Volver

Best Practices for Mechanical Integrity System Implementation
MTBE Facility Case Study

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Synopsis

As part of a Petrochemical APM Project implementation, was conducted a particular Mechanical Integrity System assessment, which revealed a relevant gap on different issues of this function and represented significant contributor to low performance on Mechanical Integrity and Fixed Asset Reliability turning on negatively impact for the operation costs, equipment availability and production field factor. Poor performance around cost, effort, and a negative impact to production and maintenance got the attention of management, therefore was needed a plan to improve its Mechanical Integrity performance. Their goal was to reduce all these negative perception and impact and improve safety and profit.

Based on APM (Asset Performance Management) Assessment was decided to proceed within an APM implementation project, which considered an implementation of a Mechanical Integrity System as one on main fixing solution. This part of project, starting within an performance assessment, which revealed a relevant gap in the program and represented significant contribution to low performing Mechanical Integrity and Fixed Asset Reliability negatively impacting the operation costs, equipment availability and production field factor. Using the expertise of the client around its Inspection, Process, Operation and Maintenance Departments we performed a series of activities to implement a Mechanical Integrity System that included RBI (Risk Based Inspection), Thickness Monitoring, Inspection Management, Integrity Operating Windows, Asset Integrity Strategies and Corrosion Control Principles. This allowed them to gain a complete understanding of their Asset Performance Management System.

A petrochemical Mechanical Integrity system is based on systematic and continuous relationship between work process methods (functional) and technology platform (software) to achieve the appropriate identification, extension and analysis of each element that could trigger a deterioration mechanism. This approach is needed in order ensure the reliable performance throughout the life cycle of an asset and at same time ensure profitability and compliance of business needs.

The key to success for this client's implementation was the use of best practices to implement an effective Mechanical Integrity System. They started with almost nothing around Mechanical Integrity and moved where they were treating all threats proactively which allowed them to achieve real cost saving benefits of **1.6 MMUS$ through reduction of Turnaround Scope in less 1.5 years during implementation phase.** As a result of this pilot study they were able to bolster their asset management by introducing a Mechanical Integrity Culture which changed their inspection activities to a predictive function from the reactive way they were used in the past.

Introduction

On the face of worldwide experience the major challenge could be to achieve an effective, practical, and reliable integrity system to support the asset management system. However, there is not a specific guideline to develop this issue, even more when each business has particular characteristic and at meantime the people on charge of this functionality try to accomplish only the point of view related to improvement requirements or insurance priorities. Thus normally have been implemented different tools or methodologies without a specific plan, integration or interrelation that could give the result expected according within business needs.

Mechanical Integrity is a complex issue but depreciated by many managers and people responsible to handle the process and operations. it is very common to see how a Catalyst Tubes of Hydrogen Reformer are over exposed to high temperature and stresses, and the concern is how this event happen when is really known at worldwide the threshold for this component according within its metallurgy. This situation is like the patient that did not know ~~that~~ some issue ~~could~~ affected his life, however~~even~~ all doctors knew the solution his pain after was too late. ~~and only later the health assessment due a hard pain is in notice of how could be avoid this disease.~~

The Oil, Gas & Petrochemical industry has shown normally ~~up that~~ the biggest event come out from a ~~failure on~~ Mechanical Integrity failure; Pipelines, Vessels, Reformers, Reactors, Columns, etc. However ~~and~~ when ~~is compare the~~ the generic failure frequency of fixed equipment is compare against ~~against~~ from others type of component is really easy to see that the amount of failure of rotate, instrumentation or electrical component normally ~~-~~are bigger. The problem is ~~But~~ the size and impact from fixed equipment failures are more critical for business ~~is huge~~ and normally is required only one of this event to get the top of Incident Pyramid, and thereafter all resources, effort and discussions to determine what has happen. It is too late, the key is not fixing the failure, and the challenger is avoiding its occurrence.

~~By other side~~In the other hand It is amazing to see a lot of facilities ~~how can~~ spending money and effort on this issue without getting a real profit, neither understanding and control of Mechanical Integrity c~~C~~oncerns, is like the story about crashing several times within the same stone. But that is going on, when everybody knows the stone allocation, the answer is simple in both cases; has not been gotten either the focus on Business or Mechanical Integrity needs. Therefore we should become the concerns on questions e.g. what are the real threats? What is the life cycle expectations?, what have to do done to despite any probability of failure?, in order to identify, where to and how could be approach the Mechanical Integrity System.

Mechanical Integrity does not mean common inspection perform only, either is isolated statistical collection and nor sporadic RBI (Risk Based Inspection) Assessment. This issue is about the integration of different philosophies, methodologies, technologies and strategies to ensure the reliable, profitable and safety performance of business over whole its life cycle into specify operational context. Thus the functional failure shall be avoided based on the right following and control of all variables; design quality, operational parameters, human behavior, communication process performance, inspection accuracy, that could initiate, accelerate or contributed to failure occurrence, the real mean is focusing on the asset capabilities, the business needs and the enterprise skill, furthermore any element into this boundary will be carry out in a preventive, predictive, or protective manner.

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According within the perspective described above, it have been performed several experiences around this challenge~~r~~, however often is not showed the big picture how the combination and integration of functional (methodologies) prospective and technical (software and tools) elements could be addressed to get the most important value for business: **the guaranteed of all assets (people, equipment, product, environment and community) on whole its life cycle.**

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Case Study

The assessment performed on this Petrochemical revealed a relevant gap on different issues related to this matter, which were: poor roles & responsibilities definition, lack of scope integration, absence of corrosion loops, metallurgy misunderstanding, lack of process relationship and integrity critical process variables, nor system breakdown based on interaction of process and material and damage mechanisms susceptibility and neither RBI component classification. Also there is not RBI Component structure according corrosion loops from P&IDs and PFD's. Additionally very low understanding of risk management, poor data and communication practices are significant contributors to low performance on Mechanical Integrity and Fixed Asset Reliability which was turn on negative impact for the operation costs, equipment availability and production yield factor. In order to reduce these potential risks, identifying the improvement opportunities, was developed an improvement plan aligned with business drivers and current maturity levels, which was implemented based on assessment recommendations.

