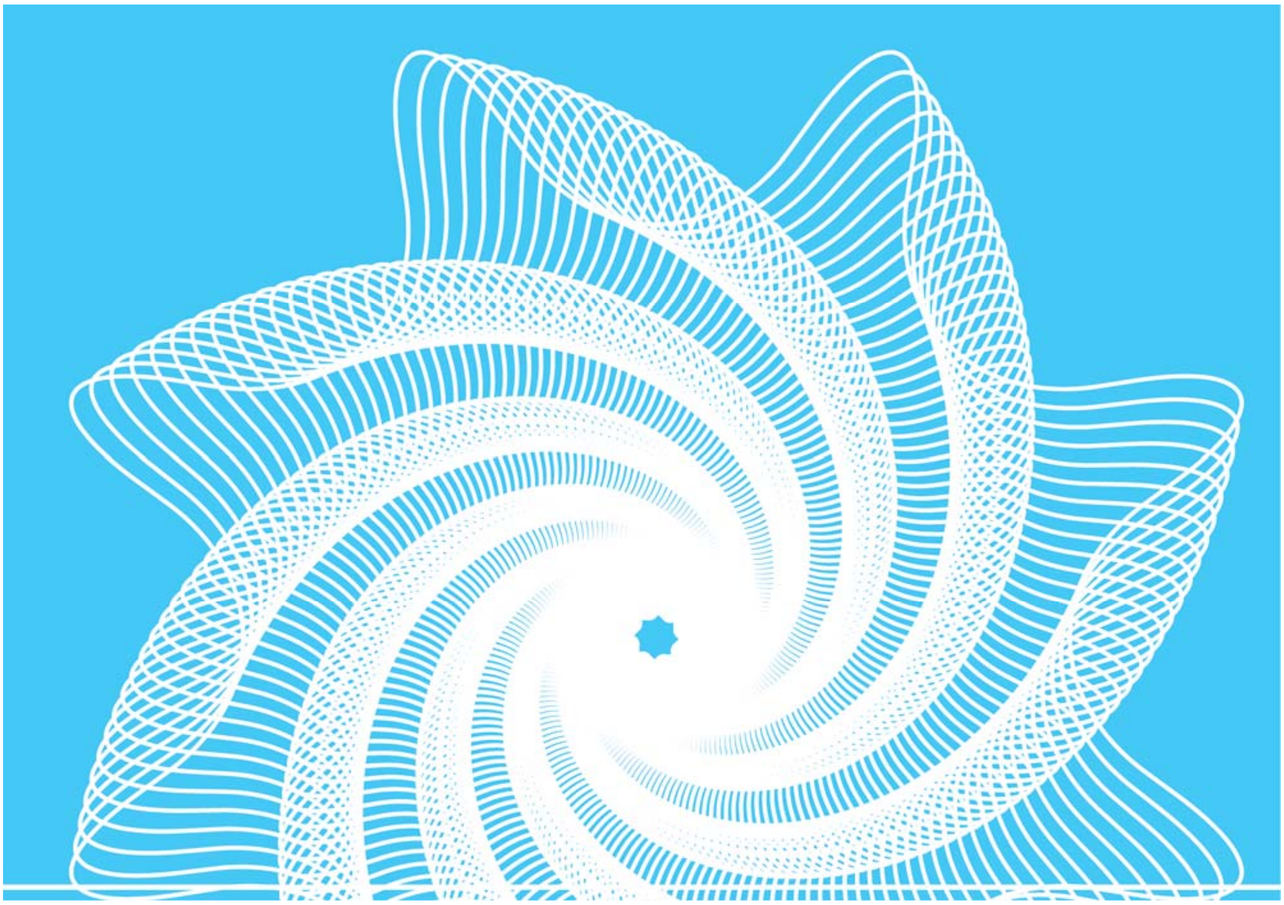
WHITEPAPER

RISK BASED INSPECTION METHODOLOGY FOR ATMOSPHERIC STORAGE TANKS

Author: Panos Topalis, DNV GL - Software



SAFER, SMARTER, GREENER

Reference to part of this report which may lead to misinterpretation is not permissible.

