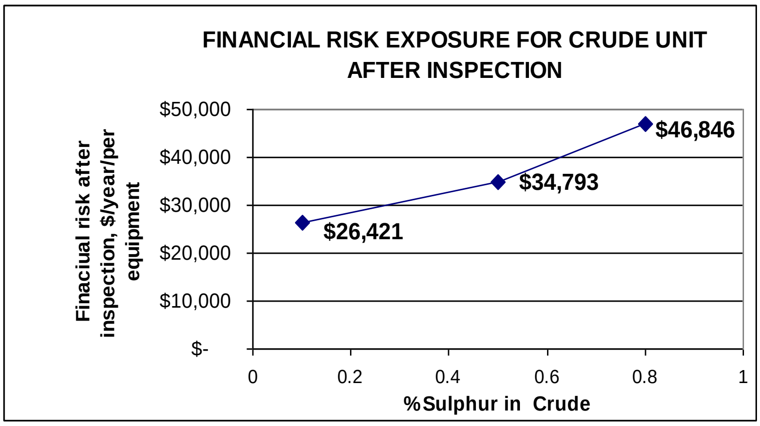


Figure 9. **Estimated annual risk exposure for Crude unit at different crude sulphur contents after inspection, based on a 10 year plan period.**

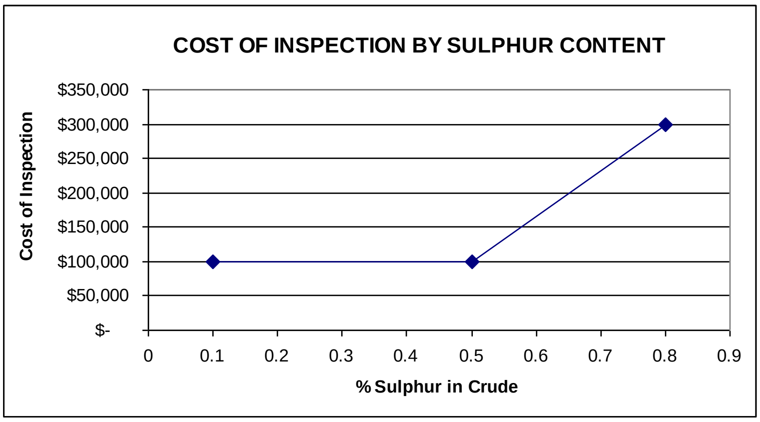
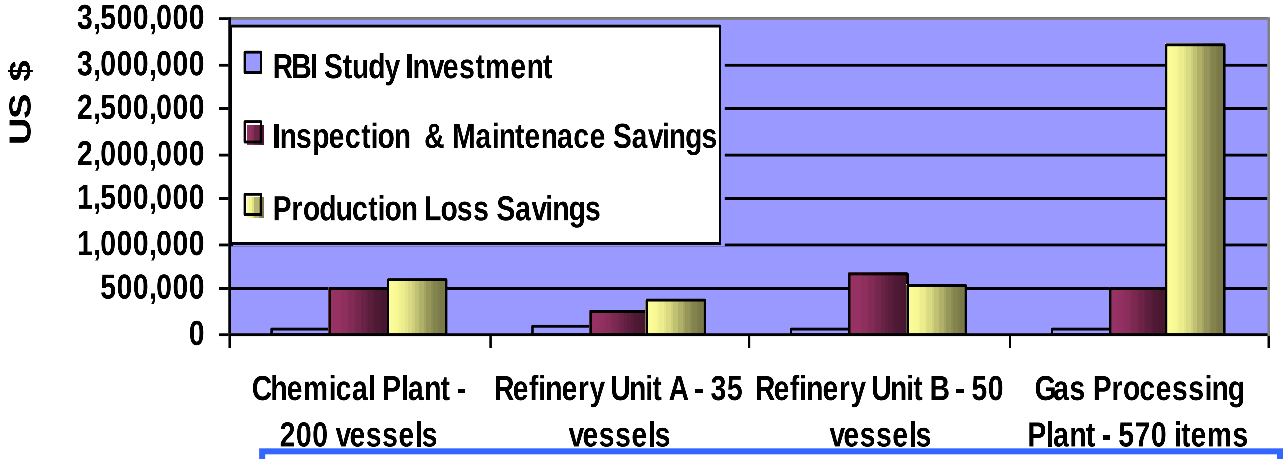
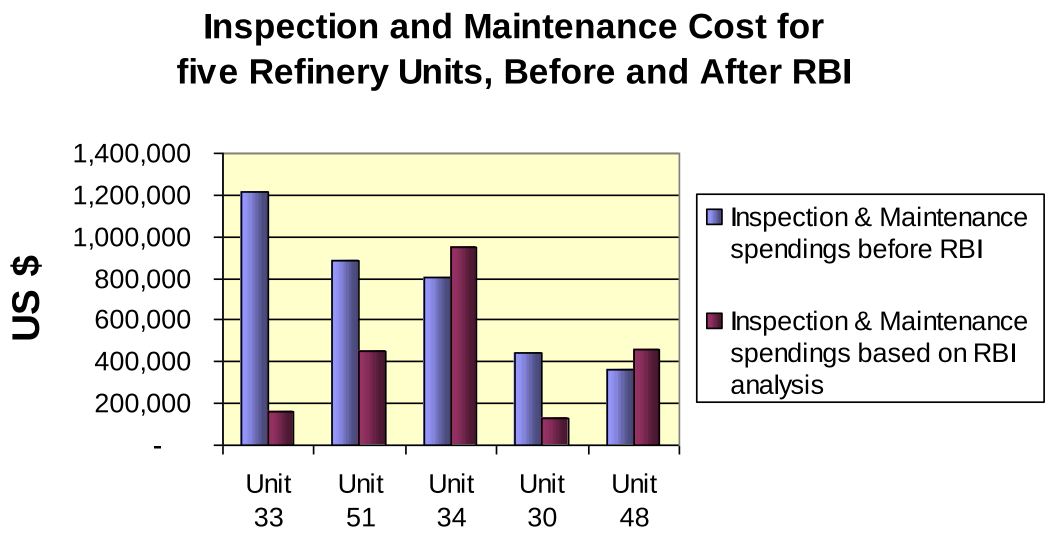


Figure 10. **Estimated cost of inspection as a function of crude sulphur content.**



Total Savings			
$1.1 M	$0.65M	$1.25 M	$3.6 M
ROI = 22:1	ROI = 8:1	ROI = 19: 1	ROI = 56:1

Figure 11. **Cost benefit of RBI analysis for chemical plant, two refinery units and a gas processing plant. It is seen that the greater the production loss savings the greater the benefit in terms of the ROI of the RBI implementation. Overall savings US $ 1,571,204 at investment of US $ 207,050**



ROI: 8:1 Average risk reduction 72%

Figure 12. **Change in client's maintenance and inspection spendings for five refinery units as results of shift in focus of inspection based on RBI analysis.**