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Navigating Success: A Methodological Approach to Developing Turnaround Inspection Work Scopes for Success

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ABSTRACT - This paper presents a methodology tailored to formulate a comprehensive, efficient, and effective inspection work scope for in-service equipment, specifically designed to seamlessly align with the intentions and objectives of a process plant turnaround. Unlike projects or upgrade initiatives, the inspection work scope is inherently dynamic and intricate, influenced by a myriad of variables, conditions, and unknown factors. Yet, it stands precisely as the cornerstone for all successful turnarounds. The methodology delineated herein integrates engineering best practices, multi-dimensional input, real-life field conditions, risk-based assessment, and process controls. This integration facilitates the development of an inspection work scope that is indispensable for the success of a turnaround.

Key Words: Work Scope, Inspection, Turnaround, Risk Based, Methodology

I. INTRODUCTION

Process plant turnarounds (TA), also known as shutdowns or outages, are meticulously planned events where an entire unit or facility is temporarily taken offline for maintenance, inspections, and upgrades. These events are indispensable for ensuring the reliability, safety, and efficiency of plant operations in alignment with business objectives for the coming years. This intention remains constant irrespective of the specific turnaround premise or acceptance criteria, as it constitutes an integral part of maintaining a process plant.

An important measure of success for a turnaround maintenance is defined by its timely execution, adherence to budget constraints, and completion of planned tasks as scheduled. However, many turnaround maintenance struggles to achieve this level of success. The inspection scope constitutes the cornerstone of any turnaround, underscoring its critical importance. While considerable literature exists on the overarching phases and management strategies for successful turnarounds, there's a noticeable dearth of detailed exploration into methodologies for crafting comprehensive, efficient, and effective inspection work scopes tailored for in-service equipment. This paper aims to address this gap by delving into the detailed methodology required to develop lean, business-focused turnaround inspection work scopes.

II. THE TURNAROUND PROCESS

The turnaround process in a process plant encompasses a series of interconnected steps aimed at safely and efficiently shutting down, maintaining, inspecting, and restarting plant operations, all done without a specific duration and budget. Each of these steps is crucial and demands meticulous planning, coordination, and execution to guarantee the success of the turnaround event. Typically, it requires 18 to 36 months of preparation before the execution phase commences. A general overview of the turnaround phases is depicted in Figure 1.

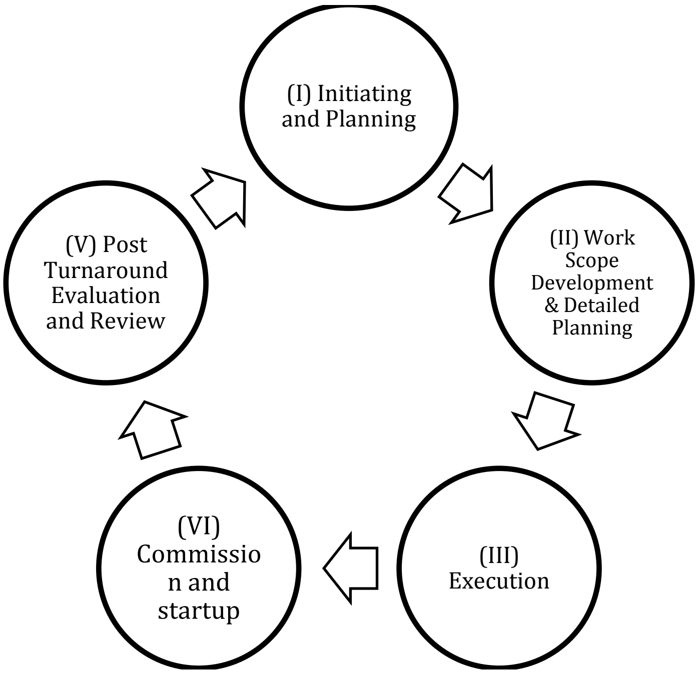

Fig -1: Turnaround Phases

(I) Initiating and Planning

This phase involves evaluating maintenance schedules, equipment performance, regulatory requirements, and operational goals for a turnaround. A diverse team is formed from operations, maintenance, engineering, procurement, safety, and other relevant departments. Together, they outline the turnaround scope, including premise, objectives, acceptance criteria, activities, resources, timelines, and budget, while also identifying risks like hazards, regulatory compliance, and supply chain risks.