No.	Date	Reason for Issue
1	2014-02	First issue
2	2017-09	Revision and re-branding

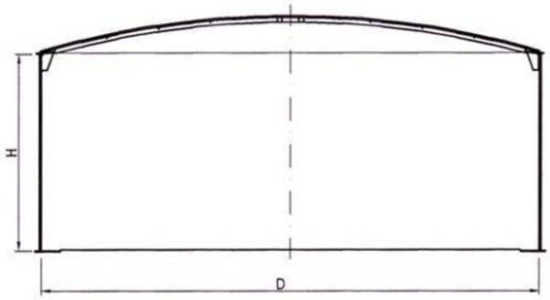
Date: September 2017

Branded by DNV GL - Software

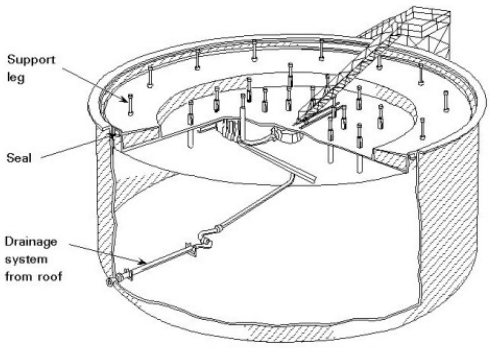
INTRODUCTION

Atmospheric Storage Tanks (ASTs) are significant and common equipment items in the oil, chemical and transportation industry. Figure 1 shows two common types of tanks, one with a fixed roof and another with a floating roof. ASTs are often used to store very large amounts of inventory, mostly flammable liquids and sometimes toxic liquids. Their content might be kept under atmospheric temperature and pressure but can also sometimes be refrigerated. The hazards from ASTs can be serious given the large amounts of liquid. ASTs can cause serious environmental problems should a liquid leak reach surface or underground waters. Another difficulty with floor leaks is that they go undetected for a long time and can cause serious contamination of the soil or sub-surface water. Rapid floor failure or catastrophic shell failure are rare events but they do occur and they can have very serious consequences. Clean-up of the ground, the groundwater and the surface water are very costly operations that tank owners would obviously wish to avoid.

API 653 [13] is the standard code for inspection, repair, alteration and reconstruction of ASTs. It should be noted that internal examination of the tank, especially of the floor, is difficult and costly. So it is important for operators to identify the tanks that do not require frequent internal inspection and repair and avoid the wastage of maintenance and inspection resources, instead using their resources where it matters: that is when the risk is high and the inspections are useful. This has led tank operators to look for a risk based inspection (RBI) methodology applicable to aboveground storage tanks. EEMUA 159 [16] is a well-known guidance (particularly in Europe) for inspection, maintenance and repair of ASTs and it fully endorses RBI techniques.



Fixed Self Supporting Dome Roof Storage Tank



Pontoon type floating roof tank

Figure 1: Aboveground storage tanks of fixed roof and floating roof respectively.

It is worth summarizing the reasons that motivated the development of the AST RBI methodology:

- Environmental concerns have increased. There is a large number of tanks with leaking floors and the fear exists of the rare but serious event of tank catastrophic rupture. Costs for environmental clean-up and penalties are increasing.
- Internal inspection of the tanks is costly and difficult. Access to floors is difficult and shell inspection requires complex scaffolding and preparation.
- Backlog of tank inspections. Many tanks are overdue for inspection.
- Inconsistency in regulatory requirements. Inspection intervals vary from country to country and they are even different among US states (inspection intervals varying from 8 to 20 years).
- Prioritization of tank inspections has been largely subjective before the adoption of RBI.

Risk Based Inspection

The risk based inspection (RBI) approach had already been well established and widely used in the oil & gas, refining, petrochemical and chemical industries. The essential elements of a “quality” risk based inspection analysis have been documented by the American Petroleum Institute (API) in API RP 580 (2016)[1]. API RP 581 (2016) [2] describes a specific RBI methodology with full details: data tables, algorithms, equations and models. The implementation of the RBI methodologies has been facilitated by commercial software tools such as Synergi Plant RBI Onshore (Topalis, 2007) [3], SYNERGI Plant RBI Offshore (Topalis et al, 2011) [4], API RBI (Panzarella et al, 2009) [5], RISKWISE (Ablitt and Speck, 2005) [6] and others. The RBI benefits are well known (API RP 580, 2016) [1] and they can be summarized as follows:

- Risk ranking and prioritization of inspection and maintenance activities
- Optimize spending on maintenance and inspection
- RBI may significantly alter the inspection strategies to become more “efficient”
- RBI may provide substantial cost savings
- RBI may contribute to reducing operational risks or improved understanding of current risks
- Improved communication between operations, inspection and maintenance

- RBI study provides a database for easy future inspection scheduling, updating and risk control
- RBI improves the mechanical integrity system and provides the means to measure the effectiveness of inspection

However, it should be said that any RBI methodology relies on the quality of the input data, the assumptions made, and so on.

