

## GAP ANALYSIS ON RISK BASED INSPECTION (RBI) IMPLEMENTATION AT PT.XYZ

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### ABSTRACT

Inspection methodologies have evolved in exploring optimal inspection intervals. The latest approach is the Risk Based Inspection method, referring to API-580 and API-581. Risk Based Inspection (RBI) has been implemented mainly in oil and gas industry to manage the risk of aging facilities. The RBI plan has also been introduced for new facilities and become part of the design requirements, making it the right time for PT. XYZ to improve their RBI implementation to support the Facility Risk Integrity Management System. In general, this study aims to evaluate the effectiveness of the ongoing RBI implementation at PT. XYZ in general while specifically identify the part of RBI and related Asset Integrity Management already implemented and those that still need further improvement. This study is a semi-quantitative study on primary data collected through focus group discussion using the 15 evaluation parameters of RBI based on API 580, API 581, and field observation and secondary data from previous RBI reports, maintenance program, and inspection program. The results of this study show that the overall score is 106 out of 150, this indicates a good implementation of RBI but after further analysis there is the largest gap from the maximum score = 10.0 which is identified as RBI on specific equipment (score=3.0), documented RBI management policy and strategy (score=3.8), risk target and risk acceptable level (score=4.0), and specific damage mechanism components (score=5.3). This will assist a more focused approach to the parts that need improvement while maintaining the industry standards needed to ensure safe operation with low uncertainty.

**Keywords** : Inspection, RBI, Risk, Safety

### ABSTRAK

*Metodologi inspeksi telah berkembang dalam mengeksplorasi interval inspeksi yang optimal. Pendekatan terbaru adalah dengan metode Risk Based Inspection, mengacu pada API-580 dan API-581. Risiko Berbasis Inspeksi (RBI) telah diterapkan terutama di industri minyak dan gas untuk mengelola risiko fasilitas yang sudah menua. Rencana RBI juga telah diperkenalkan untuk fasilitas baru dan menjadi bagian dari persyaratan desain, menjadikannya waktu yang tepat bagi PT. XYZ untuk meningkatkan implementasi RBI mereka untuk mendukung Sistem Manajemen Integritas Risiko Fasilitas. Secara umum studi ini bertujuan untuk mengevaluasi efektivitas implementasi RBI yang berjalan di PT. XYZ sedangkan secara khusus untuk mengidentifikasi bagian RBI dan Manajemen Integritas Aset yang sudah diterapkan dan yang masih perlu perbaikan lebih lanjut. Studi ini adalah studi semi-kuantitatif dari data primer yang dikumpulkan melalui diskusi kelompok terfokus menggunakan 15 parameter evaluasi RBI berdasarkan API 580, API 581, dan observasi lapangan serta data sekunder dari laporan RBI sebelumnya, program pemeliharaan, dan program inspeksi. Hasil studi ini menunjukkan skor keseluruhan adalah 106 dari 150, hal ini menunjukkan implementasi RBI yang baik namun setelah dianalisis lebih lanjut ada kesenjangan terbesar dari maksimum skor=10,0 yang teridentifikasi adalah RBI pada peralatan tertentu (skor=3,0), kebijakan dan strategi manajemen RBI yang terdokumentasi (skor=3,8), target risiko dan tingkat risiko yang dapat diterima (skor=4,0), dan komponen mekanisme kerusakan spesifik (skor=5,3). Ini akan membantu pendekatan yang lebih fokus ke bagian-bagian yang perlu ditingkatkan sambil mempertahankan standar industri yang diperlukan untuk memastikan operasi yang aman dengan ketidakpastian yang rendah.*

