PM Oversight in Mega-Projects: Lessons from Column Trays Installation[1]

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Abstract

In recent years, the importance of critical aspects of project management (PM), especially in the context of industrial column tray installation, has gained relevance, especially in the context of engineering mega-projects. In fact, the technical aspects associated with column operation are always crucial; however, the complexity associated with their installation processes needs to be addressed from an entirely new dimension of PM, specifically focusing on risk management, quality management, and stakeholder coordination. In fact, the context of the Jafurah Gas Processing Project highlights the significance of misaligned tray support rings and improper shim plate installation associated with industrial column trays, thus facilitating broader risks associated with column operation and performance. In an integrated context, the significance of technical adherence to column tray installation, vendor compliance, and associated field execution processes needs to be addressed for effective risk management and associated stakeholder coordination to facilitate enhanced efforts associated with industrial projects, especially for column tray installation.

Keywords: Construction Management - Risk Mitigation - Quality Assurance - Stakeholder Coordination - Installation Challenges - Project Execution

Introduction

Role and Mechanism of Columns in Industrial Processes

In the Oil & Gas industry, columns are the vertical containers used for the separation, purification, and recovery of components of gas-liquid or liquid-liquid mixtures. Column design ensures efficient, safe, and reliable operation of columns in industries such as refining, petrochemicals, and gas processing.

[1] How to cite this work: Alghamdi, M. A., Hassan, Y. M. (2025). PM Oversight in Mega-Projects: Lessons from Column Trays Installation, *PM World Journal,* Vol. XIV, Issue XI, November.

Trays or packings inside the column serve as surfaces where the repeated interaction between the vapor and the liquid takes place. Components having lighter properties move as vapor to the top, while the heavier ones condense at the bottom.

Industrial columns can be classified based on their applications:

1. Separation of Mixtures
Columns are used to fractionate a mixture based on the difference in vapor-liquid equilibrium (e.g., boiling points, volatilities). For example, in the process of crude stabilization, the function of the stabilizer column is to fractionate crude or gas condensate, and the light gases.

2. Absorption
Columns remove impurities or solvents by absorbing the desired compounds based on a solvent in a liquid phase. For example, Amine absorbers used for the removal of CO_2 and H_2S from gas production in gas processing facilities, employing an amine solvent.

3. Stripping
Columns are used for the removal of gases from liquids through the reduction of pressure or an increase in temperature. For example, solvent recovery columns are used for the stripping of the solvent from the amine solutions used for the absorption of the sour gas, thus regenerating the solvent.

Technical Background

The design of internal trays is to provide controlled interaction between the gas-liquid phases for effective mass transfer. Tray design focuses on ensuring optimal contact time, surface area, and flow dynamics to achieve separation, absorption, or desorption.

Mechanism of Mass Transfer: Gas flows upward through the valves or perforations in the form of bubbles in the liquid layer. Liquid spreads out on the tray and flows to the downcomer through weirs. Bubbles are broken up at the liquid surface, forming droplets and enhancing the mass transfer.