Synergi Plant RBI AST implements DNV GL's methodology for risk based inspection of aboveground storage tanks. The origin of the methodology is the AST Risk Assessment Manual RAM (API, 2002) [8] initially created for the AST committee of API and later encouraged by the RBI committee of API. The initial scope was mainly tank floor thinning. The methodology was later extended to include a quantitative method for shell thinning, as well as susceptibility analysis (supplement analysis) for shell brittle fracture and cracking.

Figure 2 shows a typical process plant hierarchy and the AST data structure and position in this hierarchy. The tank is part of a process unit involving several more tanks, while the tanks are sub-divided into Floor and Shell. This distinction is because of different failure scenarios for the Floor and the Shell. The Shell is further sub-divided into Courses. Each course may have a different thickness and Point of Failure (PoF).

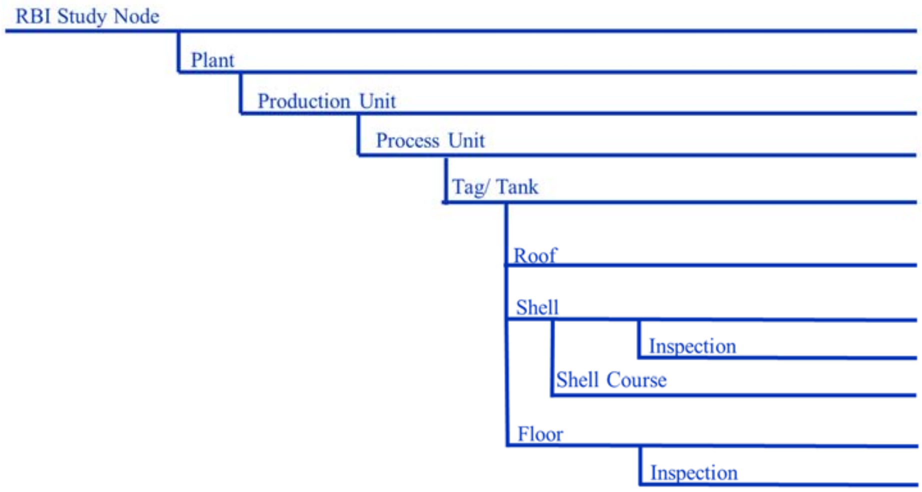


Figure 2: Asset Hierarchy for RBI of Atmospheric Storage Tanks

Figure 3 shows how risk is calculated for an equipment item in a quantitative RBI analysis, such as the approach in Synergi Plant RBI AST. This is the product of the probability of failure (PoF) and the consequence of failure (CoF). CoF can be expressed in terms of the environmental/safety consequence effects and the economic effects. On the other hand, PoF is the product of the Generic Failure Frequency (GFF), statistical frequency of failure for a given type of tank, based on API members' survey (API, 1994) [9] and other sources, and the damage factor (DF).