(II) Work Scope Development& Detail Planning

Define the scope of work by assessing equipment inspections, maintenance needs, repair/replacement requirements, safety enhancements, and other relevant factors. Prioritize maintenance tasks considering equipment criticality, operational impact, regulatory adherence, and resource availability. Collaborate with stakeholders to align on the scope of work and turnaround goals. Develop a comprehensive work plan outlining tasks, schedules, resource allocations, and contingency measures.

Simultaneously, detailed planning is undertaken, encompassing resource allocation and scheduling. Resource allocation involves identifying the human resources, materials, equipment, and services necessary to fulfill the turnaround scope. Coordination is established with both internal departments and external contractors/vendors to secure essential resources well in advance. Historical data, performance metrics, and turnaround priorities are leveraged to optimize resource allocation effectively

Scheduling requires the creation of a comprehensive turnaround schedule that organizes tasks, assigns resources, and reduces downtime. Take into account factors like equipment availability, critical path tasks, resource limitations, and dependencies on external factors. Utilize scheduling methodologies and tools such as critical path method (CPM) analysis and resource levelling to refine and optimize the turnaround schedule.

Throughout this phase, communicate schedule and resource allocations to all stakeholders and update it regularly to reflect changes and deviations from the plan.

(III) Execution

Execute the turnaround work scope as per the scheduled sequence while maintaining strict adherence to safety protocols, regulatory standards, and environmental guidelines. Monitor progress closely against predetermined schedule and budget objectives, addressing any deviations or delays promptly. Foster coordination among operations, maintenance, and other relevant departments to facilitate seamless task execution and mitigate disruptions effectively.

(IV)Commissioning and Startup

Conduct thorough equipment inspections and testing to validate the satisfactory completion of maintenance activities. Execute safety checks and

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quality assurance procedures to certify the readiness of the plant for startup. Develop comprehensive startup procedures and protocols to facilitate the safe and efficient resumption of operations. Collaborate closely with operations and maintenance teams to commission equipment and systems, promptly addressing any issues encountered during the startup phase**.**

(V) Post-Turnaround Evaluation and Review

Perform a comprehensive post-turnaround evaluation to evaluate the event's performance against predefined goals and objectives. Review turnaround metrics such as downtime, budget compliance, safety incidents, and quality of work. Identify key lessons learned, best practices, and areas for enhancement to enhance future turnaround planning and execution. Document all turnaround activities, outcomes, and recommendations meticulously for inclusion in the plant's knowledge management system.

By following this structured turnaround process, organizations can enhance their ability to plan, execute, and evaluate turnaround events, thereby improving plant reliability, safety, and efficiency. Effective communication, collaboration, and continuous improvement are essential for achieving success in turnaround management.

III. IMPORTANCE OF INSPECTION WORK SCOPE

Often, inspection activities dictated by inspection work scope represent about 60% of a unit turnaround workload, with the remaining being from upgrades and maintenance [1]. The turnaround inspection work scope serves as the most important and biggest blueprint for the entire event, guiding decision-making and resource allocation. A well-defined work scope ensures that all necessary maintenance activities are identified and planned for in advance, reducing the risk of delays and cost overruns. The absence of thoroughness in the scoping process leads to a myriad of issues. Bundling maintenance tasks, which could be executed while the plant operates, into turnaround maintenance elongates shutdown periods needlessly and redirects manpower from critical tasks during the turnaround maintenance event.

Furthermore, a comprehensive work scope facilitates effective communication and coordination among stakeholders, including operations, maintenance, engineering, and procurement teams.

The input for work scope is derived from all relevant disciplines and projects. Regardless of how a turnaround strategy or premise is defined, the overarching objective remains consistent: to ensure the safe and reliable operation of the process plant while enhancing efficiency, achieving cost savings, and adapting to new product interfaces. These aims are aligned with the business needs for the years ahead. Of utmost importance, a turnaround event aims to guarantee production availability between each turnaround.

