Resolving Inspection and Test Plan Deficiencies for In-Service Pressure Equipment Repairs in Singapore's Petrochemical Plants

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Abstract: *The objective of this paper is to identify and resolve the Inspection and Test Plan (ITP) deficiencies in the petrochemical industry, emphasizing for pressure equipment repair in Singapore.*

Through literature review and study of the quality and effectiveness of the Inspection and Test Plans in Singapore, inadequacies against today's quality planning standards were identified and this paper discloses the attributes and significances in an ITP that would enable it to be precise & clear, operatively effective, risk managing and meeting latest quality planning industrial standards for in-service repair of pressure equipment. Deficiencies found included those that impacts the core of ITP, which are the acceptance criteria and the inspection role and responsibilities: A recipe for unaffordable quality and integrity risk. The approach presented can also be applied to new fabrication and construction.

Key Word*:* *Inspection & Test Plans, Deficiencies, Quality Risk, Petrochemical, Pressure Equipment*

1. Introduction

Inspection and Test Plan (ITP) is a common quality tool used in Petrochemical Industry. It is also called quality inspection plan. It's part of the quality plan under the quality assurance and quality management program. It's used in fabrication, plant shutdown inspection and repair work. As defined in API 588, Inspection and test plan is a plan that summarizes minimum inspection, testing, and quality control requirements for a defined scope of work [1].

Almost all downstream petrochemical plants in Singapore today engage contractors to do their fabrication and repair work. The use of inspection and test plans to control is unavoidable and decisive. These plans are essential tools for ensuring that products meet quality standards, regulatory requirements, and customer expectations. ITPs encompass a structured approach to quality assurance, encompassing inspection points, acceptance criteria, testing methods, and documentation protocols. In Singapore, due to its openness to workforce recruitment, cost competition and lack of training program in this area, the inspection and quality personnel often comes from all over the world. Challenges in ensuring quality and consistencies therefore exist and has persisted for a long time. This paper would present them and address them.

While fabrication and construction projects often can be closely replicated from project to project, the nature of in-service inspection of repair work creates greater challenges because a repair work varies in process and inspection considerations between each job, therefore the level of play field in technical competencies, care and details for ITP development increases substantially.

2. Literature Review

The following literatures relates to Inspection and Test Plan / quality inspection plan in the industry. The review in this section looks at some papers and guides that contributes to the development of ITP and application for in-service repair work.

Bexel Newsletter, Demystifying Inspection and Test Plan, A Comprehensive Guide, by Bexel Inspection Software, Sept 2023 [2]. Inspection and Test Plans (ITPs) ensure every project phase meets quality standards, helping to identify and address issues early, thus preventing costly rework and delays. The components of an effective ITP include clear objectives, relevant standards, detailed inspection criteria, frequency of inspections, and documentation requirements. Comprehensive coverage of ITPs is applied at various stages: starting from pre-construction, where quality standards are set and inspections are planned; during construction, requiring ongoing compliance checks at key stages; and final inspections to ensure all work meets requirements before handover.

In summary, this article presents a macro view of the key elements of ITPs, their benefits, stages, and the roles and responsibilities involved.

Kil-Jong Kwahk, Min-Ho Park, Ju-Hyung Kim and Jae-Jun Kim, Development of a Progress Management System Integrated with the Quality Inspection Process: Case of a nuclear power plant construction project in Korea, Journal of Asian Architecture and Building Engineering, Published online: 24 Oct 2018 [3]. The article describes a quality inspection process using several steps: Inspection and Test Plan (ITP), Work Notification, and Inspection Reporting (IR). Master data used in the quality inspection process include inspection phases, inspection items, and documents attached to inspection reports. The article highlights that with the implementation of this quality inspection process, progress in provisional value was updated in near real-time alongside the results of quality inspections. This led to a significant reduction in conflicts between clients and contractors. Additionally, the system demonstrated improvements in the accuracy and efficiency of processing quality inspection documents.

In summary, this paper presents the importance of ITP, an overview of the information within it, and the process of closing the inspection.

American Petroleum Institute, API RP 588, Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment, July 2019 [1]. This internationally accepted practice outlines the minimum requirements of an Inspection and Test Plan (ITP), which include task descriptions, work requirements, QA/QC methods, and acceptance criteria. The specifics are left to individual equipment and contractual requirements. It also outlines the expected headings of an ITP, which include descriptions of activities, applicable standards, responsibilities of involved parties and their roles, activity requirements, acceptance criteria, quality records, and verifying documents. This document is one that provided much more details into the requirements of ITP but it still stays away from providing a format and ground level details.

In summary, this practice establishes the minimum requirements for ITPs for new fabrication items, details on what to do but not how to do. It does not cover in-service repair work.

R.M. Chandima Ratnayake, Challenges in Inspection Planning for Maintenance of Static Mechanical Equipment on Ageing Oil and Gas Production Plants: The State of the Art., Proceedings of the ASME 2012 31st International Conference on Ocean, Offshore and Arctic Engineering, OMAE2012 July 1-6, 2012, Rio de Janeiro, Brazil [4]. In the area of inspection, particularly in-service inspection, the article highlighted several challenges: difficulties in inspection planning due to a lack of knowledge transfer, an incomplete understanding of the problem, and the low quality of inspection programs due to insufficient experience. The use of various modeling techniques did not yield the expected results in the context of in-service inspections. It was concluded that methodologies are highly dependent on the depth of the analysis, the area of application, and the quality of the results.