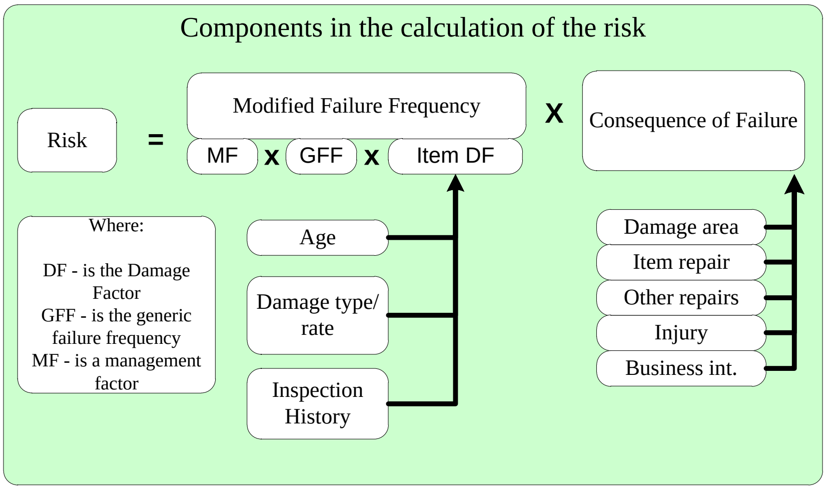


Figure 3: Calculation of Risk for an equipment item

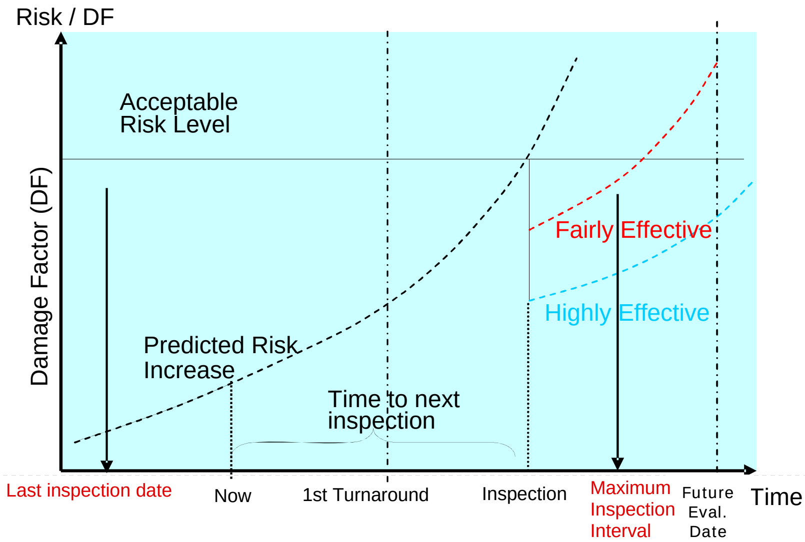


Figure 4: Evergreening: How RBI automatically proposes inspection dates/effectiveness

Figure 4 illustrates the process of determining the next inspection date and the inspection effectiveness. A maximum acceptable risk level is set by the user. A future evaluation date is then selected by the user and the risk is calculated as a function of time. If the risk at the future evaluation date exceeds the maximum acceptable level, an inspection is suggested. The intersection of the risk curve and the maximum acceptable line sets the next inspection date. The inspection may need to be included in the next turnaround, if it cannot be done on-stream. The inspection effectiveness is selected so that, after inspection, the risk does not exceed the maximum acceptable level at the future evaluation date.

The reader is also referred to the API codes for ASTs (API 650) [10] and inspection codes (API 651, API 652, API 653, API 12D and API RP 575 [11]-[15].

AST RBI Scenarios, PoF and CoF Models and Inspection Planning

Table 1 shows the liquid release scenarios typically considered in an AST RBI methodology according to the API 581 methodology. These include:

- One floor leak scenario and one floor catastrophic floor rupture (floor to shell region)
- Three shell leak scenarios and one shell catastrophic rupture
- Roof gas leak scenario according to EEMUA 159

Figure 5 shows the six modelled consequence outcomes in order of increasing severity:

- Release inside the dyke
- Release inside the plant fence but outside the dyke
- Release offsite
- Sub-surface soil contamination
- Groundwater contamination
- Surface water contamination

Figure 6 shows the overall methodology for calculating corrosion rates, PoF, CoF, Risk and Inspection planning for the floor and shell:

- Corrosion rates are estimated first, on the product side, soil side and external corrosion
- Damage factor DF and PoF are then calculated
- CoF is then calculated depending on the scenarios and this is followed by risk calculation
- The inspection planning is decided based on the planning targets for DF, Risk or PoF

The RBI methodology calculates the total cost (CoF) as the sum of the environmental cost, equipment damage cost, outage cost and safety cost:

CoF Total Cost = Environmental Cost + Equipment Repair Cost + Outage Cost + Safety Cost

Equipment damage and safety cost only apply to Shell releases, while floor releases are assumed not to cause safety costs.