**Kata kunci** : Inspeksi, Keselamatan, RBI, Risiko

## INTRODUCTION

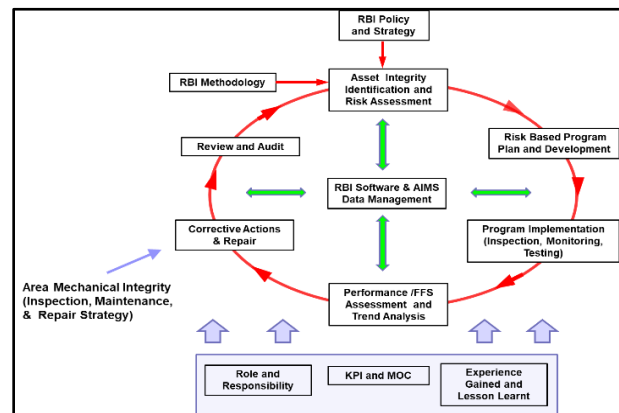
PT. XYZ is designed to process Crude Oil and the first units, consisting of a 100,000 BPSD (Barrel Per Stream Day) Crude Distillation Unit, a Naphtha Splitter and a 6,300 BPSD Fixed Bed Platformer, which were commissioned in 1973. This refinery is currently in the state of aging facility that it requires the implementation of Risk Based Inspection (RBI), which has been implemented since 2007. Risk based inspection (RBI) is a decision-making tool that deals with integrity management of static equipment and piping through focus on prioritizing inspection based on the risk. The RBI is primarily designed to evaluate the risk of pressurized system or static equipment (piping, pressure vessels, tanks, and pipelines) exposed to some possible damage mechanism, damage rates, and failure modes (Khan, et.al., 2003). The implementation of risk-based inspection involves a large number of data, requiring the use of the RBI Software. This study aims to evaluate the effectiveness of the RBI implementation in PT XYZ through a gap analysis.

Risk-based inspection technology was successfully implemented in crude distillation units of Abadan Oil Refinery and Esfahan Oil Refinery. Only a small percentage of equipment items, 12% and 15% respectively for EORC and AORC plants, were categorized as high risk or high-medium risk (Shishesaz et al., 2013).

Asset integrity management system (AIMS) involves planning, organizing, executing, and controlling all process asset risk and integrity through inspection, monitoring, and maintenance programs in order to operate equipment safely and reliably, as well as to operate oil and gas facilities in the most cost-effective way (Khan, et.al., 2006). AIMS are implemented to manage the risks to the acceptable level

throughout the whole life cycle of the assets. The integrity life cycle is presented in Figure 1.

Risk Based Inspection and maintenance methodology integrates the Reliability Centered Maintenance (RCM) analysis with takes into consideration not only reliability and economic aspects, but also the company's reputation and environmental impact (Bertolini, M., et.al., 2009).



**Figure 1. Mechanical Integrity Life Cycle**

For static equipment, i.e. piping, pressure vessel, tank, heat exchanger, and other pressurized system (American Petroleum Institute), the backbone of AIMS is RBI. The risk of the equipment is evaluated to determine the next inspection and monitoring plan (Khan, et.al., 2004). Upon inspection, all data are evaluated and if anomaly or defect is found, Fitness for Service (FFS) is conducted to determine the remaining life and Maximum Allowable Working Pressure (MAWP). Proper recommendations for corrective actions are then given, proposing whether an equipment should be repaired, replaced, or down-rated. Since RBI becomes a central role in AIMS, it is of critical important to evaluate the effectiveness of RBI implementation in PT. XYZ so that the overall AIMS purposes for the static equipment can be achieved

**METHODS**

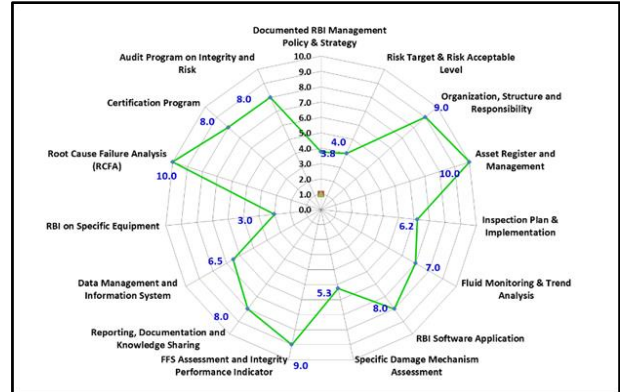
Based on API 580, RBI can be performed in qualitative, quantitative and semi-quantitative. The results of each method are almost the same, but by qualitative method a unit can be evaluated quickly. Quantitative method involves us in more detail and calculation, but with more accuracy.