Thus, while ITP was not specifically mentioned, inspection planning, which serves a similar purpose, is a vital component. In-service inspection faces significant difficulties due to its complexities and the unpredictability of the work.

COQ Board Article, GUIDE: How to create an Inspection and Test Plan (ITP), Construction Quality Australia, May 2023 [5]. This article states that a recent survey shows writing a good Inspection and Test Plan (ITP) is a struggle for engineers and contractors. The need to prepare an ITP for each individual item, with details on specific references, methods, acceptance criteria, frequency, verification details, responsibilities, and records, should be included in this plan. It also suggests an ITP development process, communication strategies, multiple levels of ITPs, and an approval process.

In summary, this guide presents the necessary steps and considerations for creating an effective ITP and shared that writing an ITP is a struggle.

Overall, the literature discussed the uses of ITPs, expectations, and guidelines for developing an ITP, including recommended practices. It is also acknowledged that in-service work is complex and unpredictable.

Areas that are not included:
- How details should be clearly documented to ensure precision and clarity.
- How inspections should be assigned and controlled to avoid the risk of misinterpretation, which could result in unacceptable quality not being identified and addressed.
- there is a lack of guidance for in-service repairs in petrochemical plants.
- There is a lack of suggested formats with detailed instructions, leaving this aspect to the industry. The guidelines are more conceptual and outline.

Consequently, despite quality assurance and management standards like ISO 9001 and ISO TS 29001, and despite articles and publications providing definitions and guides for developing ITPs, the industry continues to struggle with the difficulties and inability to amplify on these to create a fit-for-purpose, definitive, and effective ITP for implementation.

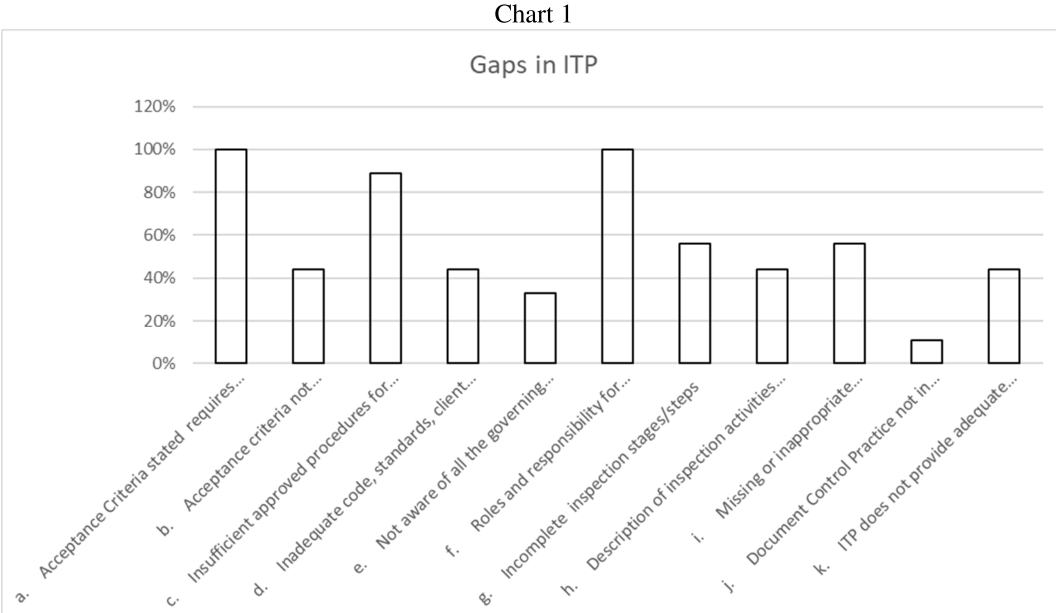
3. Study of Contractors' ITPs & Case Examples in Singapore

A study of each initial ITPs submission to a Chemical Plant in Singapore from nine active and established fabrication and repair organization in the industry exposed deficiencies in the following areas:

a. Acceptance Criteria defined was not specific or incomplete
b. Acceptance criteria not defined/wrongly defined
c. Contractors did not have sufficient or documented approved procedures for performing inspection
d. Contractors did not document all applicable code and standards and client specification
e. Contractors were not aware of all the governing codes, standards and client specifications for the repair work
f. Roles and responsibility for inspection were vague.
g. Missing inspection stages/steps
h. Description of inspection activities incomplete/vague
i. Missing or inappropriate inspection/test records found for some inspection/ test activity
j. Document Control Practice not in place. There was no revision status documented
k. ITP not formatted to provide adequate details and information was not found elsewhere

The chart below records the percentage of submitted ITPs having the above issues.

Chart 1



This study aligns closely with the recent survey conducted by Construction Quality Australia [5]. It is evident that the industry faces challenges in developing inspection and test plans, posing a clear quality risk and challenge to the construction and fabrication and even more for in-service repair work.

The following two real case examples to further elaborate on the findings of the study.