McQuillan [2], state that the impact of turnarounds on overall reliability can be expressed as:
Plant “unavailability” =breakdown outage + shut down duration/shutdown interval

From this, it is seen that work done during turnaround would:

- Reduce or eliminatethe probability of breakdowns
- Protect future plant performance
- Increase the interval between turnaround
- Reduce the duration of each turnaround

The figure below shows the approach to developing and optimizing turnaround inspection work scope:

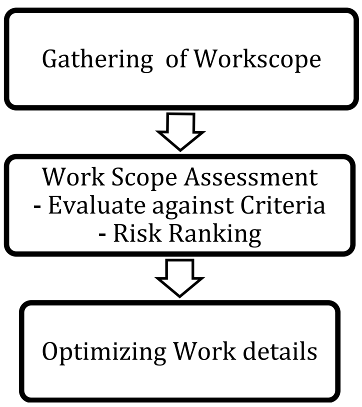

Fig- 2: Work Scope Development & Optimization

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IV. GATHERING OF WORK SCOPE

During a turnaround, the scope encompasses contributions from various functions, including integrity, electrical, operations, technology, reliability, maintenance, and upgrading projects. The focus of the work scope development outlined here pertains specifically to the inspection of in-service equipment.

To start with and the most important step is to have a competent Scoping Team. This team must have the following competence and experience:

- Intimate knowledge of the unit equipment performance and condition.
- Detail understanding of the process and the corrosion related to them.
- Competence in Risk based analysis
- Experienced in turnaround scoping and execution work.
- Competence in inspection and repair techniques

It should be clear that competence is much beyond certification. Competence is defined as “the ability to apply knowledge and skills to achieve intended results.” [3]. The Scoping Team has the support of and input from operations, execution, reliability, mechanical and technologist

The development of a turnaround inspection work scope draws inputs from various sources. A fundamental aspect of this scope is the mitigation of the risk associated with equipment failure, which could lead to plant outage, financial losses and customer’s confidence. Additionally, considerations extend to safety and environmental concerns, where any loss of containment could result in unacceptable safety and environmental consequences. Therefore, comprehensive inputs for a turnaround inspection should include:

a) Business plan for the plant and current business environment.

These considerations will impact the time allocated, budget, resources, risk acceptance, and ultimately the scope of work. For example, in periods of high product demand, there may be a tendency to minimize or postpone turnaround time and scope of work to maximize business and profit. If the objective is to enhance environmental performance, the turnaround may incorporate upgrades to reduce emissions or bolster safety measures. Conversely, if the goal is to augment production capacity, the scope may entail expanding or modifying existing equipment

b) Outcomes of previous turnaround evaluation and review.

This will offer insights into areas for improvement, effectiveness or ineffectiveness of inspection strategies, unexpected findings, and critical components requiring special attention.

c) Equipment that can only be inspected during shutdown.

These pieces of equipment are integral to the process chain and cannot be bypassed in the event of failure or underperformance. They play a critical role in the process, and any disruption will lead to an outage. In most plants, they have already been identified and confirmed by operations. Therefore, they should be included in the input for the inspection work scope.

d) Statutory and Regulatory requirements.

As in any country, the imperative to comply with statutory and regulatory requirements is non-negotiable. Each country specifies the type of equipment that must undergo inspection within a prescribed timeframe, overseen and witnessed by authorized personnel. Compliance is mandatory, leaving no room for choice—all such equipment must be included in the inspection.

e) Integrity Operating Windows (IOW) exceedance

Within process plants, established limits for process variables (parameters) are critical and they are established in order to maintaining equipment integrity. Deviations from these limits over a predetermined duration can impact equipment integrity [4]. These variables, known as IOW, are monitored and analyzed by specialists such as Corrosion Engineers. Exceeding these limits, depending on factors such as duration, frequency, and magnitude of the exceedance, can lead to equipment degradation and affect downstream processes. Data collection, tracking, reviews and studies are conducted to assess the extent of equipment damage, and nondestructive testing may be employed to determine the severity. Equipment identified as concerning becomes an input for the inspection work scope.

f) Equipment End-of-Life

Equipment reaching its end of life can be addressed through replacement, repair, or extension of its operational life with intensified monitoring. Prior to deciding on the appropriate course of action, conducting a comprehensive assessment of the end-of-life equipment is crucial. This assessment should determine its current condition, remaining useful life, and potential risks associated with continued operation. Evaluate whether the equipment can safely operate until the next turnaround, or if its continued operation poses immediate safety, integrity, or reliability concerns.

g) Forecasted remaining life of equipment

Inspection is to be conducted upon reaching half of the remaining life of the vessel [5]. Corrosion is an inevitable occurrence in any plant, and as per API 510 requirements, equipment is to be inspected when it reaches half of its remaining life to validate its condition.

h) Potential Damage mechanism

Through literature review, benchmarking similar plants, and consulting corrosion engineering expertise, potential or expected failure mechanisms can be identified. These mechanisms may arise from factors such as material selection, previously unrecognized mechanisms, or changes in operating parameters. Building upon this understanding, proactive analysis of past data and known process parameters allows for the inference of potential damages to each train or equipment prior to inspection.