Table 1: Release scenarios analysed in the AST RBI methodology

Release Failure Scenarios	Comment
Small bottom leak. Leak may persist for an extended period, depending on local leak monitoring.	One hole size is considered: small leak (0.125" diameter hole). This is the main floor failure scenario that is addressed in the RBI methodology, and is focused on bottom corrosion. The Probability can be influenced by inspection.
Rapid bottom failure. Instantaneous release of tank contents from failure at the critical zone (Floor-to-Shell region).	One scenario, catastrophic failure. Addressed in the RBI methodology through the corrosion model and compliance with recognized design and inspection/maintenance codes. The Probability is only to a limited degree influenced by inspection.
Small Shell leak. Leak detected visually or by monitoring.	Three hole size scenarios: 0.125", 0.5" and 2" diameter hole. This is the main Shell failure scenario that is addressed in the RBI methodology, and is focused on Shell corrosion. The Probability can be influenced by inspection.
Rapid Shell failure. Instantaneous release of tank contents from brittle fracture or large rupture of the tank Shell.	One scenario, catastrophic failure. Addressed in the RBI methodology by screening, and is not influenced by inspection for corrosion.
Roof leak	Scenario modelled semi-quantitatively according to EEMUA 159

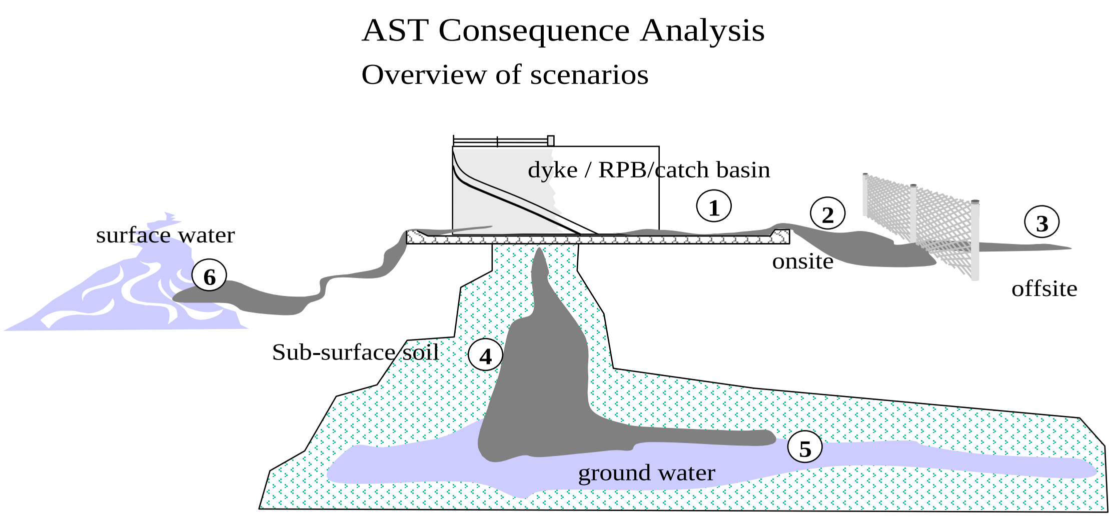


Figure 5: Environmental and economic scenarios

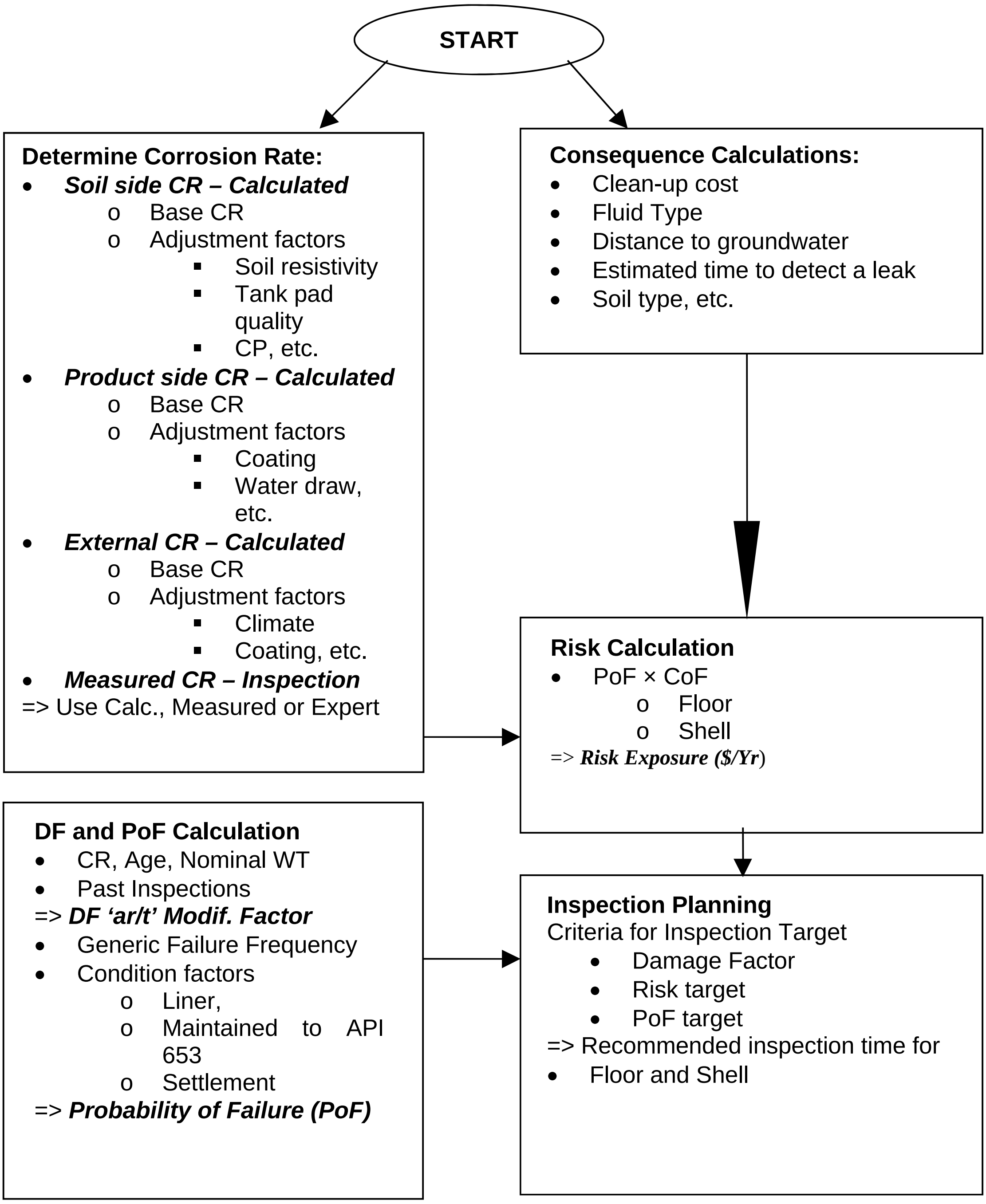


Figure 6: Overview of the floor and shell RBI methodology

Results

The AST RBI methodology produces risk results for a set of tanks (floor & shell risk matrices, executive summaries) but it also produces a detailed risk profile and inspection plan for each tank (equipment summary sheet). This can answer questions about what, when and how to inspect (what technique/ effectiveness & coverage). This is shown in Figure 7.

If one or more risk targets are set, the inspection time will be determined by the intersection between the risk curve (function of time) and the “target” line. Figure 8 shows a real case study where the RBI suggested date is later than the old regulation inspection date and the date determined by API 653. But this is not always the case and RBI can sometimes suggest an earlier date depending on the tank risk.