Case 1: Explanatory Notes

XXXXXXXXXXXXXX PTE LTD QA/QC DEPARTMENT	DOCUMENT NO. : ITP-S-502A/B SHEET : 2 OF 8 AE PJ NO. : 15AE079 ITEM NO. : S-502A/B

ABBREVIATIONS:

CODE	DESCRIPTION	DEFINITION
M	MANUFACTURER HOLD POINT	MANUFACTURER - VENDOR AND / OR SUBVENDOR'S INSPECTION / IMPLEMENTATION (1)
H	HOLD POINT	A POINT AT WHICH THE PURCHASER'S INSPECTOR AND / OR AI MUST BE PRESENT DURING THE SPECIFIED ACTIVITY. WORK SHALL NOT PROCEED UNTIL RELEVANT INSPECTION COMPLETED.
W	WITNESS POINT	*A POINT AT WHICH THE PURCHASER'S INSPECTOR AND / OR AI MUST BE NOTIFIED IN ADVANCE AND MUST BE PRESENT DURING THE SPECIFIED ACTIVITY UNLESS WAVIED BY WITNESSING PARTY IN WRITING. WORK SHALL PROCEED WITHOUT FURTHER RESTRICTION.* (2)
R	REVIEW OF DOCUMENTATION	REVIEW AND ACCEPTANCE OF DOCUMENTS, REPORTS, RADIOGRAPHS, CHARTS, ETC. (3)
S/W	SPOT WITNESS	RANDOM MONITORING / SURVEILLANCE ON INSPECTION RELATED FABRICATION ACTIVITIES. (4) WORK SHALL CONTINUE UNHINDERED.

	Gaps on Case 1 ITP Notes
1	The wording used merely acts as a placeholder for the activities without defining any specific results or responsibilities. The term "hold point" lacks elaboration, leaving it open to interpretation.
2	Defining the number amount of advanced notice or referencing them will ensure clarity.
3	This section fails to distinguish between the processes of review and acceptance/approval. Although there may be an intention to assign a dual role, implementing such a system would be challenging because each party involved in the work process may have its own ideas on how the review and approval roles should be organized. In quality assurance, it is recommended to separate these two roles.
4	The term "spot witness" is used, but its definition denotes monitoring or surveillance. This discrepancy makes it difficult to correlate the language used with SW typical intended meaning.

Based on the explanatory notes, the gaps identified in these notes indicate a lack of culture and clear awareness regarding the roles, responsibilities, duties, and intentions of each inspection role. This suggests potential shortcomings in the contractor's quality assurance and control department and personnel. Addressing these gaps goes beyond the scope of an ITP. It was recommended that the owner manages the associated risks by collaborating closely with the quality control team and ensuring alignment with their understanding and clarity.

Case 2: An ITP with Major Concerns

检验指导计划 Inspection and Test Pan (ITP)	编写/Written: AAAA 日期/Date: 2013-10-19 校核/Checked by : zzzl 日期/Date: 2013-10-19	项目名/Project Name: ____ upgrading for column and heat exchangers project 定单号/P.O. No.: 4500960463 设备名称/Equipment Name/: ____ Column level: 位号/Item No.: AYZ column	Edition REV: 4 文件号/Doc: -ITP- 13-044 Vessel category: column Inspection

Note:

(1) 本计划（ITP）仅适用于 Owner 项目的容器设备；
This Plan (ITP) is only applicable to the equipment of Owner.

(2) 按合同要求决定本 ITP 是否需外部认可，如需要，请在下表签名（参见注（5））
Acceptance of this ITP from outside agency (see note (5) is based on contract.
Required, please sign the following table.

检验机构代码 Inspection agency Code	签字 Signature	日期 Date
(1) Contractor ABC		
(2) TPI		
(3) Owner		

(3) 检验点如下/Inspection Points are as follows:
R: Review point 文件审核点 (1) W/SW: Witness/Spot Witness 见证检验
H: Hold Point 停止点

W 点和 H 点必须提前 10 天书面通知。
Witness point and Hold point shall be notified by witness form in advance 10working days.

(4) 检验结果/Description of Inspection Result:
√ :means 通过验收/O.K.
NCR No.; means 不一致品报告号/Nonconformity Report No.
RJ : means 拒收/Reject

(5) 检验机构代码/The code of other else inspection agency:

Inspection and Test Plan(ITP)检验及试验计划

Active No.	Activity Description 内容	Acceptance Criteria 验收标准	Verifying Document 文件报告 (2)	Involved Party 参与方		
				AIC	TPI	Owner
4.10	堆焊后 100%PT 100% PT for final surface of overlay	1. Approved drawing (3) 2. ASME V 3. Owner spec ouoiuio	PT Report Check Off List	H	SW (6)	R (7)
4.11	焊缝检验（拼缝） Inspection of overlay welding	1.Approved WPS (4) 2. PROJ. SPEC. 3. Owner spec adfdsf	Welding Check Off Lists	H	SW	SW
4.12	封头成型后的接货检验 Receiving checking after forming	1.Approved drawing (5)	Check Off List Forming inspection report	(8) H	/	/
4.12.1	封头的测厚 Checking thickness for head	1.Approved drawing 2.ASME Ⅷ UG-81	Head dimension report	H	SW	R
4.12.2	封头尺寸外观检查 Checking dimensions and	1.Approved drawing 2.ASME Ⅷ UG-81 visual	Head dimension report	H	SW	SW
4.13	过渡段内表面 100%PT，外表面 100% MT 100%PT for inside and 100% outside surface of the knuckle region	1.ASME V 2.Approved drawing MT for 3. Owner spec adoufds	PT Report MT Report Check Off List	H	SW	SW
	封头成型后过渡段焊缝					