With insight into potential damage mechanisms and degradation, the inspection scope can be tailored to include necessary inspections and repairs, minimizing surprises during turnaround and ensuring preparedness with the required resources for the work.

One proactive risk management technique widely employed across industries is Failure Mode and Effects Analysis (FMEA). FMEA involves analyzing possible failure modes, their causes, and their effects on overall operations.

Thesewill provide valuable insights for budgeting purposes, especially considering that turnaround cost estimates typically underestimate actual costs by approximately 16%. Moreover, the budgets themselves exhibit considerable variability, often ranging closer to ±30% [6].

i) Impact of Upstream/Downstream Failures

When a failure occurs in upstream equipment, it's necessary to review downstream equipment to assess if similar conditions exist, potentially to varying degrees. If there are indications of potential issues, inspection becomes necessary.

j) Organization Designated Inspection Intervals

In many organizations, there may be a rule mandating the inspection of equipment at specific intervals regardless of circumstances. Therefore, these pieces of equipment would also be included as inputs for inspection.

k) Anticipated Repair work

In cases where equipment damage is identified but repairs cannot be immediately executed due to long lead times, and the equipment can still operate for a certain period, the turnaround presents an opportune time to address these repairs.

l) Corrective Repair work

Leaks may occur between the outage and turnaround periods. If these leaks have not been repaired, they are typically managed using temporary mitigation measures, such as placing a mechanical clamp over the leak area. During the turnaround inspection, these leaks must be addressed as part of the work scope.

m) Opportunity Inspection

The turnaround work scope can stem from various disciplines within an organization. For instance, operations teams may observe a decrease in output within a specific train and pinpoint a piece of equipment responsible for it. Likewise, technologists may raise concerns about unexpected fouling on certain equipment, prompting the necessity for inspection and cleaning. These scenarios present risks of potential damages that are not typically anticipated and should thus be incorporated into the inspection scope.

Moreover, in situations where equipment is cleaned and opened for other purposes, ensuring sufficient access for thorough inspection is prudent. This proactive measure can potentially save future inspection costs and prevent unforeseen issues from arising.

The turnaround inspection work scope draws inputs from various sources critical for its formulation. However, each turnaround event operates within constraints such as budget, acceptance criteria, premises, and goals. Therefore, processes like risk ranking, streamlining, and optimization become essential.

To facilitate these activities, it's imperative to document the work scope in a manner that supports effective decision-making. This documentation serves as a roadmap, guiding stakeholders through the complexities of the turnaround process and ensuring alignment with overarching objectives.

A useful form of documentation work scope is the use of a work list that includes:

- Location of equipment
- Description of work
- Justification like regulatory, corrective repair etc.
- Consequence of not doing the work
- Likelihood of consequence
- Cost of work

Concurrently, detailed scopes for each piece of equipment will be established and documented.

V. WORK SCOPE ASSESSMENT

Next, the work scope list undergoes assessment to ensure alignment with the turnaround intention, premise, and acceptance criteria. This involves assembling a multidisciplinary Assessment Team (A-Team) comprising experienced senior personnel from Operations, Turnaround team, Maintenance, Technologist and Integrity. The A-Team collaborates with the Inspection Scoping Team to conduct a comprehensive review and assessment, consisting of two main parts: first, evaluating against predefined criteria, and second, conducting risk ranking.

Evaluation is grounded in data and facts, ensuring alignment with the turnaround's intention, premise, and acceptance criteria. The team evaluates the scope to ensure:

a) Compliance with the premise and acceptance criteria.

b) Adherence to regulatory and statutory requirements.

c) Verification of organization-designated inspection intervals. If necessary, further analysis, including Risk-Based Inspection using API 581 [7] or in-house systems, or Non-Destructive Testing, is considered as alternatives to intrusive inspection [5].

d) Confirmation that the work necessitates an outage.

e) Exploration of potential merging opportunities with other outages, such as pit stops or catalyst changes.

f) Assessment of potential reassessment, which may defer the work to a later time.