Using the expertise from client on its Inspection, Process, Operation and Maintenance Departments on **MBTE Facility, and Best Practices** were performed a series of activities to implement a Mechanical Integrity System, which included as element: RBI, Thickness Monitoring, Inspection Management, Critical Process Variables, Asset Integrity Strategies and Corrosion Control Principles, after forward was getting a complete understanding of this Management System, a whole relationship between different departments and functions, but achieving the most important value for business, the preventive and proactive aptitude to preserve the cycle life of it and assure the profitability of stakeholders and the appropriate performance for people and environment.

The mechanical integrity system was implemented taken as pilot a Major Turnaround and the results gotten from this initiative due to decision taken based on risk were a reduction of 25% on Inspection Man Hours (10000 man hours / 45 us$ per hour), identification of potential issues as damage mechanism no research before (corrosion detection on tubes of heat exchanger, identification of premature probability of failure of PSV (Pressure Safety Valve) by poor transportation (60% of failure on Pot test), additionally was gotten a reduction of 45% of rework, a draft for next scope of work (around 60% of scope defined) , total traceability of condition and damage susceptibility on inspection points which. Thereafter the Inspection Dossier could be issued in 15 days and whole data is auditable and were identified lesson opportunities that have been included into a plan implementation in short term.

The key on this implementation was to use best practices to implement an effective Mechanical Integrity System. So that a place with almost nothing on this Philosophy was possible to change its performance, implementing proactive actions to achieve in less than 1 year a Mechanical Integrity Process as culture within a real benefit of **1.6 MMUS$ on reduction of cost on Turnaround Scope.**

The most important issue was the Knowledge Transfer, which allow to develop this client staff to a high level of understanding, that afterwards will allow to handle and improve the Fixed Asset Performance into an evergreen process as well the business require. It’s an intention to share an overview of the Mechanical Integrity System proposed as best practices based on effective interrelation of functional and technical factors to contribute to achieve the business objectives.

Mechanical Integrity System Development

The new methodologies and process work schemes to ensure the right performance of asset based on its reliability and availability has pushed to stakeholders and managers to looking for a better prospective on this matter. Therefore a wide portfolio of tools and methods is available to be used on this objective. The key is how the technology and methodology should be combined to address the application and implementation on the adequate way in order ensure the reliable performance on asset whole life cycle ~~asset~~ and at same time profitability and compliance of business needs.

Comentario [D8]: asset whole life cycle (?)

Inside of reliability and asset management portfolio, was included the Implementation of Mechanical Integrity System, which is orientated to follow up and controlling the physical conditions of fixed components belong to process and utilities systems. Those are based on optimal inspection plans to define in predictive and proactive way further performance of asset, according within chemical and physical interaction of fluid critical variables, and the materials of construction. For Mechanical integrity the word “optimal” means performing of best strategy that include the most practical technology of deterioration mechanism detection, reasonable frequency as part of maintenance strategies and realistic location where could occur the damage activity.

Mechanical Integrity System is based on systematic and continuous relationship between work process (functional issues) and technology platform (software) to achieve the appropriate identification, extension and analysis of each element that could trigger~~ing~~ the deterioration mechanism. Herein Risk Based Inspection (RBI) is a high priority to get the definition of risk level based on probability of deterioration occurrence and its consequences in case of final failure. RBI delivers are a proactive inspection plan: inspection strategies, nondestructive techniques, frequency, coverage, and logistic required to be implemented.

Comentario [D9]: trigger (?)

The implementation of RBI assessment either lonely or without any relation within execution tools is normally, the cause of low effectiveness in inspection plan and it does not allow to achieve the objectives in terms to reduce failure rate, main time to failure, and main time between failure. Thus is necessary performing an inspection task schedule into an effective a capable Inspection Management System, where the inspection program can be performed in effective way (on time and right place). The implementation can be tracked by management, additionally this tool must be capable to catch, store and report the conditions and facilitate the appropriate generation of recommendations and notification on CMMS (Computerized Maintenance Management System), therefore the implementation of mitigation actions will be adjusted to handle and keep the risk level under an acceptable boundaries.

Comentario [D10]: adjusted (?)

For those damage mechanisms, such thinning and localize corrosion where its progression through the material is deterministic to estimate remaining life, it is required a systematic tool as Thickness Monitoring System to schedule the thickness measurement, capture the field data, calculate the deterioration rate, and forecasting the projection on deterioration trends over the time. As a complementary functionality on these tools portfolio the monitoring of critical process variables is demanded as part of a proactive prospective, therefore must be defined all variables and its threshold for damage mechanism activation.

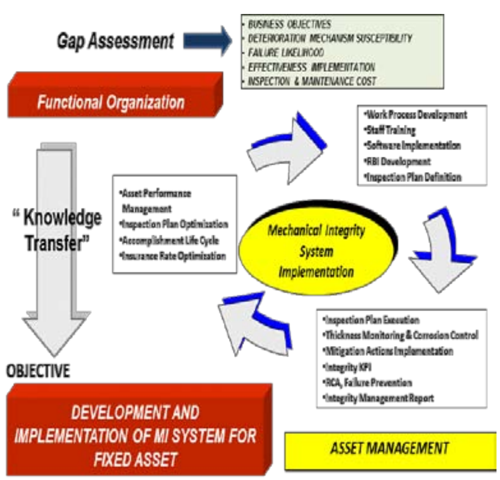
After the functionalities have been identified ~~the functionalities needed~~ to be integrated into a mechanical Integrity System, the common questions are How?, Who?, How Long?, How Much?, and When?. This initiative have to be applied thru all of these tools on the business considering a Cost-Risk-Benefit Analysis as support to Management, in order to approved the resources (economical and human) for this initiative. Normally the managers and drivers on reliability need performance information, quotation, proposal, presentation and others incomes to define and decide how could be developed this kind of project, to avoid confusion, wrong purchased or mismatched activities, or low investment, against the real requirement to satisfy business needs.

Comentario [D11]: After the functionalities have been identified….

Implementation Strategies

Design and Implementation of Mechanical Integrity System for Fixed Asset, required a complete management definition based on a evergreen process (continuous improvement loops) that can integrate functional and technical issues (figure No 1) and have been handled using a knowledge transfer methodology, and conducted into a Project Management methods in order to ensure the right implementation throughout a skills gap closure and promoting the commitment to achieve the maturity of process and technology in a medium term.

The main objectives of mechanical integrity system implementation are the achievement of asset life cycle into a profitable, safety, and reliable business environment, which support an efficient data management.