This is a semi-quantitative study using primary and secondary data. Data used were primary data that were collected through focus group discussions using RBI evaluation parameters and field observation, and secondary data obtained from reviewing RBI reports and maintenance and inspection programs.

The 15 RBI evaluation parameters (American Petroleum Institute, 580 and 581) are developed and discussed with panel experts including with the key site personnel to evaluate the implementation of RBI from various aspects, such as organization and management; administration and paper works; inspection activities; method and technology; software and database application; and human resources availability and competency. Moreover, specific methods used to follow up defect or failure found were also evaluated, such fitness for service (FFS) assessment for defect and root cause failure analysis (RCFA) for failure. All parameters that reflect the components of AIMS cycle shown in Figure 1.

The individual parameters consisted of more detail evaluation parameters with particular scores to signify the identified actual conditions. The parameter was then plotted in the form of spider graph (Figure 2) in order to visually understand the gap width between the actual conditions and the ideal condition. Scoring was then performed with the following categories: >135 =

excellent, 106 to 135 = good, 76 to 105 = average, 46 to 75 = basic, and <45 = poor.



**Figure 2. Gap analysis results**

The recommended actions would be planned according to the level of importance based on the priority matrix in Figure 3, if some findings fall into the low score in the evaluation and the priority is high, the actions should be executed within 1 to 2 years.

On the other hand, if the finding obtains a high score and the priority is low, actions may be executed in more than 3 years. The matrix and color indicated have nothing to do with the risk level or criticality; it only shows the level of priority or importance for future follow up in the case when a gap is found.

AIM Development & Implementation Phase based on Priority and Score				
		Score		
		8-10	5-7	0-4
Priority	H	4	2	1
	M	7	5	3
	L	9	8	6

**Figure 3. Matrix to indicate level of importance and priority actions**

**RESULT**

The further purpose of gap analysis in this study is to evaluate the effectiveness of the ongoing RBI implementation at PT. XYZ. The results of the gap analysis are summarized in the spider graph in Figure 2, presenting 15 evaluation parameters or components. Results show an overall score of 106 of 150, showing a good

implementation of RBI. However, upon further analysis, shown on Table 1 indicates the largest gaps as follows, in the respective order: i) RBI on the specific equipment (score=3 point), ii) Documented RBI Management Policy & Strategy (score=3.8 points), iii) Risk target and risk acceptable level (score=4 points), and iv) Specific damage mechanism (score=5.3 points).

**Table 1. Gap Analysis Spreadsheet**

No	Evaluation Parameters	Max Score	Evaluated Score	Criticality	Action Priority
1	Documented RBI Management Policy & Strategy	10	3.8	H	1
2	Risk Target & Risk Acceptable Level	10	4.0	H	1
3	Organization. Structure and Responsibility	10	9.0	M	7
4	Asset Register and Management	10	10.0	M	7
5	Inspection Plan & Implementation	10	6.2	M	5
6	Fluid Monitoring & Trend Analysis	10	7.0	M	5
7	RBI Software Application	10	8.0	M	7
8	Specific Damage Mechanism Assessment	10	5.3	H	2
9	FFS Assessment and Integrity Performance Indicator	10	9.0	H	4
10	Reporting. Documentation and Knowledge Sharing	10	8.0	M	7
11	Data Management and Information System	10	6.5	M	5
12	RBI on Specific Equipment	10	3.0	M	1
13	Root Cause Failure Analysis (RCFA)	10	10.0	L	9
14	Certification Program	10	8.0	M	7
15	Audit Program on Integrity and Risk	10	8.0	M	7

**Table 2. Evaluation Parameter and First Priority Recommended Actions**

No	Evaluation Parameter	Evaluated Score	Action Priority	Recommended Action Plan	Due Date (Years)
1	Documented RBI Management Policy & Strategy	3.8	1	PT. XYZ, Stat - Eng Department is recommended to develop an RBI Manual or Guideline.	Within 1 - 2 Years
2	Risk Target & Risk Acceptable Level	4.0	1	It is recommended for PT. XYZ to develop the RBI for Organizational Work Program ( <i>Tata Kerja Organisasi</i> , TKO) or similar RBI Procedure. It is recommended to define the risk target (USD/year) as an alternate criterion /baseline for next inspection plan.	