	Gaps on Case 2 ITP
1	The roles and responsibilities in each type of inspection involvement are inadequately differentiated, with no explanatory notes provided. It's evident that there is no inspection/test role and no designated responsible party to approve/accept the work. This lack of clarity will cause misaligned interpretation and expectations during the course of the work and more critically, insufficient or unfitting inspection. Its not acceptable to have no approval and acceptance.
2	There are no approved procedures listed to control the quality and manner of inspection work. Qualified procedures, which are often mandated by code requirements, are essential in many areas of work, such as PT (Penetrant Testing). On those non mandated by codes, the rule of thumb should be based on today's industrial accepted quality principles/management, like that of ISO 9001.
3	The acceptance criteria provided are unsuitable, as ASME V does not specify PT (Penetrant Testing) acceptance criteria. Additionally, in this case, the acceptance criteria are not defined in the owner's specifications and drawings. Furthermore, the definitions are overly general, referencing the entire standard without specifically pointing towards acceptance criteria and year of publication. This lack of specificity leaves interpretation opens to individual discretion, use of wrong criteria, often leading to varied decision-making processes or even ignoring the criteria.
4	Welding typically involves several stages of inspection. However, this definition only outlines one stage of inspection, which is unsatisfactory. In welding industry, item 4.11 should precede item 4.10. Therefore, the sequence of inspection provided is not in the right order.
5	The acceptance criteria for this incoming inspection from the subcontractor should be based on the manufacturing data and QC report provided by the subcontractor.
6	In this case, the distinction between SW (Spot Witness) and W (Witness) is not clearly defined. SW typically entails a quick spot check within a long process. However, since PT (Penetrant Testing) is not a lengthy process, it should

7	not be a SW. Additionally, PT involves a test with no data, leaving little for the owner to "review." Thus a "R" is inappropriate. This understanding may not be agreed by all. By disagreeing, it shows that the explanatory notes need further elaboration.
8	The use of "check off lists" appears to be generic throughout this ITP, serving various purposes. Consequently, there is an issue with differentiating the quality records. For an experienced reviewer, the possibility that specific quality records may not exist and this "list" is written just to fulfill the record requirements of this ITP are real.

Upon further examination of the inspection and test plan, it becomes apparent that there are many deficiencies. These issues reflect a lack of understanding regarding roles and responsibilities, inadequate in-house procedures for controlling inspections, weaknesses in understanding acceptance criteria, and inconsistencies or a lack of record-keeping for QC inspections. In this scenario, one option available to the owner is to conduct a technical audit on the quality department to verify the status of the quality management system, inspection performance and personnel within the organization.

As observed, these two extracted ITPs illustrate many of the findings from the ITP study conducted in Singapore. A reviewer should be capable of identifying potential quality risks when the ITP is initially submitted. Case 2 clearly indicates an organization with a weak and ineffective quality function, requiring actions beyond mere reviewing and commenting. Conducting a technical audit on-site would be the most appropriate course of action moving forward. That was done and the findings supported the reviewer's anticipation.

An ITP is not only a quality planning for the job/work/project. It is also a quality indicator of the contractor, allowing pre-empt action before it becomes too late, prompting the owner to work backwards if necessary.

ITP is part of quality planning and as in Juran Quality Handbook [6], it describes:
"An effective quality planning goal must have five characteristics for it to provide a team with enough information to guide the planning process. The goal must be
- Specific
- Measurable
- Agreed to by those affected
- Realistic—It can be a stretch, but it must be plausible.
- Time specific—when it will be done" [6]

ISO 9001:2015 requires monitoring and measurement (i.e. inspection) and analysis of result and evaluation (i.e. pass/fail, accept, reject), documented evidence of results (i.e. inspection records), and performed effectively [7]

ISO 10005:2018 [8] requires quality plan (i.e. including ITP) to consist of the following:
- The monitoring and measurement methods to be applied, including the inspection and testing procedures.
- The stages at which these methods should be applied, ensuring they are conducted at necessary checkpoints throughout the process.
- The quality characteristics to be monitored and measured at each stage, specifying the parameters and features to inspect.
- The procedures and acceptance criteria to be used, which should include detailed inspection procedures and specific acceptance criteria for determining compliance.

It's evident that the findings from the study and the two cases, it is not uncommon that ITPs do not fully meet the requirements of today's quality planning, as outlined in Juran's Quality Handbook and the respective recognized standards related to quality planning, inspection and quality management. There are notable gaps and inadequacies in various aspects, including inspection procedures, acceptance criteria, roles and responsibilities, and overall quality assurance practices.