(Figure No 1)

The implementation should be based on continuous improvement loop will keep the traceability and sustainability of facilities and process through the Reliability and integrity Indicators. The implementation should consider five stages to be develop in sequentially and systemically way, which are mentioned bellow:

- Management Model Development of Mechanical Integrity System
- Technology Platform (APM-MIS Software) Implementation
- Knowledge Transfer Process (Specialist and Champions Development)
- Functionalities Development and Implementation
- Functionalities (methods), Technologies (mechanical integrity tools, process control and historian, and CMMS) integration.

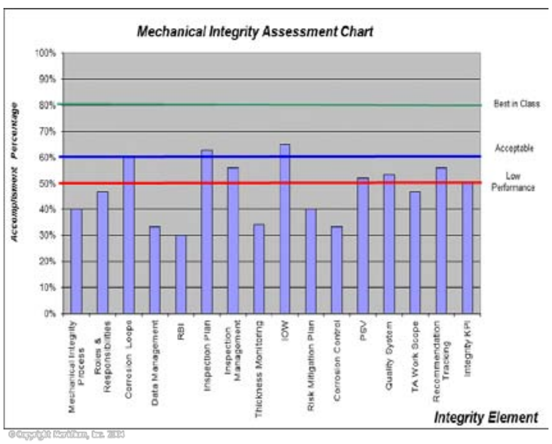
1. Management Model Development of Mechanical Integrity System

a) Gap Analysis: The first action to initiate a System Implementation to be done by the Facility Management in order to identify what are the real needs for their asset, process and business into the cycle life, is to perform a Gap Analysis, which will give a definition of actual situation regarding experience, skills, technologies, work process, performance level, and priorities.

The Gap Analysis performed considered the following elements in order to get a complete overview of face situation of the Mechanical Integrity Process, Organization Structure and Fixed Asset Performance:

- Mechanical Integrity System
- Inspection Skills, Competency, Roles and Responsibilities
- Damage Mechanism Breakdown Structure
- Data Management
- RBI Processes and Analysis Assessment
- Inspection Plans and Execution Effectiveness
- Inspection Manager and Thickness Monitoring Processes and Data
- Critical Process Variable (CPV); Processes and Data
- Mitigation Actions Plan
- Corrosion Control Plan
- PSV Calibration Control & Monitoring System
- Quality Assurance System
- Turnaround Risk Review Process
- Recommendation Tracking System
- KPI's and Metrics
- Inspection Audit System

The result of this audit gave a diagnostic (See Figure No 2) about the gap existing on the facility and all actions required to mature and improve the mechanical Integrity performance. The recommendations coming out from this evaluation are consolidates and used to develop the Project Plan and its Implementation, in order to define the priorities, resources (budget, personnel, contract, logistic) and timeline base, so which can ensure the achievement of right understanding, good performing, enough maturity and continuous improvement of asset mechanical integrity.



(**Figure No 2)**

b) Mechanical Integrity Management Model: This issue represents the overview of all tools, elements and philosophy to be taken as Road Map~~map road~~ for concepts and bases of Mechanical Integrity System, which should be based on a life cycle model to ensure the optimum asset performance (figure No 3), business needs compliance, safety and environment objectives, and process availability and asset reliability as well.

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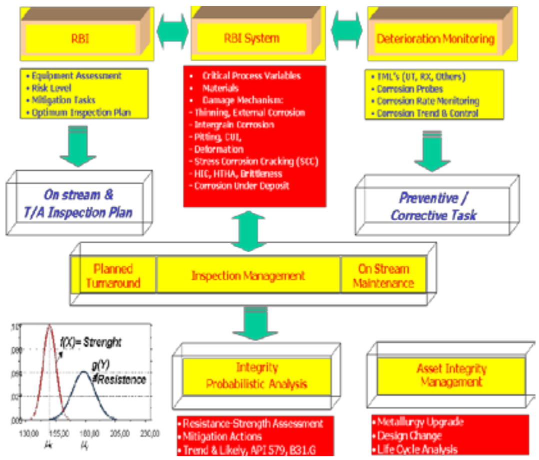
Mechanical Integrity Elements: the methodologies and tools considered as element of this system were:

- *RBI System (Corrosion Loops)*
- *Process Critical Variables (IOW)*
- *Inspection Strategies*
- *RBI Analysis (Risk Classification)*
- *Inspection Management System*
- *Thickness Monitoring System*
- *Corrosion Follow Up and Control*
- *Statistical Analysis*
- *Recommendation Management System*



(Figure No 3)

The system is structured taking the RBI System as core function, where were identified all susceptible damage mechanisms than could be generated according within metallurgy, process conditions and geometric configuration, on this function are define the critical process variables as well. Therefore this information will be used to perform the RBI Analysis in order to determine the Risk Ranking based on pressure containment, mitigation actions, inspection strategies and inspection plan (NDT activity, frequency and coverage).

The inspection plan delivered was integrated within maintenance and operational strategies for routine and turnaround perform as well, this integration allowed the effective execution of inspection activities into a reasonable availability window and cost.

The bidirectional communication between RBI System and RBI Tool (analysis) give the incomes to the Deterioration Monitoring Functionality, which is in charge of carry out Thickness Monitoring activities into an effective tool capable to gather all field data, analyze and forecast the remaining life for each particular section or component as well in order to predict and prevent any possible failure. As part of this function are corrosion probes and chemical injection activities.

The integration of these elements and its outcomes allowing an adequate interaction of information, which is orientated to define the preventive and corrective tasks to minimize the effect of damage mechanisms, e.g. chemical injection adjustment.

The prospective from inspection plan and mitigation actions have to be loaded on an Inspection Management System, this tool stores whole information like asset profile, plan, schedule, records, reports, and attachments. The inspection manager tool has to be flexible, uses a workflow, and should be related to a recommendations tool and notifications system (CMMS).

Comentario [D13]: stores (?)

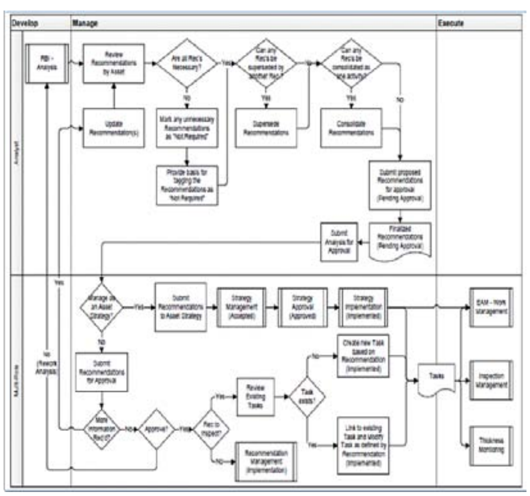
As complementary functions, of Mechanical Integrity System should be considered the Integrity Probabilistic Analysis, like Resistance-Strength Analysis, Weibull, Fitness for Service, Fracture

Mechanical Analysis, and Asset Integrity Management, which include the metallurgy upgrade, design change and life cycle analysis. These functions give up a deeper analysis to support the high management decision but will depend on the quality and effectiveness of data management into Mechanical Integrity System.