3	Specific Damage Mechanism Assessment	5.3	2	It is strongly recommended for PT. XYZ to evaluate the risk of static equipment (pressure vessel, heat exchanger, piping, etc) that is susceptible to HTHA damage mechanism considering that there are many cases in refinery worldwide that experience catastrophic failure, leading to major-fatal-accident caused by HTHA. To be more focused, this assesemnt should be separated from the on-going RBI assessment.	
4	RBI on Specific Equipment	3.0	1	To be effective, it is recommended to plan PSV inspection and test according to the risk category as shown by the oil and gas industry trend worldwide.	

Actions that will be recommended should be planned according to the level of importance as listed in the priority matrix in Figure 3. For example, if findings fall into a low score category of evaluation and the priority is high, the actions should be executed within 1 year.

On the other hand, if the finding obtains a medium score, the action can be executed within 2 years while for those with low scores the action may be executed within 3 years. The findings of this study have led to recommendations to fill the gap based on the priority scale starting from high priority actions as shown in Table 2.

**DISCUSSION**

A system failure is rarely caused by a single cause, but rather the result of a combination or series of interacting events. As a result, Risk Based Inspection & Maintenance should not be considered as a static exercise that is only done once. It is a dynamic process, which should be continuously updated as additional information becomes available.

***Documented RBI Policy and Strategy***

Analysis using a RBI approach can increase the effectiveness of the mechanical integrity inspection program while minimizing risk to health, safety, and the environment plus maximizing resource utilization. RBI offers established a

methodology for effective plant maintenance. It helps to achieve operational excellence and maximum asset performance by using inspection resources more cost-effectively and with confidence (TWI, 2009)

In this parameter, evaluation was conducted to assess the availability of specific RBI Management policies (e.g. well documented in manuals or guidelines) and documented RBI strategies for the assets. Evaluation was also performed to assess the presence of evidence of the awareness on RBI in all levels of the organization (senior management, engineer and technicians). Finally, an evaluation was also conducted to assess whether the RBI management strategy has been integrated to the safety and asset management; inspection, testing, and monitoring; and operation strategies.

It was reported that RBI has been conducted since 2007 in PT. XYZ for all unit. However, the previous RBI software owned by this company is currently expired and, as a result, the RBI was not fully implemented at the time of the study. However, during the site visit, it was understood that the company had just purchased a new RBI software and they were in the process of data migration from the previous software. The same is true for the inspection plan. Nevertheless, the role and importance of the RBI Concept has been fully understood by the management, engineers, and supervisors, albeit no formal

documents indicated this condition. Practically, RBI concept has been integrated to the safety and integrity of the assets, but the formal document of this integration is still lacking. It is necessary to develop this high-level document so that all levels of personnel in PT. XYZ have the same perception and understanding on RBI concept and implementation.

### ***Risk Target and Risk Acceptable Level***

Risk targets should be defined by management in consultation with all the team and stake holders. This needs to be done before proceeding to RBI assessments. Risk target is considered as maximum degree of tolerable risk for continued operation without requiring a mitigation action. Once the target has been met or exceeded, an activity such as inspection is triggered (Ali & Sabry, 2019).

In this section, the availability of the RBI procedure was evaluated and a risk target or maximum risk acceptable level had been defined. Moreover, whether the financial risk was considered in the last RBI assessment in addition to the safety aspect was also evaluated.