4. Closing the Gaps in Industrial ITP for In-Service Repair

The literature review and organizational ITP studies in Singapore uncover challenges and deficiencies in developing a robust, controlled, and effective ITP that meets quality requirements and expectations. The absence of suggested formats and specific details, combined with the available expertise in the market, renders this task daunting for organizations in Singapore. This challenge is further compounded when considering in-service repair work.

In-service repairs ITP are inherently dynamic and non-standard, requiring substantial engineering expertise to develop appropriate repair methodologies. These methodologies often encompass a range of processes such as cleaning, grinding, welding, heat treatment, non-destructive testing (NDT), coating, fitting, distortion and deformation control, performing forming operations, and bolting.

Personnel involved in repair and fabrication work must possess a in depth understanding of these codes and standards, as well as their specific application. The intention of this paper is not to delve into the elaboration of these repair process details but on the ITP. The following sections will outline how the identified ITP gaps can be addressed and closed.

5. Inputs for In-Service Repair Inspection and Test Plan

In the petrochemical sector, the integrity, reliability and safety of its equipment and processes are paramount. In this context, ITPs play a pivotal role in:

- Ensuring product quality and integrity of an equipment
- Providing evidence of a work process management and quality control.
- Mitigating risks associated with product defects or non-compliance.
- Facilitating regulatory compliance with industry standards and regulations.
- Providing identification and traceability to equipment history & condition.
- Reveals competency of contractors.
- Communication tool to all stakeholders
- Optimizing production processes and minimizing waste.
- Enhancing customer satisfaction and brand reputation.
- Provide data for quality and inspection planning, improvement and future learnings.

Process plants in Singapore, almost all of the owners engage contractors to do the equipment repair, overseen by their own Inspection Engineers. The information to be considered as an input into an ITP for in-service repair of pressure vessels are shown in the undermentioned figure.

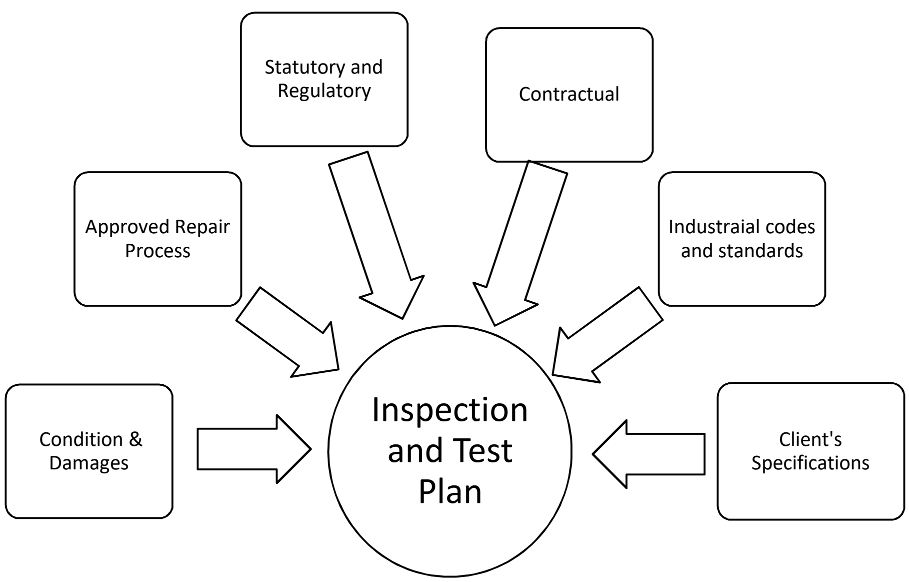


Fig -1: Input for an Inspection & Test Plan

(I) Condition & Damages

Unlike fabrication and construction, in-service repair work is influenced by the location of the repair, the type of damages, and the operating conditions. For instance, equipment used in a caustic environment requires thorough cleaning before repair, as failing to do so could lead to embrittlement during welding. Additionally, such equipment demands more extensive non-destructive examination and heat treatment compared to a pressure vessel carrying clean steam. A good reference for this would be API 571 that discusses damage mechanisms.

(II) Approved Repair Process

Repair work processes differ on a case-by-case basis, depending on the type of damage, location, and operating conditions. All ITPs start with understanding the condition and damages and designing an appropriate repair process to be approved, known as the Repair Method Statement. For example, a crack on a heat exchanger shell would require excavation of the crack, extending the check beyond the crack location, crack arrest, and inspection to ensure the crack has been fully excavated. Conversely, general wall loss on the shell of a heat exchanger might only require leveling up the damaged surface for weld build-up. Consequently, the inspection requirements for each scenario will differ. While experience and related engineering knowledge is still essential, a source of some information on repair can come from ASME PCC-2, ASME's PCC-2 - Repair of Pressure Equipment and Piping Standard.

(III) Statutory and Regulatory

This section is applicable to all countries. In Singapore, all pressure equipment using steam is regulated by the Ministry of Manpower (MOM) under the Workplace Safety and Health Act [10]. This regulation requires the engagement of an Authorized Examiner and their approval and witnessing for inspection and repair work processes. All testing conducted under this regulation must be supported by laboratory-accredited reports, commonly adhering to ISO 17025 standards [11].