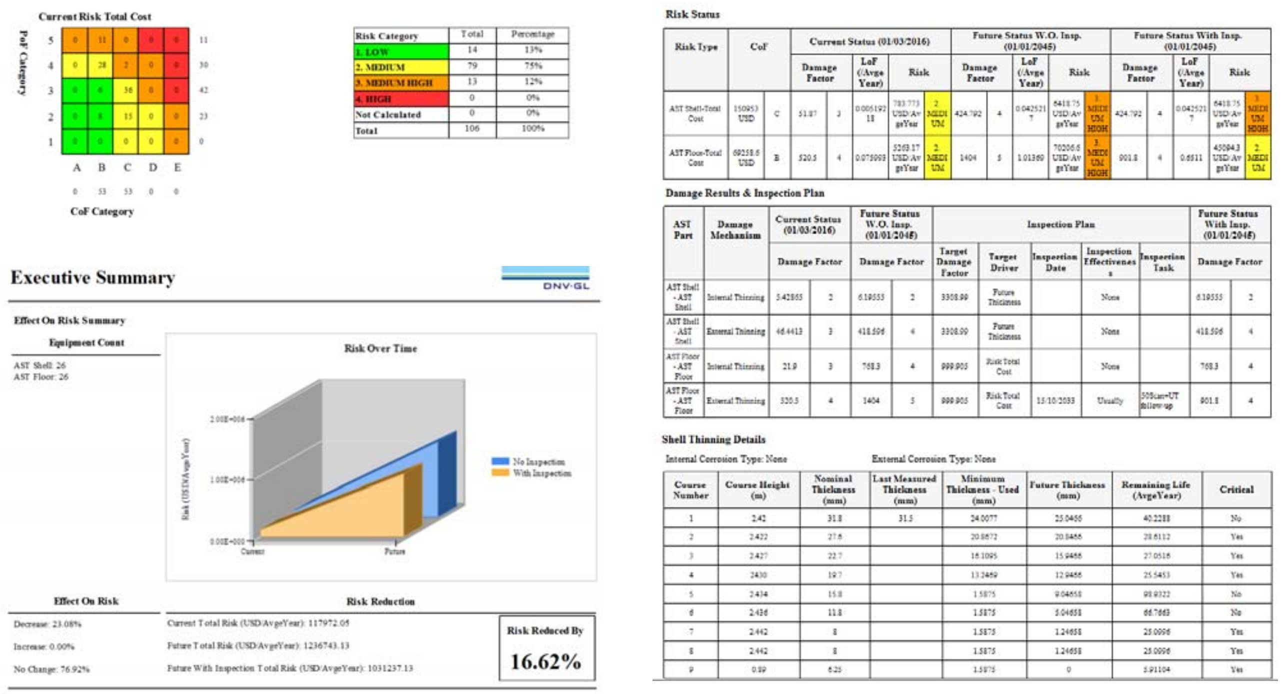


Figure 7: Risk Matrix, Executive summary and AST summary reports

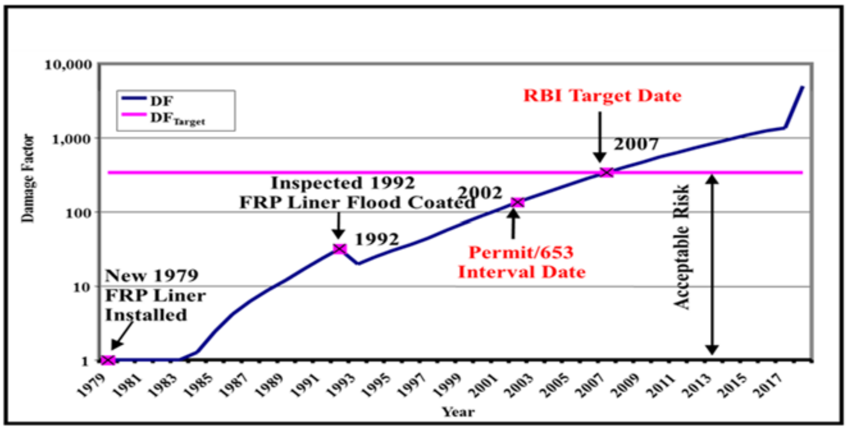


Figure 8: Real case with RBI suggested date against the old regulation inspection date and the date determined by API 653

CONCLUSION

A risk-based inspection (RBI) methodology for aboveground storage tanks has been presented in this paper. The objective of this work is to allow management of the inspections of atmospheric storage tanks in the most efficient way, while at the same time minimizing accident risks. This RBI methodology is an evolution of an approach and mathematical models developed for DNV GL, the American Petroleum Institute (API) and EEMUA 159. The methodology assesses damage mechanism potential, degradation rates, probability of failure (PoF), consequence of failure (CoF) in terms of environmental damage and financial loss, safety loss, risk and inspection intervals and techniques. The scope includes assessment of the tank floor for soil-side external corrosion and product-side internal corrosion and the tank shell courses for atmospheric corrosion and internal thinning as well as the roof. It also includes preliminary assessment for shell brittle fracture and cracking. The data are structured according to an asset hierarchy including Plant, Production Unit, Process Unit, Tag, Part and Inspection levels.