The model designed was developed covering the key elements of business as technology transfer, asset life, process unit availability, asset register, technology challenger and capabilities, turnaround plan and strategies, asset criticality and business objectives, otherwise the tools implementation will run isolate and will not give the compliance level required to achieve the Mechanical Integrity objectives, so the snow ball effect (poor and enormous data collection) can be introduced into de asset management system affecting the effectiveness of management decision.

c) Work Flow Development: As support of Mechanical Integrity System have to be developed a work process flow (figure No 4), which is going to be the reference document to standardize and institutionalize the system through whole organization. As per Mechanical Integrity System is no a solely responsibility of inspection, reliability or integrity department, a teamwork should be assigned as responsible to ensure its effective implementation and sustainability.

The work flow needs guidelines and references document (format, instructions, and procedures), thereafter can be performed an effective implementation within criticality definition based on susceptibility to material deterioration, inspection plan development according best mitigation of failure scenarios, inspection task scheduling based on business availability, definition of proactive corrosion control, optimum recommendation tracking, and mechanical integrity indicators as management key, in order to optimize the inspection plans based on continuous improvement philosophy.



(Figure No 4)

2. Technology Platform (APM-AIS Software) Implementation

The implementation of Mechanical Integrity System (MIS) was supported by a technology platform allowing adequate gathering, interrelation, management, and storage of data associated to asset, thus this technological portfolio content a series of functionalities to ensure the effectiveness and performance of asset mechanical integrity. Requisites to be covered by this system are:

- Capability to interrelate and transfer data within Financial Management Systems (ERP) systems and Maintenance Management System (CMMS), which are used to manage all business issues but are not capable to handle particular issues on mechanical integrity: risk calculation based on damage mechanism susceptibility, consequences by leaks, deterioration trend calculation, corrosion rate and remaining life definition.

- Capability of create fixed asset structure based on Unit taxonomy hierarchy, corrosion loops, RBI component (piece of equipment), component or asset profiles (inspectable areas), inspection point, and thickness measurement location (TML). Additionally it must handle design and operation data, damage mechanism files, non-destructive testing lists, and corrosion parameters based on international standards.

- Capability of Risk calculation (criticality by pressure containment loss) in quantitative or semi quantitative way (risk matrix by damage mechanism), based on Risk Based Inspection methodology (API 580, 581, and 571 as well) and applicable to Equipment or Component, it should be enable to generate damage mechanism library, either particular or general inspection strategies.

- Enable to generate RBI recommendations (manually or automatically) by activation or progress of deterioration mechanisms, which have to be addressed by inspection strategy aligned to maintenance strategies (routine or turnaround), and must be flexible to issue inspection programs (plan and schedule). It should be capable to update last and next task date, and generate inspection work package to be used as input on inspection contracting activities.

- Capable to develop inspection profiles templates by equipment or component linked to failure taxonomy, NDT library, task priority and report functionality, which must be enable to customize the formats and attaching any supplementary file (graph, drawing, and schematic). It is recommended the report system have flexibility to issue the information by unit, system, equipment or component from any functionality of Mechanical Integrity System.

- Capability to generate report of task programs and overdue, at same time linked to notification system (CMMS), and recommendation tracking in order to follow up and control the inspection programs performing, and the maintenance task recommended.

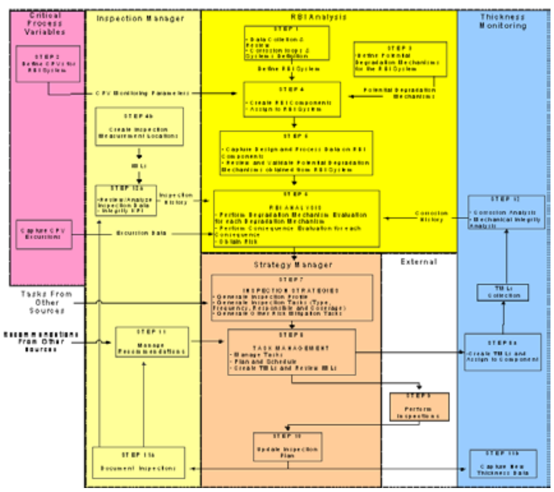
- Enable to transfer field measurement data on specific or massive way, from measurement datalogger or devices, and for calculating integrity parameters like corrosion rate, remaining life and minimum thickness required, based on this issues must produce the next inspection date according within international standards required, local regulations or internal policies and practices. At same time is required that functionality can collect data from process historian system in order to monitoring and record any kind of process deviation or threshold trespassing could de trigger of damage mechanisms.

The Mechanical Integrity Platform must be developed based on Modules Interrelation, and must content at least the functionalities like Basic Asset Framework, RBI, Thickness Monitoring, Inspection Manager, Process Critical Variables, Strategies Management, and Recommendation Tracking as well.

Software Customization

The functionalities of Platform were customized according within business needs in order to facilitate the data management and get better performance on its application. The customization should be reasonable and feasible, ensuring the right data travel between the different modules (figure No 5) , which can be collected, analyzed and readdressed from one module to another one, this ability give an effective and opportune response time and allow to keep the traceability and quality of whole information manage into the system.

The customization cover the particular requirements within other system outside the integrity suite like CMMS or Process Historian System, but was necessary be developed carefully to avoid unnecessary spend of resources and budget.



(Figure No 5)

3. Technology Transfer Process (Specialist and Champions Development)

The implementation of Mechanical Integrity System was supported by a real knowledge transfer process, which helped on skill development, and capabilities of own personnel. Hence the stakeholders will be responsible for the implementation, institutionalization, and sustainability of this technology and work methods through all life cycle of business.