(IV) Contractual Requirements

These are specific requirements for the contract that a contractor must include in their inspection and test plan (ITP). For example, the contract may mandate the engagement of certain qualified personnel or skills to perform the work within a specified time frame. Additionally, the roles and responsibilities of different parties and stakeholders within the ITP will likely be defined in the contract.

(V) Industrial Codes and Standards

These requirements are sometimes written in detail in a contract or defined more generically. In the petrochemical industry, some common standards used in Singapore are those listed para 6-D. These codes and standards provide a framework for allowable repairs, acceptance criteria, personnel qualifications and the roles and responsibilities of involved parties.

(VI) Client's Specifications.

All major petrochemical companies typically have their own in-house requirements, such as Shell Global's Design Engineering Practices. When developing an ITP, the client's specifications must be included. These client-specific requirements are often added on top of industry codes and standards, covering similar areas to ensure comprehensive quality and compliance.

6. An Inspection and Test Plan Template for In-Service Repair.

There are no officially prescribed templates for an inspection and test plan (ITP) and always left to the industry. However, across the industry and in recommended practices, an ITP is expected to consist of the following elements:
(Note: The A to H description corresponds to the template in Table 1)

A. **Title**: The title describes the nature of repair work, equipment to be carried out.

B. **Description of Activities**. This describes the stages of inspection and testing that correspond to the repair workflow. It has to follow an acceptable flow of work and inspection based on approved repair process method statement for the work. It covers preparation, initiation, in-process and final inspections, and acceptance. Additionally, it includes all required documentation for the work.

C. **Procedure, Document /method statements**. It's essential to state procedure and/or work method statement that clearly outlines how the inspection and testing tasks will be conducted in a controlled manner. These documents should align closely with the specifications and acceptance criteria outlined in the following paragraph (D). To maintain clarity and avoid ambiguity, it's preferable to include reference numbers and revision statuses, or utilize an equivalent document control method. Furthermore, these documents should undergo approval to ensure their suitability for the task before being incorporated. It should be assumed that a procedure is applicable for every job. In this industry, codes & standards does mandate qualified procedures for many areas of inspection.

D. **Specifications/ Acceptance Criteria**. The acceptance criteria for the repair work may be derived from various sources such as the contract, relevant codes and standards, drawings, client specifications, or any agreed-upon values or tolerances established by the owner's authorized technical authority if it is not governed elsewhere. When referencing acceptance criteria, it's crucial to include specific details such as the document name, year, paragraph, and section. This ensures clarity and precision, pinpointing the exact location within the document where the requirements are defined. This practice helps to mitigate misalignment, mistaken criteria and ambiguities commonly found in the industry. For instance, referencing ASME B31.1 alone would be insufficient, given the multitude of acceptance criteria within this code. Instead, it's imperative to specify the precise paragraph, section, or table containing the relevant criteria pertinent to the work at hand.

Acceptance criteria is a critical gap, a non-exhaustive list of codes and reference commonly used for pressure equipment repair in Singapore are:

(I) American Society for Mechanical Engineers
- Section II, V, VIII, IX, PCC- 1 & 2, B31.3, B31.1, B16.5, B31P

(II) American Welding Society
- The Practical Reference Guide for Welding management - Visual Inspection of Pressure Vessels and Pressure Piping
- Welding Inspection Technology Handbook
- D10.10

(III) American Petroleum Institute,
- API 570, 510, 571, 572, 577, 582, 653

E. **Records**. These inspection records encompass various forms, including checklists, data recordings, photography, and inspection reports. Their creation process must adhere to the guidelines outlined in Paragraphs C and D above, ensuring alignment with all specifications and industrial standards. Before use, their format requires thorough review and approval. Each form or record should be clearly labeled with its name and revision status, preferably reference number or any other acceptable document control methods to prevent the inadvertent use of obsolete or improper records.

In Singapore, inspections conducted on equipment regulated by the Ministry of Manpower's statutory and regulatory frameworks must be accompanied by reports accredited by the Singapore Accreditation Council.

Records are often said to be paperwork and it is common to see “desktop” and QC/Inspection record and not real time. The records that are not real time are not unacceptable. Requirements of records to be constantly on site and available real time would close this implementation gap.

F. **Quality & Inspection.** In this, the party responsible for carrying out inspection, quality, review and approval work will be assigned. In an in-service repair, it is common that the parties involved would be the main-contactor, third party, owner or its representative and others. Others can be a government authorized representative, which in Singapore is known as Authorized Examiner, or another testing company or possibly a safety representative. They all can be involvement in several possible ways (I, M, W, R, A, H) that must be clearly identified and provide details in an explanatory note as part of the ITP’s documentation. A trial and tested explanatory notes are as follows:

<u>Inspection/Test</u> (I):
Responsible for performing an inspection and/or test work where it is mandatory that the involved party inspect/test the component/equipment/repair work that was done at that stage. Inspection/test shall be done by competent personnel with relevant qualification, and provide conclusion on whether the inspection and test results are accepted or rejected based on acceptance criteria. No work shall proceed if the results demonstrate unacceptable quality or inspection/test has not been fully completed and concluded.