From the results of the evaluation thus far, no RBI procedure was in place and no risk target was defined by the Company. The risk acceptable level used only followed the automatic RBI Software recommendations. No reference to the financial risk was made in the RBI assessment.

### ***Organization, Structure and Responsibility***

The corporate dimension is reflected in the organization's policies, work procedures, management systems, control systems, and communication flows (Lestari, Fatma, et.al., 2020). There is a widespread belief that safety culture is an important contributor to operational safety. This parameter evaluates whether the company's organization chart

exists and, if yes, whether the chart elaborates the clear responsibilities and reporting path for the RBI management system, including the clear statements of roles and responsibilities of the engineers involved. This parameter also evaluates whether qualification, experience, and expertise available appropriate to the role for people in charge. It also determines whether training is available for the individuals in the area of RBI and inspection plan.

From documents available and from the results of the focus group discussions, it was evident that the organization for RBI was well established in PT. XYZ and that the role and responsibility of each person was stated, meaning that the job description and scope of work were clearly defined, including for the contractor who performed the actual inspection and RBI assessment. The expertise for RBI-related field was reasonably adequate and training related to inspection and RBI was also available. However, at the time the study was conducted, no corrosion engineer was available.

Since RBI is a team-based process, it requires a proficient team consisting of individuals with relative experiences and from various departments. A good team can be formed by including specialists from process, operations, production, maintenance/reliability, corrosion and inspection, knowledgeable and expert in the plant site conditions and history. This team shall be led by an RBI engineer or specialist (from the plant site or outsourced external consultant) having expertise in RBI methodology and previous experiences with RBI projects (Ali & Sabry, 2019).

### ***Asset Register and Management***

In this parameter, evaluation was made on whether individual equipment had a tag number/ID number attached and was well documented. It also assessed whether P&ID

and PFD were available and revised, including the MOC to identify the equipment in the system.

It was shown that all assets and data, including the Management of Change (MOC), were fully documented and well-managed and, therefore, no issue was identified in this section.

### *Inspection Plan and Implementation*

In this section, the availability of any plan for inspection based on risk in place is assessed or whether the time based approached is still used. If the RBI is indeed applied, evaluation is also performed on whether the inspection plan is considered to be effectiveness or whether the quality level complies to the RBI Methodology (American Petroleum Institute 581, 2016). In addition, evaluation is also made on whether the on-line monitoring facility location is well identified in the equipment, P&ID, PFD, or isometric drawing, and whether the inspection involves advanced NDT (e.g. phased array UT, backscattered UT, etc.). Finally, this section also confirms whether the internal inspection on equipment is planned based on RBI or not.



Figure 4. Pipe Clamp

It was observed that the actual inspection plan was still mixed or combined between risk-based and time-based, and that the effectiveness criterion was only partially implemented. It was also concluded from discussion that all equipment was well identified in P&ID, PFD and Isometric. In some instance, the advanced NDT had partially been used depending on the case (Figure 4). Finally, the internal inspection was still based on turn-around or shutdown period for every 4 years. From our point of view, unless the risk of some critical equipment is high, this time-based approach is still adequate considering the immensity of vessels or reactors dimension and their complex nature of operation.

### *Fluid Monitoring and Trend Analysis*

One of the key roles of RBI is to understand and know the possible damage rates on the equipment, and, therefore, it is of interest to know if trend analysis of impurities on fluid/product is monitored and made regularly, and to make sure whether this trend of the chemical impurities is plotted against time. Moreover, it is important to know that the trend of the corrosion rate is plotted against time. It is also important to confirm whether the corrosion circuit on the piping is made available or not in the system.