Through the time have been shown up in several integrity assessments that the organizations, interesting on implement Mechanical Integrity System (MIS) are weak in understanding, and skills on technical and functional areas, its MI process have been managed based on isolate procedures and software within limited capabilities to be integrated to Management System, which create more dependency from few inspection personnel and some specific contractor, even though the intention is to ensure the asset running and the results of this management reveal a huge lack of accomplishment within Business Goal and Objectives, at meantime are spending high budget and there is not a realistic outcome of indicators and either improvement of asset performance.

Specialist and Champions Development

The development of specialists on this area of asset management needs a consistency process of training, coaching and mentoring, to achieve this objective were measured the level of understanding and skills in each functionality, either on functional (methodological) level, and technical (software) as well across the staff in charge for implementing the integrity system. Parts of organization were involved on this process are inspection, maintenance, process, operations, and safety in order to develop the drivers that support the activities and task on this matter.

As fundamental issue on knowledge transfer, the knowledge base development considered the follow tasks:

a) Formal training on (MIS) framework basic capabilities, either on specific functionalities of each module; Risk basic Inspection (RBI), Inspection Manager, Thickness Monitoring and Strategy Management, as complementary training is included RBI Methodology (API 580 and 581), Damage Mechanism (571 and NACE), and an introduction on Equipment Inspection (API 510, 570 and 653) and NDT techniques (ASME section V).
b) Coaching of particular characteristics definition for system configuration, data management, report design, implementation plan perform, deliverables issue, KPI's and system management.
c) Direct mentoring on integrity parameters definition, data collection, components structure, corrosion loops definition, RBI analysis, inspection strategies and inspection plan development, profiles and templates definition, critical process variables identification (associated within damage mechanisms), and recommendation management as well

4. Functionalities Development and Implementation (RBI Assessment, Inspection Plan Development, Thickness Monitoring Standardization, CPV Definition, Recommendation Tracking Integration and Corrosion Control Optimization)

This strategy is orientated to perform the implementation on field in an effective way. Like have been mentioned above, the key of success on this initiative is the integration between all business functions. Due the information is carry out in different systems and from several sources, whole data must be addressed on integrated way to ensure the adequate manage of Asset on its life cycle.

The content of this strategy implementation was based on definition, development and performing of following issues:

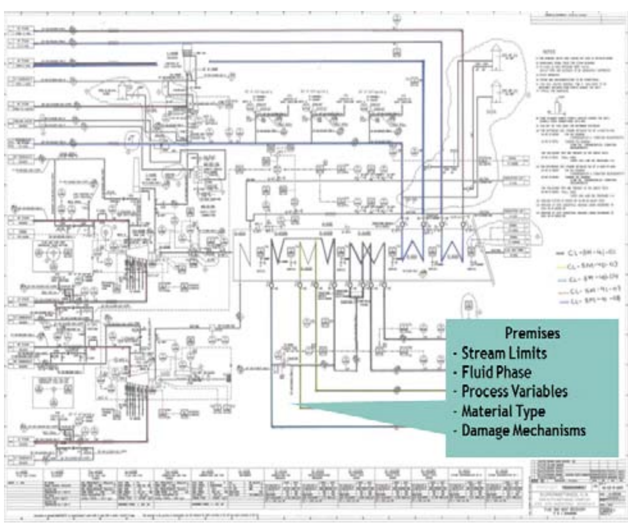
- Damage Mechanisms Breakdown
- Process Critical Variables
- Inspection Strategies
- RBI Analysis
- Inspection Plan

- Thickness Monitoring Structure
- Inspection Management Structure
- Corrosion Control Program
- Recommendation Tracking
- Integrity Key Perform Indicator

Damage Mechanisms Breakdown

Each one of process unit is breakdown on RBI Systems normally know ing as Corrosion Loops, which are developing from the susceptibility analysis of damage mechanism through certain length of fluid running, taken as fundamental parameters the metallurgy type, process parameters and operational conditions related to occurrence o activation of potential deterioration.

The corrosion loops structure, give the guide to identify internally or externally the probable damage mechanism on any component, which should be considered as base into RBI analysis. The probability and consequences should be modeled over a specific deterioration, in order to determine the criticality level and the inspection strategies (NDT, frequency and coverage) to monitor on preventive way the presence of damage on material. Additionally RBI systems allows to define the inventory of fluid to be used on consequences calculations, as per it is the parameter required to calculate the magnitude of fire, toxicity, equipment damage, production cost and environment pollution as result of loss of containment.

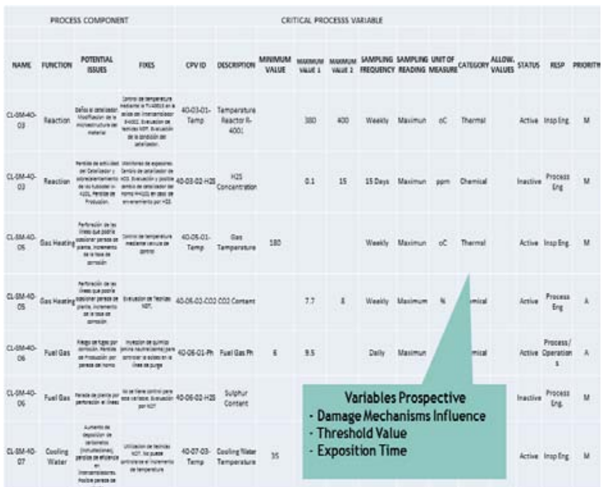


(Figure No 6)

The structure of RBI System (figure No 6) as graphical representation shows the extension of each group of fixed component, but it is important to differentiate those against PDF's and P&ID's, because are a different prospective to be defined and to be used as well. Even these systems could be marked up on any of drawings just mentioned above, however is an excellent help for Integrity Engineer to identify susceptible areas and based on this performing RBI study on systematic and effective way.

Process Critical Variables Identification

The activation and propagation of degradation mechanisms normally are the result a process variables deviation over the threshold of material resistance, so which can be effected by mechanical, chemical, thermal and environmental factor, thus these parameters were identified and handle on a system (figure No 7). The capture and collection of excursion show to Integrity or Inspection Engineer the alarms and deviation of process variables, in order the inspection activities will be scheduled to verify the evidence of damage activity or process adjustment to avoid the initiation of damage mechanisms through the asset life.