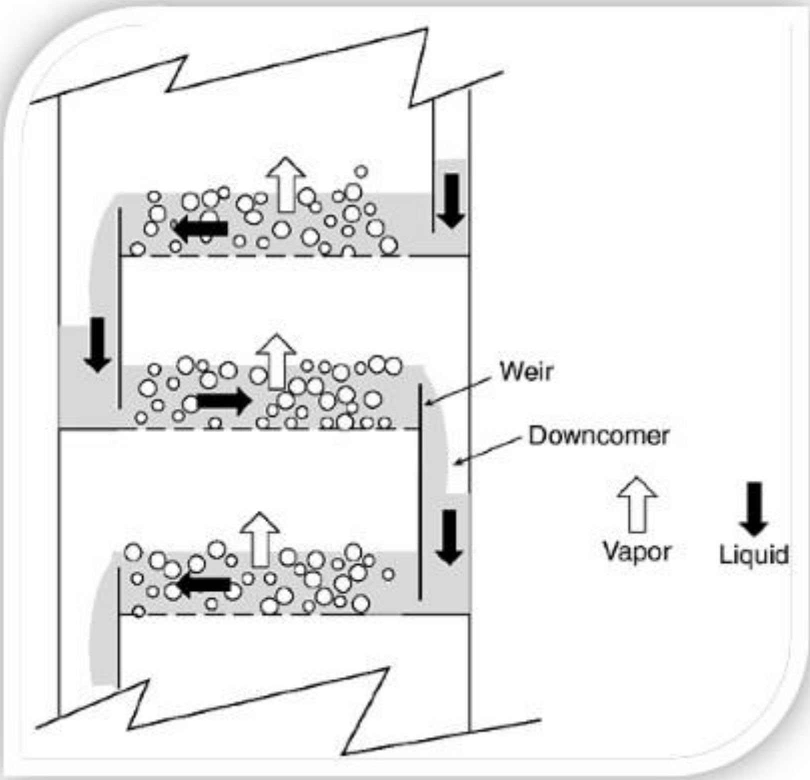

Figure 1: Vapor and Liquid flows within the trays and downcomers.

Weir Height:

- This controls the liquid hold-up on the tray, balancing contact time and pressure drop.
- If this is too low, then there might be insufficient contact time, while if it is too high, the pressure drop may be excessive.

Tray Spacing:

- This determines the vertical distance between trays, influencing gas velocity and bubble size.

Downcomer Design:

- This channels liquid between trays, preventing gas bypass and ensuring uniform distribution.

Perforation/Pore Size:

- This ensures an optimum gas flow rate with smaller bubble sizes. Small holes would result in smaller bubbles and thus a higher surface area.

Tray Types

Various column trays exist for the diverse process conditions, feed characteristics, and operational needs of different industrial applications. The vapor and liquid flow rates determine the selection criteria besides pressure and temperature. Also, economic factors, ease of maintenance, and reliability during the column's lifetime are critical in their choice.

Figure 2: Valve Trays

Design:

- A perforated plate with lift valves-spring-loaded or free-floating-that open or shut according to the passage of gas.

Advantages:

- It responds to variable gas flow rates because the valves automatically modulate.

Figure 3: Sieve Trays

Design:

- A flat plate with fixed holes for the passage of gas (perforation).

Advantages:

- This design is simple and inexpensive.

Common Operational Failures Due to Poor Installation

Proper installation of trays is critical to ensuring column performance, safety, and longevity. Misalignment, improper sealing, or poor material selection can lead to severe operational and safety issues, regardless of the column type (distillation, absorption, stripping, etc.). Below are the key consequences:

- **Reduced Column Efficiency:** Misalignment between trays disrupts liquid and gas flow distribution, reducing contact efficiency between phases, which leads to incomplete mass transfer, resulting in lower purity of products.
- **Energy Waste**: Inefficient trays force columns to operate at higher pressures or temperatures to compensate, increasing energy consumption.
- **Weeping**: Liquid is carried over to the next tray due to insufficient weir height or high gas velocity.
- **Flooding**: Excessive gas flow causes liquid to be entrained upward, halting mass transfer.
- **Channeling**: Uneven gas/liquid distribution reduces contact efficiency.
- **Corrosion or Fouling**: Deposits on tray surfaces block perforations or valves, altering flow dynamics.

- **Leaks**: Poor sealing (e.g., loose bolts, corroded joints) can result in gas or liquid leaks, posing environmental risks (e.g., VOC emissions) or toxic exposure (e.g., H_2S in amine systems).
- **Pressure Imbalances**: Misaligned trays disrupt gas-liquid flow dynamics, causing localized overpressure or vacuum conditions. This stresses equipment and increases the risk of rupture or explosion.

Installation Works

Installation works involve setting up a temporary material staging area near the vessel for efficient handling, using cranes, davit arms, pulleys, or electric winches to lift materials to each platform level, accessing the vessel interior via rope ladder, and manually inserting pre-sized internal components through manholes using temporary pulleys for ease of installation.