It is common scope ranking is in the following order of criticality:

- Regulatory
- Impact on reliability and integrity
- Corrective Repair Work
- Opportunity Inspection.
- Rejected work scope

The critical scope comprises essential tasks that are indispensable and cannot be omitted. These encompass activities governed by statutory and regulatory requirements, those vital for preventing plant shutdowns, and those aligned with overarching business objectives.

Beyond the critical scope, a screening process emerges through risk ranking. During this phase, meticulous analysis is conducted on the likelihood and consequences of failure to determine if the risk to the organization justifies inclusion in the scope. If the risk is deemed low, deferring the work until the next outage may be a viable option.

The fundamentals of risk can be based on API RP 580, which expresses [8]:

Risk is the combination of the probability of some event occurring during a time period of interest and the consequences, (generally negative) associated with the event. In mathematical terms, risk can be calculated by the equation:

Risk = Probability × Consequence

This leads to the application of Risk Ranking for turnaround, utilizing a developed risk matrix tailored for turnarounds and the organization's established criteria. API 581 serves as a detailed resource for this, while larger organizations often have their own risk assessment matrices. Additionally, various commercial software solutions are available for this purpose. Typically, ranking is achieved by considering a combination of risk management, reliability, and financial resource considerations, which cover:

- Health, Safety, Security, and Environmental risks
- Business and Financial risks (including assets, production, and sales)

This assessment takes into account the likelihood and severity of these impacts relative to the turnaround timeframe and intervals.

Based on organizationally defined criteria, the risk ranking results in the work scope list that is now factually analyzed, justified with an objective vision. The expected results wouldbring about:

High-risk work is to be carried out.
Greater focus on critical equipment that impacts integrity and reliability
Allows for planning prioritization
An objective-based selection
Elimination of work that does not generate value
Drive to look for choices
Extending work to the next turnaround or other outage.

This would strike a balance in ensuring essential and necessary scope to be captured, saving cost and time, concurrently retaining confidence in the integrity and reliability of the plant. A successful example is about a case of a Canadian refinery using risk-based approach was reported to have 40% of pressure vessels in 2023 turnaround deferred to the next turnaround and 27 reassessed and likely deferred for two turnarounds [9].

At this point, the final scope can be considered for a scope freeze and the accepted scope is considered the base scope.

VI. OPTIMIZING WORK DETAILS

Integrity inspection is dynamic and multi-dimensional, with an inherent element of uncertainty that cannot be entirely eliminated. While a scope freeze implies no additional scope, the nature of in-service equipment inevitably necessitates additional requirements due to evolving operating conditions, emerging issues, and new data. These additions are managed through scope addenda and discoveries, which are handled separately from the base scope.

Within the approved base scope, further optimization of work details occurs through a comprehensive work scope appraisal. A Scope Appraisal Team (SA-Team), comprising both internal and external specialists, meticulously reviews the details of each inspection scope for every piece of equipment. The objective is to determine if the defined inspection scope can be enhanced in precision and effectiveness.

The formation of the SA-Team is crucial. It must consist of competent specialists with extensive field experience in In-Service Inspection, Non-Destructive Testing, Corrosion, Maintenance, and Process Technology. These specialists should possess years of hands-on experience in both in-service operations and turnaround activities, along with solid engineering fundamentals, relevant certifications, and experience in scope development. Importantly, they must have demonstrated the ability to work independently.

Engaging external specialists adds value by bringing fresh perspectives and additional experience to the organization. To ensure the effectiveness of the SA-Team, it is imperative that they are not assembled hastily; instead, they should be provided with access to all relevant information well in advance of the scope appraisal.

The objective of this detail scope appraisal is to ensure that the scope defined is at its optimum sharpness and accuracy with regards to effort, technique, cost and finally a sound conclusion to the integrity of the equipment. The SA-Team's review and appraisal are expected to have positions on:

a) Prediction of damage mechanism.

As damages arises from a number and range of variables, it is not uncommon not to have a perfect fit condition. A specialist with relevant knowledge and experience can help illuminate the missing pieces of the puzzle.

b) Scrutiny on selection of locations/components for inspection.

Is it necessary to inspect selected locations, or are there areas that might be overlooked? For example, the type and severity of damage mechanism does vary along the height of a vertical column, and there are certain locations where deterioration isn't anticipated. Therefore, the selection of locations for inspection could significantly impact the effectiveness, the workload and the cost.

c) Confirmtion on the effectiveness and suitability of inspection technique.