PROCESS COMPONENT				CRITICAL PROCESSS VARIABLE												
NAME	FUNCTION	POTENTIAL ISSUES	FIXES	CPV ID	DESCRIPTION	MINIMUM VALUE	MAXIMUM VALUE 1	MAXIMUM VALUE 2	SAMPLING FREQUENCY	SAMPLING READING	UNIT OF MEASURE	CATEGORY	ALLOW. VALUES	STATUS	RESP	PRIORITY
CL-SM-40-03	Reaction	[illegible]	[illegible]	40-03-01-Temp	Temperature Reactor R-4001		380	400	Weekly	Maximun	oC	Thermal		Active	Insp Eng.	M
CL-SM-40-03	Reaction	[illegible]	[illegible]	40-03-02-H2S	H2S Concentration		0.1	15	15 Days	Maximun	ppm	Chemical		Inactive	Process Eng	M
CL-SM-40-05	Gas Heating	[illegible]	[illegible]	40-05-01-Temp	Gas Temperature	180			Weekly	Maximun	oC	Thermal		Active	Insp Eng.	M
CL-SM-40-05	Gas Heating	[illegible]	[illegible]	40-05-02-CO2	CO2 Content		7.7	8	Weekly	Maximum	%	[illegible]		Active	Process Eng	A
CL-SM-40-06	Fuel Gas	[illegible]	[illegible]	40-06-01-Ph	Fuel Gas Ph	6	9.5		Daily	Maximun	[illegible]	[illegible]		Active	Process/ Operations	A
CL-SM-40-06	Fuel Gas	[illegible]	[illegible]	40-06-02-H2S	Sulphur Content		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Inactive	Process Eng.	M
CL-SM-40-07	Cooling Water	[illegible]	[illegible]	40-07-03-Temp	Cooling Water Temperature	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Active	Insp Eng.	M

(Figure No 7)

Inspection Strategies Definition

Each damage mechanism is evaluated following a specific inspection strategy, which is addressed to increase the capacity of its detection and monitoring. There is different sources recommends appropriate technique or method in order to catch any evidence of deterioration. At meantime the experience on this kind of issue by Corrosion Engineer or Inspector Engineer, and based on maintenance and operation philosophy the scope of inspection strategy is defined.

In this project were developed 168 Inspection strategies, so which those will help to optimize the NDT requirements, frequency to be performed and the coverage required to ensure the maximum capacity of detection, because this issue is the trigger to develop the inspections task to be scheduled further. Thus to ensure its implementation these are populated (automatic) or generate manually according within the criticality level and cost –risk analysis, in order to apply the right tool that will give the best confidence and address the reduction the level of probability based on inspection effectiveness and feasibility of its performing.

RBI Analysis Approach

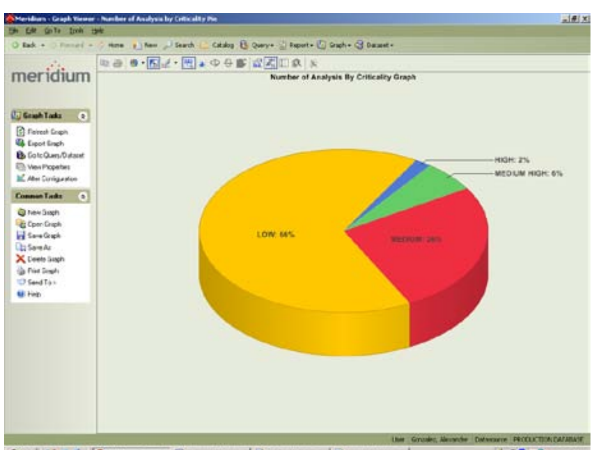
RBI as methodology based on API 580 y API 581 is a complete tool to determine the asset or component criticality, however, the requirements to calculate the probability and consequences has a certain level of complexity that is very difficult to be handle manually, by this reason was implemented a practical and useful RBI module that allow on systematic and effective way the values of this condition and its implication on business life cycle.

The best implementation can be achieved only if RBI is integrated on continuous loops within remaining functionalities, because have to be handled as evergreen process. The successful of this process depend on the data collection quality, which is a responsibility of facilitator but influenced so much by the functions or departments as process, operation and SHE as well. After data collection has been completed and RBI system developed, all parameters are loading on the software for running each RBI Analysis and get a complete approach to address the inspection strategies implementation.

The key of accuracy of RBI analysis in this case was based on quality data, even though the strategies to reduce this issue were orientated to get the best teamwork performance, and throughout sensitivity analysis reduce the gap normally find out in facilities databases or documents storages. The implementation of RBI study required a lot effort and took a relevant time, actually is applied on new projects on face stage to be prepared within inspection plan before first running. In facilities on service is recommended to define the priorities, which normally aiming to process unit on first face and the utilities after.

Risk Matrix

The risk matrix is the reference to position the criticality level of each asset, one issue to consider is the capability of this matrix to rank the risk level, in order to define the inspection priorities and assigning on effective way the inspection strategy to be applied, otherwise the results will be gotten into a wide range and will depend of analyst experience to define the next inspection date, which is used to be the final result of RBI analysis and into best practices is only one of outcomes, this issue have to be complemented by the others elements on mechanical integrity prospective like life cycle, strategies integration, inspection schedule optimization, and scenarios proposal to determine base on risk-cost others mitigation actions over the life cycle like metallurgy update, maintenance activities or redesign as well.



(Figure No 8)

As management support the RBI gave the risk overview (figure No 8) of all components to visualize in fast way the facility position into integrity criticality, and can determine the management strategies to be implemented on business to keep or move this issue into acceptable boundaries. This snapshot is a useful tool on insurance audit and can influence the final result and payment rate because mechanical integrity status.

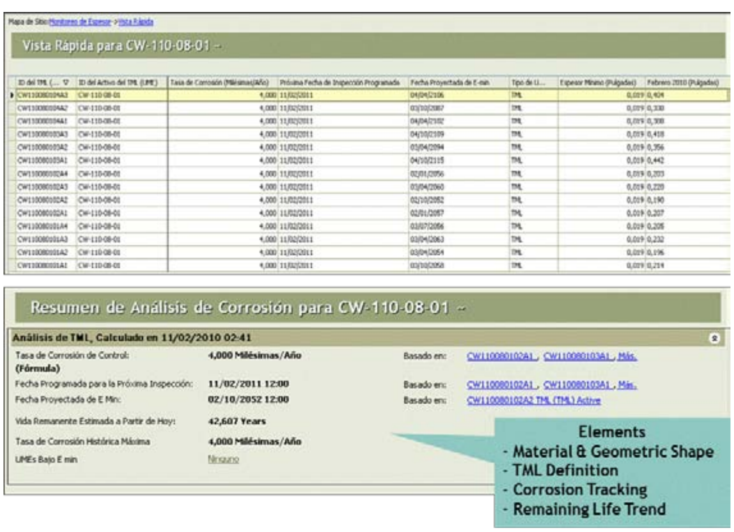
Inspection Plan Development

Once RBI study was performed, its results were consolidated and became in an Inspection Plan, normally established for a period of ten years based on component criticality and inspection strategies define previously, therefore could be developed the inspection schedule and determine the resources required for monitoring and control the failure probability, this issue have to be realistic and feasible to be implemented, otherwise will be a death paper on a system data that will introduce more disturb on Asset Management and Business Management, within issues like backlog raise, recommendations pending, and reliability misunderstanding.