Gap: Due to variation in the competence of inspection/test personnel and weak contractor’s emphasis on quality control and assurance, it becomes critical to assess the competence and ability of these personnel before work. Another common issue in the industry is the provision of inspection record with no clear decision against the acceptance criteria. Thus, by defining the need to qualify the results as being accepted or rejected, it ensures a sound understanding of requirements and the duty and responsibility.

Monitoring (M):
Monitoring is to check on the process and/or product periodically to ensure quality requirements are met. The Owner shall be notified according to contract in advance of the start and scheduled end of an activity at each worksite. The activity can proceed with or without the Owner's attendance. The assigned party shall carry out the activity according to agreed frequency.

Gap: It is a common gap in the industry to not define the amount of monitoring required and "forgets" to ensure a record is made each time the monitoring takes place. As such, the amount and frequency of monitoring inspection becomes subjective and in Singapore whereby the manpower is often stretched, "none" may actually take place despite it being part of the inspection program. Therefore, it will be important to define the frequency and/or amount of monitoring and a record on each monitoring.

Witnessing (W):
Witnessing party has the duty to recognize that the activity/Inspection/Test is carried out accordingly to procedure and acknowledges the result. Notification in writing according to the duration specified in the contract in advance of the activity shall be given. Once proper notification is given, the activity may proceed according to the schedule regardless of the attendance unless it is defined as a hold point.

Gap: By being present and knowing the outcome is an incomplete witnessing process. This is gap in the witnessing process. It is critical that the witnessing party is able to witness that the inspection/tests are being performed in accordance with reference documented procedure and recognize the results. It is a vital that in critical inspection stages that impacts the process safety, the witnessing work shall be a hold point.

Review (R):
Review can be a done on a document/ qualification/ activity/report. The reviewing party shall be given time and during in advance of the occurrence of the activity or provided the document in a period of time specified by the contract. The activity may proceed with or without the review results. Any inadequacies found from the review shall be documented and those justified findings satisfactorily rectified.

Gap: A common misconception is Review is an approval. It should be noted that a review is not an approval or acceptance. It is just an additional scrutiny.

Approval/Acceptance (A).:
It is mandatory that the approve/acceptance of document/ qualification/ inspection/ activity, test results and records must take place. Work shall not proceed to the next stage/step without evidence of approval and acceptance. Authorized personnel accepting or approving work must be a qualified person.

Gap: Acceptance of engineering inspection and test must by qualified and competent personnel and not mere positions.

Hold Point. (H):
A vital step where it is mandatory that the inspect/test activities shall not proceed until all responsible parties are present for that activity. The Hold Point can only be waived in writing. The contractor shall notify responsible party in advanced according to agreement. Process safety hold points shall not be waived.

G. **Comments/Remarks**. This section is used for additional information, concerns, considerations that are not found in this template. An example would be: monitoring shall be done at least once every 4 hours.

H. **Signed on Behalf of**. In this section, each authorized representative shall sign on their respective columns as evidence that they have read and agreed with this inspection and test plan.

An ITP has to be prepared by the main contractor that has a contract with the plant owner to do the work. There may be several ITPs of different levels and certainly different types of documents referenced by the ITP.

The table below shows a template of an ITP for in-service repair that was developed, trial and tested to document all necessary information, meeting all quality planning industrial requirements, and minimizing quality risk:

Table 1: An ITP Template for In-Service Repair

A	**Inspection & Test Plan**								
Title:					ITP No:			Contract No:	
S/No	Description of Activity	Procedure, Document, Method Statements	Specifications / Acceptance Criteria	Records	Date:				
					Quality & Inspection (I, M, W, R, A)				Remarks/ Comments
					Contractor QC	Third Party	Owner	Others	
	B	C	D	E		F			G
Legend: I – Inspection/Test. M- Monitoring. W - Witnessing. R – Review. A – Approval/Acceptance. H- Hold point									
Signed on Behalf of	H	Contractor		Third Party		Owner		Others	
Signature									
Name									
Date									

(A to H corresponds to the above explanation)

7. An Illustration of In-Service Repair ITP

Table 2 below shows an example and detail how an ITP for in-service inspection can be prepared. An ITP is communicated to several working and inspecting parties and stakeholders. It is expected that differing understanding and interpretation would certainly happen. Therefore, being precise, clear, measurable, agreeable, realistic [6] is imperative for the ITP to be effectively implemented.