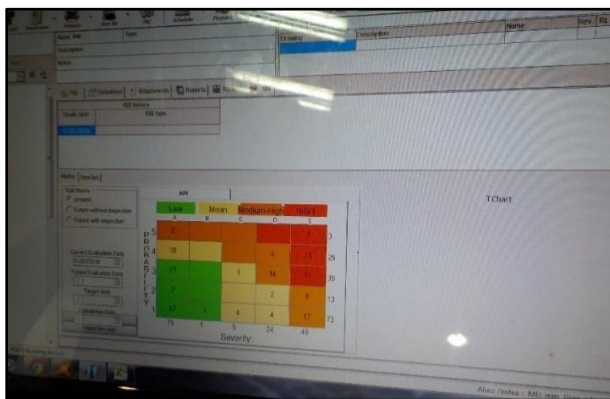
It was observed that the fluid composition was monitored periodically. However, this was only partially plotted against time. The corrosion rate had been plotted against time for some Units. The corrosion circuit module was available in the RBI Software, but PT XYZ had not yet had the system for data migration to new RBI Software from the previous software and RBI assessment was still being carried out.

**RBI Software Application**

Software is required to perform RBI for multiple equipment i.e. several hundreds or thousands of assets generally found in small to large facilities, since manual calculations are not practically feasible due to complexities involved, although it is possible to do them for few equipment as shown by Kaley (2009). Software’s can be used for calculations, keeping records of thickness trending and inspection data and most importantly automating the whole integrity management system of a facility by connecting with enterprise resource planning (ERP) system or computerized maintenance management system (CMMS).

Since RBI program involves a large number of assets, data, and continues information, it is desirable to know whether RBI Software is available and utilized in PT. XYZ. This may take the form of commercial RBI software or Excel spreadsheet-based.

During the discussion and site visit, it was evident that the company had just purchased a new software, thus the software is currently available and used by PT. XYZ (Figure 5). This new software would be maintained and updated/upgraded regularly or deemed as an “all time license” software. At the time of the study, data migration from the previous system was still ongoing.



**Figure 5. RBI Software PT XYZ**

**Specific Damage Mechanisms**

Since PT. XYZ has entered aging condition, to thinning mechanism due to metal loss it is critically important to evaluate other possible time-dependent damage mechanism. It is of interest to know whether HTHA has been evaluated for the equipment and piping, provided that major and catastrophic accidents have occurred in refineries worldwide due to HTHA damage mechanism. Further, SCC, Fatigue, and CUI should be evaluated for the equipment and piping.

To avoid conditions that could cause HTHA, it is important that actual operating conditions are known and monitored, and regular HTHA inspections performed. When proper safety considerations and controls are established, the risk of HTHA failures is greatly reduced in ammonia, refinery, and chemical plants using tubes, heat exchangers, and pressure vessels containing hydrogen at elevated temperatures (Benac & McAndrew, 2012).

It was identified that HTHA was not specifically evaluated in PT. XYZ and that the Stress Corrosion Cracking (SCC) and Fatigue had also not specifically evaluated in PT. XYZ as they only did it on case-by-case basis. The CUI was partially evaluated and there was no overall plan to inspect possible CUI attack on piping and vessels.



**Figure 6. Window Opening for CUI Inspection**



### ***FFS Assessment and Integrity Performance Indicator***

RBI and FFS technologies can be complementary techniques since both provide inputs to each other, as identified by Buchheim (2001). Generally, RBI programs provide design t-min as a remaining life or retiring criteria, an asset that has reached its design t-min can be assessed by FFS for evaluating a thinner required t-min. If FFS study finds the new t-min fit for service, this reduced t-min can replace the original design t-min for risk calculations and thus impacting the PoF and resultant risk (Ali & Sabry, 2019).

This parameter is designed to know whether all information from inspection, test, and monitoring activities are collected and gathered to enable data assessment. Furthermore, if FFS is conducted upon all defect types or anomalies discovered during inspection, the next step will be evaluating whether the remaining life and MAWP of each equipment is evaluated regularly based on the most current inspection information.

It was observed that the fitness for services (FFS) assessment, specifically related to corrosion issues, had been regularly performed in PT. XYZ on piping or vessels containing defects to ensure the integrity of the equipment. The remaining life and MAWP (as product of FFS Assessment) were also regularly calculated based on the updated and most recent inspection data.