The inspection plan developed and managed on MIS platform represent the scope of work to be implemented on the short and middle term, orientated to evaluate the asset conditions, thus can be determined the real presence of discontinuities or defect that could generate a failure by loss of containment. To get the effective implementation of inspection plan is required the alignment within maintenance plan, budget availability, management commitment and understanding of integrity indicators in order to get a forecast about the expectation of remaining life into a safety and reliable operations conditions.

Thickness Monitoring System Build Up

As part of integrity tools is orientated to collect the actual thickness measurement taken along the process system, in order to determine de corrosion rate and remaining life (see Figure No 9), thus can be defined the actions and task to get an effective corrosion control based on process variables adjustment, improvement of chemical injection parameters (preparation, injection rate, concentration, type of chemical and others), metallurgy upgrade and deterioration monitoring on real time.



(Figure No 9)

~~The key on this tool implementation is the previous guideline development, the adequate configuration of thickness measurement locations, and effective and accurate transfer data between the measurement device and TM System, which give an appropriate reference to NDT technician for TM performing.~~ There are two issues to be considered on this function that required a lot of effort and careful technical handling; TML identification on drawings based on field accessibility, and definition of corrosion setting into the system. Quality and effectiveness of this particular element is affected so much either for any discrepancy or mismatching of these parameters. The key on this tool implementation was the guideline development, which allowed the adequate configuration of thickness measurement locations, based on an appropriate definition of Isometrics and its related TML's according within RBI strategies requirement. Therefore the readings collection allowed the effective and accurate transfer data between the measurement device and TM System, which give an appropriate reference to NDT technician for TM performing.

Comentario [D14]: Please comment if the system has the Inspection Iso-metrics with specific TMLs

Comentario [D15]: Please comment if the system has the Inspection Iso-metrics with specific TMLs

Inspection Management System

The inspection plan gotten from RBI approach was consolidated to be optimized on its implementation, but to be manage on an effective way was used a capable system where can be developed each inspection profile (piece of equipment or area) belong to asset, additionally are associated the NDT to be perform and the susceptible damage mechanism.

The inspection management represents a combination of document control and scheduling functionalities, which is able to carry out all inspections tasks required, according within execution schedule. The Inspection Task will address to responsible executor, collecting whole identified conditions, attach any schematic, drawing or NDT result format. Also it will show on the failure mode, and deterioration mechanisms could occur.

Additionally the frame is integrated to asset failure taxonomy, mitigation activity according within maintenance task strategies, which allows an appropriate data collection and effective performance indicators built up on Asset Performance Management (APM) and work order management (CMMS). The inspection recommendations generation must be linked to CMMS in order to populate the work notifications directly to planning group to be incorporated into maintenance program.

Corrosion Control and Follow Up

The Mechanical Integrity System Implementation is over the generation, approval, and execution of Inspection Plan, therefore Corrosion Control is performed on reliable and effective way, through them is evaluated the performance of materials exposed to fluid and its operational conditions. The conditions detected on inspections reflect the activation of damage mechanisms, and it contribute to determine the efficiency of chemical injections programs (inhibitors, neutralizing and passivation feed), and process variables control. This issue some time represents a conflict between Inspection & Corrosion department against Process Department, which should affect the achievement of business objectives, the intention is getting the alignment between all actors and take the actions to improve the materials protection.

The isolation between physical corrosion rates determined by TM system and chemical analysis performed by contractor lab, normally produce a huge money wasting and an increase on failure rate affecting the availability and production plans. It is the reason because corrosion control has to be integrated on mechanical integrity strategies and must to feed the variables of RBI based on the result of thickness monitoring program.

As part of Corrosion Control the facility must to have installed devices as coupons, ERP or ERL to monitor on real time and gathering the changes on fluid composition based on either Iron Content or material loss, which can adding some evidence about the raise of thickness reduction probability. The level of technology, functions integration and organization expertise will give the level of confidence on this activity, however, the effectiveness on thickness monitoring perform is deterministic to ensure the detection and accuracy of deterioration mechanisms progression.

Recommendation Tracking

Comentario [D16]: Please comment if the system considers temporary repairs tracking.

Based on conditions the recommendation generation is the normal way to identify the task required to mitigate any deviation or deterioration progression, this issue normally is a technical prospective, which content represents the work scope to be perform and the requirements to carry out the failure probability, for its implementation have to be become in a maintenance or project plan, therefore the content of this notification must be clear and complete. This particular functionalities is enable to track permanent and temporary repairs in order to satisfy any requirements from management systems like Process Safety Management (PSM), Insurances Needs or Local Statutory Regulations.

MI System is integrated to Recommendation System (APM Framework) to ensure the implementation, following up, and execution control of recommendation in order to ensure the traceability, indicators accomplishment level, quality, and effectiveness of implementation. It is responsibility of management level to have enable a system where is register all notifications, alarms, and completion record from execution. The recommendations compliance is one of most important indicators for shareholders and insurance surveyors.

Integrity Key Perform Indicators

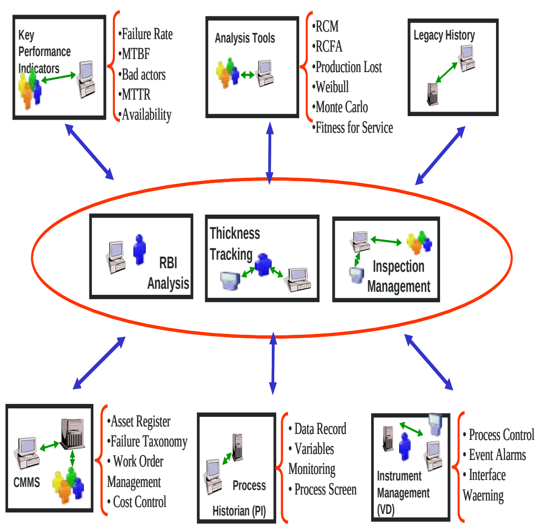
As management tool, Mechanical Integrity System have specific indicators to measure, monitoring and control the performance of this functionality, the parameters to be collected are able to reproduced reliable indicators that can give a effective decision based on business management. As part of indicators are considered: remaining life, failure rate, deterioration threshold excursions, recommendations accomplishment, corrosion rate, bad actors, inspection plan execution and inspection cost as well.