This methodology can help the process and tank farm industry to address the issues currently affecting ASTs, particularly leaks, difficulty in conducting internal tank inspections and inconsistent regulations or subjective methods to set inspection intervals.

ABOUT THE AUTHOR

Panos Topalis is a chemical engineer and holds a PhD in Process Simulation and Thermodynamics from Institut National Polytechnique de Toulouse. He has conducted numerous risk assessments both offshore and onshore and has developed consequence analysis software for Phast software. Panos has been product manager of RBI software in DNV GL since 2000 and has responsibility for development, direction, training, advanced technical support and business development.

NOMENCLATURE

API	American Petroleum Institute
AST	Aboveground Storage Tank
CMMS	Computerized Maintenance Management Systems
CR	Corrosion Rate
CoF	Consequence of failure
DF	Damage Factor
DNV	Det Norske Veritas
GUI	Graphical User Interface
EEMUA	Engineering Equipment & Materials Users Association
ERP	Enterprise Resource Planning
GFF	Generic Failure Frequency
FRP	Fibre-reinforced plastic
PLL	Potential Loss of Life
PoF	Probability of Failure
RAM	Risk Assessment Manual
RBI	Risk Based Inspection
RPB	Release Prevention Barrier

REFERENCES

API RP 580, 2016. Risk-Based Inspection. API Recommended Practice 580, 3rd Edition, February 2016.

API RP 581, 2016. Risk-Based Inspection Technology. API Recommended Practice 581, 3rd Edition, April 2016.

Ablitt C. and Speck J., 2005. Experiences in Implementing Risk-Based Inspection, Middle East Nondestructive Testing Conference & Exhibition , 27-30 Nov 2005, Bahrain, Manama.

API, 2002. Aboveground Storage Tank, Risk Assessment Manual (RAM), API Aboveground Storage Tank Committee, January 2002 (draft Appendix A and B) 2002

API, 1994. A Survey of API Members Aboveground Storage Tank Facilities, Washington, 1994.

API, 2000. Welded Steel Tanks for Oil Storage, API 650, 10th Edition, November 1998, including Addendum 1 January 2000 and Addendum 2, November 2001.

API, 1997. Cathodic Protection of Aboveground Petroleum Storage Tanks, API RP 651, 2nd Edition, November 1997.

API, 1997. Lining of Aboveground Petroleum Storage Tank Bottoms, API RP 652, 2nd Edition, December 1997.

API, 2001. Tank Inspection, Repair, Alteration and Reconstruction, API 653, 3rd Edition, December 2001.

API, 1994. Specification for Field Welded Tanks for Storage of Production Liquids, API 12D, 10th Edition, November 1994.

API, 1995. Inspection of Atmospheric and Low-Pressure Storage Tanks, API RP 575, 1st Edition, November 1995.

EEMUA, 2014. Engineering Equipment and Materials Users Association. Users Guide to the Inspection, Maintenance and Repair of Aboveground Vertical Cylindrical Steel Storage Tanks. 4th Edition, Publication 159: 2014. www.eemua.org.

Panzarella, C.H. and Zheng R.H., 2009. Overview of API RBI Technical Basis and Future Enhancements. API RBI Software Users Group, June 2, 2009

Topalis, P., Alajmi G.F, Teo Y.S, Sattar A., Zafar S., 2007. Implementation Of An Integrated Risk Based Inspection (RBI) System For An Onshore Installation. ESOPE 2007, Paris, Sept 2007.

Topalis, P., Korneliussen G., Singh M., Wiggen F., 2011. New Generation Risk Based Inspection Methodology and Software for the Process Industry, COMADEM 2011, Stavanger 2011.

ABOUT DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.

SOFTWARE

DNV GL is the world-leading provider of software for a safer, smarter and greener future in the energy, process and maritime industries. Our solutions support a variety of business critical activities including design and engineering, risk assessment, asset integrity and optimization, QHSE, and ship management. Our worldwide presence facilitates a strong customer focus and efficient sharing of industry best practice and standards.