### ***Reporting, Documentation, and Knowledge Sharing***

In this section it is important to ensure that; i) the reporting routes are clearly defined and managed effectively within the RBI strategy, ii) there are systems available to share reliability knowledge internally within the organization, iii) routine

inspection including visual cleanliness and housekeeping is reported and documented, and finally, iv) operational experience provides feedback into design.

It was observed that the reports related to inspection were partially managed within the RBI plan and that there were, up to the time of the study, formal and non-formal ways to share knowledge in the subjects. In general, the concept and inter-related aspects of reliability, integrity, safety and risk should be understood by all engineers and field inspectors.

### ***Data Management and Information System***

This section evaluates whether RBI Data, including the inspection plan, have been integrated into the existing electronic data storage system, and whether anomaly data and status are registered in a database system for tracking.

It was discovered that the inspection data was registered and managed through the use of an inspection database software and then transferred regularly to the RBI Software for risk assessment. However, there was no automatic tracking system available at the time of the study.

The quality and availability of data is one of the most important aspect as the RBI process is driven by data. At this stage of the project, it is beneficial to do an audit for this purpose to find out available vs. minimum required data for RBI assessments (Ali & Sabry, 2019).

### ***RBI on Specific Equipment***

Originally, the old version of RBI is intended to evaluate the risk of static equipment. However, the valves have also been considered and included in the API 581. In this section, evaluation is made to identify whether the Pressure Safety Valve (PSV) or Pressure Relief Devices (PRD) have been inspected and tested based on the

RBI in PT. XYZ. The same question also applies on whether the storage tank has been inspected based on RBI method.

It was stated during discussion that the PSV/PRD were still inspected and tested using time-based approach according to MIGAS re-certification program (e.g. every 3 years for PSV).

### ***Root Cause Failure Analysis (RCFA)***

As a part of the lessons learned from any equipment failure or plant accident, it is important to know whether RCFA is conducted on equipment failure (such as leak or rupture) to determine the root cause(s) and contributing cause(s) to failure that similar accidents can be prevented in the future. Also, this part aims to understand whether the RCFA report was well documented and easily retrieved.

It was recognized that PT. XYZ performed RCFA (called RCPS - Root Cause Problem Solving) internally in case of equipment failure, and that this process was well-documented and easily retrieved from the system.

### ***Certification Program***

This section seeks to understand whether static equipment re-certification program is included in the inspection and the test plan to fulfill the MIGAS requirement or not. Assessment to identify equipment with expired certification is also made.

It was stated that all static equipment (pressure vessels) followed MIGAS re-certification program. Some of the certifications of the vessels, however, were expired.

### ***Audit Program on Integrity and Risk***

The main function of audit is to identify any gap between the current practices

against the standard (Mercer, M., 1998). This section assessed whether self-audit or internal audit addressing RBI issues is periodically performed and an external audit addressing equipment integrity issues is also periodically performed.

It was confirmed that RBI audit was conducted internally as a part of Stat-Eng. inspection plan and externally as a part of, or embedded to, the Company Insurance Audit Program.

### **CONCLUSION**

The significance of RBI concept and implementation have been understood by all management level, engineers, and supervisors in the field of PT XYZ and are supported by a good organization structure and role and responsibility divisions. Except for corrosion engineer who is not available at the time of the study, the overall abilities of engineers and inspectors in dealing with inspection and RBI are considered to be adequate with some degree of competency. Furthermore, inspection plan is determined based on the RBI assessment although in the inspection execution, due to some consideration, is the assessment is still performed using two approaches, i.e. risk-based and time-based (according to the turn-around schedule). Thus, it is recommended to have documented RBI policies, RBI strategy manual or guideline, and RBI procedures so that the people involved will have the same perception and understanding on RBI. Moreover, it is also recommended to run RBI assessment specifically on certain damage mechanisms, namely High Temperature Hydrogen Attack (HTHA), fatigue, and Corrosion Under Insulation (CUI). Finally, to be more effective, it is also suggested to consider the inspection plan of Pressure Relief Devices (PRD) based on risk-approach instead of time-based management.

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