The outcomes of this system show the effectiveness of Integrity System, either it can determine how the inspection activities are performed, what kind of relevant condition have been detected, recommendation compliance status, and projection of remaining life and asset life cycle. At same time the inspection cost can be monitored, and the payback in term of failure reduction and increasing the yield factor according within asset mechanical availability needs. The structure for Integrity KPI must is aligned to the requirements of Corporate, Business and Functional Indicators, it is very important generate indicators in a real time and within add value or beside of management control policies.

5. Functionalities (methods) and technologies (mechanical integrity tools, process control and history and CMMS) integration.

The difference between an isolate implementation of technologies and software against an effective Mechanical Integrity System performing is the business integration of all technologies available into it. This mean that the acquiring of any tool have to been assessed in order to assure the flexibility and capability of tool to be linked within other functionalities in order to manage the data and results according within business needs. As ending implementation strategy, the integration of tools have to be supported by functional guidelines and certified interfaces, capable to give the guarantee of moving back and forward the incomes and outcomes from each module in order to get the interaction of the sources to relate, and analyze the data and identify the gap, actions, or recommendations required to keep up the expectations of asset life cycle and business profitability.

The integration of tools (figure No 10) depend on the capability of facility and the tools availability, as integrity issues the most common linked are; inspection manager and work order manager from CMMS, inspection manager and recommendation tracking, thickness monitoring and RBI, process historian and critical process variables, inspection manager and change management tool, asset performance management and CMMS, and any another relation considered as need of business. The key is to keep the system undergoes to data sharing, which will push to improve the quality level, the data monitoring and data record, because any mismatch will be detected in order to eliminate scratch influence on management decision.



(Figure No 10)

Benefits

The effective and adequate implementation of Mechanical Integrity System on **MBTE Facility** was a real successful, since the challenger taken from the beginning by the staff assigned to develop and perform this initiative, as per they were awarded about the skill gap and management change resistance attempt against the management objectives established. However, the maturity of Best Practices on this issue and the willingness of champions and management commitment could allow the following benefits:

Strategically

- Technology and Skill Gap Closure (Company Knowledge Development)
- Turnaround Work Scope Optimization (1.6 MMUS$ in Cost Reduction) and Damage Detection Capability Improvement
- Mechanical integrity Follow Up and Control
- Optimization of NDT performing (turnaround and routine)
- Acceptable Criticality Risk Definition (Cost-Risk Benefit Analysis)
- Mechanical Integrity Status for Insurance Surveyors
- Risk map and basis to Management Decision
- Standardization of Data Collection and Manage, Preservation and Updating of Data
- Team work culture institutionalization and business roles definition
- Integrity KPI Implementation

Operatively

- Prediction and Detection of Deterioration Mechanism
- Reduction of Data Research Time
- Failure Frequency Failure
- Inspection Cost Optimization
- Inspection Plan based on susceptibility, and potentiality of damage mechanisms
- No planning Shutdown Reduction
- Inspection strategies Development (150 strategies populated automatically)
- Simplification of piping asset register (based on piping group – 300 MUs$ of saving)
- Development of Operative and functional guideless and procedure.
- Integration of critical process variables Follow Up and Control

Conclusions

The design and implementation of Mechanical Integrity System for fixed asset have to be based on effective strategies that consider the integrity management model development, technology platform definition, skill and knowledge improvement, integrity functionalities institutionalization, and data collection system integration.

An effective implementation and accomplishment of business objectives running around the real knowledge transfer process, which was addressed to get a gap closure of understanding, knowledge and maturity of methodologies used to implement this system. Forward the team in charge to achieve the implementation of functionalities portfolio, and perform the development of this initiative according within the facility needs, like life cycle compliance, data collection and performance analysis.

Information preservation and data integration in order to identify the relevant issues and priorities, whereby it can allow the generation of integrity indicators to support the management decision to aim the strategies, and to ensure the life cycle into the most profitable and reliable environment.

The successful of implementation for client on reference was based on the management commitment, technology transfer project methodologies, willingness to learn, adequate change resistance management, projection of software integration, training and coaching on functionalities and technical issues, recognition of gap and threats, mechanical integrity best practices institutionalization, life cycle vision and business needs achieve

Bibliography

API RP 580, Risk Based Inspection, 2nd Edition API April 2011
API RP 581, Risk based Inspection technology, 2nd Edition API September 2009
API RP 750, Process Safety Management, 1st Edition API July 1995
API 510 – Vessels Repair and Service Inspection
API 570 – Piping Inspection
Meridium Mechanical Integrity Standard Practice, 3rd Review November 2014

Curriculum Vitae

Maintenance Engineer - Politecnico Santiago Marino (Venezuela), Master in Project Manager – Universidad Rafael Belloso Chacin (Venezuela), Master Business Administration – ISEAD (España), Specialization in Reliability – URBE (Venezuela), Quality Assurance – LUZ (Venezuela), Metallurgic Technologist – CUM (Venezuela). He is certified as API Piping Inspector (API 570), Vessel Inspector (API 510), RBI Analyst (API 580), and as Reliability and Maintenance Professional (SRMP).

Experience over 29 year through Manufacturing Area, Oil and Gas, Refinery and Petrochemical Industry, working as Mechanical Integrity Senior Consultant (SME) in Meridium INC, Inspection Engineer in Qatargas, Project Coordinator in Bureau Veritas, Inspection Superintendent in SINCOR (Total Branch), Also as Inspection Supervisor, Reliability Engineer, Project Engineer and Maintenance Corporate Advisor in PDVSA, QA/QC Supervisor in Manufacturas Hidromecanicas and Metallurgist Analyst in Smith Brocas and Hudges Tool Company. Also have been speaker in different conferences and workshops in Canada, USA, France, Mexico, Peru, Argentina, Ecuador and Venezuela.

Actual Job: Senior Matter Expertise in Meridium Inc. – Houston, USA