Can the inspection technique outlined in the scope deliver reliable results? For example, if the scope specifies penetrant testing for stress corrosion cracking, it might not be effective as it could miss detecting fine cracks. In such cases, the effort expended would be futile and the results unreliable.

d) Choice of alternative technique and use of technology.

Are there modern techniques and technologies that can supplant traditional methods? Consider the example of using drone inspection inside a lengthy underground pipe instead of traditional manned entry. This approach can substantially reduce the need for preparatory tasks such as digging, scaffolding, and gas testing, while eliminating the safety hazards associated with human entry into confined spaces. Consequently, this not only saves considerable time and cost but also accelerates the inspection process significantly.

e) Use of Pre-TA onstream inspection for latest data collection.

An experienced SA-Team member may assess potential shifts in the progression of degradation, which could result in either a slowdown or acceleration of the degradation process. Such observations can influence decisions regarding the necessity for inspection and repair, or they may justify deferring these actions. A suggestion like onstream corrosion mapping on a process that generates magnetite can reveal a possible change in corrosion rate.

f) Excessive or inadequate inspection coverage

Determining the extent of inspection involves analyzing multiple engineering factors. The SA-Team's input can enhance deficiencies or streamline efforts. For instance, testing all heat exchanger tubes, which can number in the thousands, can be refined based on process flow and historical incidents. Following thorough analysis, inspection percentages can be reduced by 70%-80%, cutting inspection time from 3 to 5 days to just one day.

g) Short Extension of Inspection Due Date.

Equipment due dates fall between the upcoming and subsequent turnarounds. Inspection triggers can stem from statutory requirements, RBI, or organizational policies. Data and conditions review can offer opportunities for reassessment. Reviewing Risk-Based Assessments, past inspection records, and operating data may shift the due date to the next turnaround or warrant justification for an extension.

h) A different choice.

Drawing on their experience, the SA-Team can offer alternative options for evaluation. For instance, a lengthy, intricate repair consumes time and resources. Opting for replacement, though potentially more expensive, can free up vital resources for other tasks, thus justifying the switch. Moreover, new equipment is anticipated to deliver superior performance.

Optimization of this nature involves a thorough peer review of the scope, sharing valuable experiences, benchmarking against industry standards, and gaining a profound understanding of equipment conditions and related issues. While the aim of optimization isn't solely focused on reducing every detail of the scope, it also aims to enhance effectiveness and maximize the value of inspection work. Typically, a well-defined base scope tends to undergo reduction following this optimization process. This may involve dropping certain equipment from the list, resulting in both cost and time savings while identifying and rectifying any inefficiencies in the scope. Without doubt, success hinges on the careful selection of the SA-Team and allowing ample time for thorough preparation.

VII. CONCLUSIONS

The methodology, approaches, and attributes outlined in this paper are crafted to ensure a successful inspection work scope that aligns with achieving a successful turnaround. Drawing upon a compilation of industrial best practices and refined through years of turnaround evaluations, this framework serves as a blueprint for excellence.

Within the realm of process plants, turnarounds represent the most significant maintenance event, crucial for sustaining continuous production, safety, and reliability. Any oversight in the inspection work scope can render the turnaround costly, prone to overruns, and susceptible to reliability issues during production. Indeed, a single leak has the potential to force a plant shutdown, eclipsing all other efforts.

Therefore, it is imperative that the development and optimization of the inspection work scope are grounded in facts, practical considerations, risk-based assessments, and the latest advancements in technology, drawing from multidimensional and multidisciplinary insights. The scope should undergo rigorous scrutiny to validate justifications, effectiveness, and preparedness for the unforeseen, all while striving for optimal financial, temporal, reliability, and resource outcomes within a manageable budget, thus enabling the organization to fulfill its business objectives.

Crucially, this endeavor demands the involvement of competent and experienced personnel, as the efficacy ofimplementation is only as strong as the individuals executing the work.

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Biography

[10]. Leong Kok Toong, BSc.ME, MSc, APEC Engr, Int'l P.E, CPEng, CEng, RPEQ, brings over 32 years of experience in the field. Notably, he has spent 15 years dedicated to in-service Asset Integrity within process plants, where he played a pivotal role in leading and overseeing entire turnaround processes for static equipment. He has also proficient in areas such as in Failure Analysis, Condition Assessment, ECA, Project QA and inspection.