Table 2: An Illustration of In-Service ITP Details

Inspection & Test Plan									
Title: Replacement of corroded pipe elbow joint at Line: 0025, NPS4 Sch 80s,				ITP No: XXXXX	Contract No: XXXX		Date: XXX		
S/No	Description of Activity	Procedure, Document, Method Statements	Specifications/ Acceptance Criteria	Records	Quality & Inspection (I, M, W, R, A)				Remarks/ Comments
					Contractor QC	Third Party	Owner	NDT specialist	
1	Repair Method Statement, main code: ASME B31.1	Drawing No xyx-025 rev 1 RT report No: NDT-075	Care in welding new to old pipe. Meets codes' required integrity	Signing on Repair method statement	R, A	-	R		
1	Cut out old elbow with stainless steel grinder	Mech work Procedure, MW 012 Rev 2	Cut at marked location on site.	Photographs upon completion	I	-	-	-	
2	Receiving of new elbow from Workshop, ASTM A312, TP316L	Receiving Inspection Procedure. RI 011 Rev 1	EN 10204, Type 3.1 Chem Comp & dimension	Signed mill cert as receiving.	I	-	-	-	
3	Check old pipe remaining thickness, cleanliness 3 inches from cut edge	Mech Work Procedure, MW 012 Rev 2	Nominal thickness & roundness. Clean 3in from cut edge	Pipe Data Sheet (PDS-01-1)	I	-	-	-	
4	Grind joint for weld fit up & check weld configuration.	Welding Control Procedure WC 016 Rev 2	WPS SS-012, Rev 1 ASME B31.1, Para 127.3	Pipe Data Sheet (PDS-01-1)	I	-	W, H	-	
5	PT on weld joint	Penetrant Testing Procedure, PT 017 Rev 1, ASME V Art 6 ASME B31.1 Para 136.3.2	No linear or round indications on surface	PT report (IR-PT-01)	W, H	-	W	I	
6	Welding – Check Welding Parameters Check qualified Welder Check cleanliness	Welding Control Procedure WC 016 Rev 2, Qualified Welder List, Qualified WPS	WPS SS-012, Rev 1, Qualified welder, clean joint 3' both ends, ASME B31.1 para 127.5	Welding Inspection Report (IR-VI-02)	I	-	-	-	
7	Visual Inspection after root pass	Welding Inspection Procedure, VI-020 Rev. 1, ASME V, Art 9	ASME 31.1, Para 136.4.2, ASME V, Art 9	Welding Inspection Report (IR-VI-02)	I	-	-	-	
8	PT on root pass	Penetrant Testing Procedure, PT 017 Rev 1	ASME B31.1, para 136.3.2 & 136.4.4. ASME V Art 6	PT report (IR-PT-01)	W	-	-	I	
9	Welding – Check Welding Parameters From Hot pass to cap.	Welding Control Procedure WC 016 Rev 2, Inter-pass temp, Gas flow, amperage and voltage	WPS SS-012, Rev 1	Welding Inspection Report (IR-VI-02)	M	-	-	-	After each layer
10	Final visual inspection	Welding Inspection Procedure, VI-020 Rev. 1	ASME 31.1, Para 136.4.2, ASME V, Art 9	Welding Inspection Report (IR-VI-02)	I	-	W, H	-	
12	PT on weld cap	Penetrant Testing Procedure, PT 017 Rev 1	ASME B31.1, para 136.3.2 & 136.4.4. ASME V Art 6	PT report (IR-PT-01)	W, H	-	W	I	
13	RT on weld joint	Radiographic Testing procedure, RT 110 Rev 3	ASME B31.1, para 136.2 & 136.4.5. ASME V, Art 2	RT Report (IR-RT-01)	R	-	-	I	
14	Hydrotesting	Hydrotesting Procedure, HT 001, Rev 1.	24 barg holding for 30min ASME B31.1, para 137.4 No leaks & pressure drop	Hydrotesting Report (IR-HT-02)	I	-	W, H	-	
15	Submission of report by contractor	Test Package document control, TP-002 Rev 5	Complete documentation of all work as per TP-002	All reports, reviewed and approved.	R, A	-	R	-	
Legend: I – Inspection/Test. M- Monitoring. W - Witnessing. R – Review. A – Approval/Acceptance. H- Hold point				General Notes: Use latest revision of all codes and documents. Personal qualifications for contractor QC shall be in accordance with ASME B31.1 para 136.1.4 (B.3) & (B.4)					

Signed on Behalf of	Contractor	Third Party	Owner	NDT Specialist
Signature				
Name				
Date				

(for explanatory notes, refer to section 6 F)

8. Conclusion

A review and practical study of the inspection and test plan, also known as quality inspection, which is part of quality planning concluded that deficiencies and struggle exist in development of ITP by established contractors in Singapore's downstream Petrochemical industry. It can also be seen that such struggles exist in other countries as well. These deficiencies pose quality risk, inspection not meeting requirements and mismatch expectations in an industry that least afford them. The templates, illustrations, information that are trail and tested here provides a clear, precise, definitive approach that will addressing these inadequacies, stressing on core issue for ITP and in line with today's quality planning practices. In a dynamic environment, variations to the format and utilization will certainly occur. Contract may require a sign off on the ITP once the inspection is completed and accepted as a summary of the inspection progress. These are additions and changes needed to suit each job and contract. Nonetheless, the core information, documentation methodology will be expected and needed and will have to be documented in one way or another. That will be left to the complexity of the job and contractual requirements. Not having them will not meet the today's quality planning and assurance requirements of an ITP.

It needs to be clear that the methodology presented would only yield desirable results when applied by a competent and experienced engineering personnel.

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Biography

Leong Kok Toong, BSc.ME, MSc, APEC Engr, Int'l P.E, CPEng, CEng, RPEQ, brings over 32 years of experience in the field. He holds certifications in QA, Welding, NDT, Materials, Corrosion, and Static Equipment Inspection. Throughout his career, he served the petrochemical industry across South East Asia, and did work with majors like Shell, Exxon, PCS, Brunei LNG, PT Toyo, and Petronas.

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, System and Technical Audit.