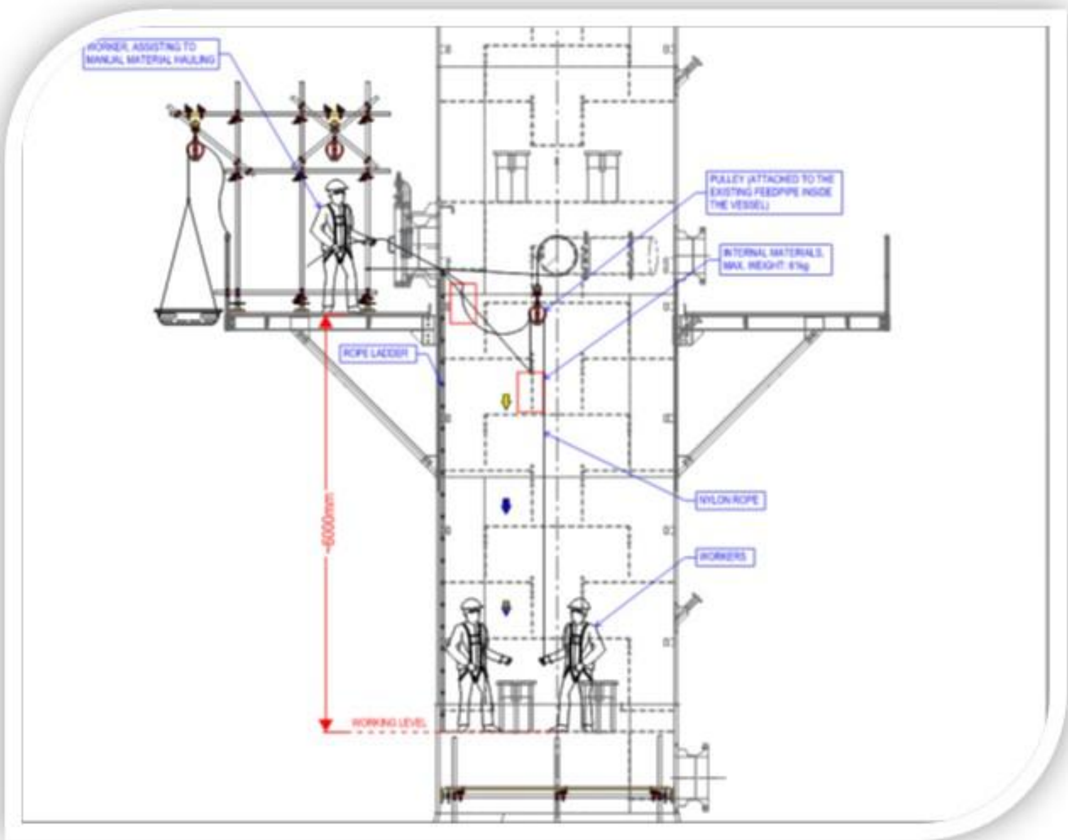

Figure 4: Internals Installation

Tray Pre-Assembling Working Bed. Tray pre-assembling working bed shall be of the same size as the diameter of the vessel involved. Carefully pre-assembled the required vessel internals (level wise) and checked precisely that all components are complete and of the correct position as if it had been installed inside the vessel. Cleanliness should be checked, and if contaminated with rust, trays to be cleaned thoroughly with approved cleaning method and solvent solution prior to installation inside the vessel. After confirmation of material and cleanliness, trays were carefully installed piece by piece inside the vessel.

Figure 5: Tray Pre-Assembling

Scaffolding Inside and Outside the Vessel. Scaffolding was erected with maximum effort not to damage the shell surface of the equipment, most especially inside the vessel as it will result in scratches and will lead to rust development/contamination. All sharp corners and protruding metal ends of scaffolding were adequately covered with rubber. Inside scaffolding was installed in such a way that enough working space is provided for installation of vessel internals. Outside scaffolding was installed with enough platform size in front of all manholes for worker's access during working activities.

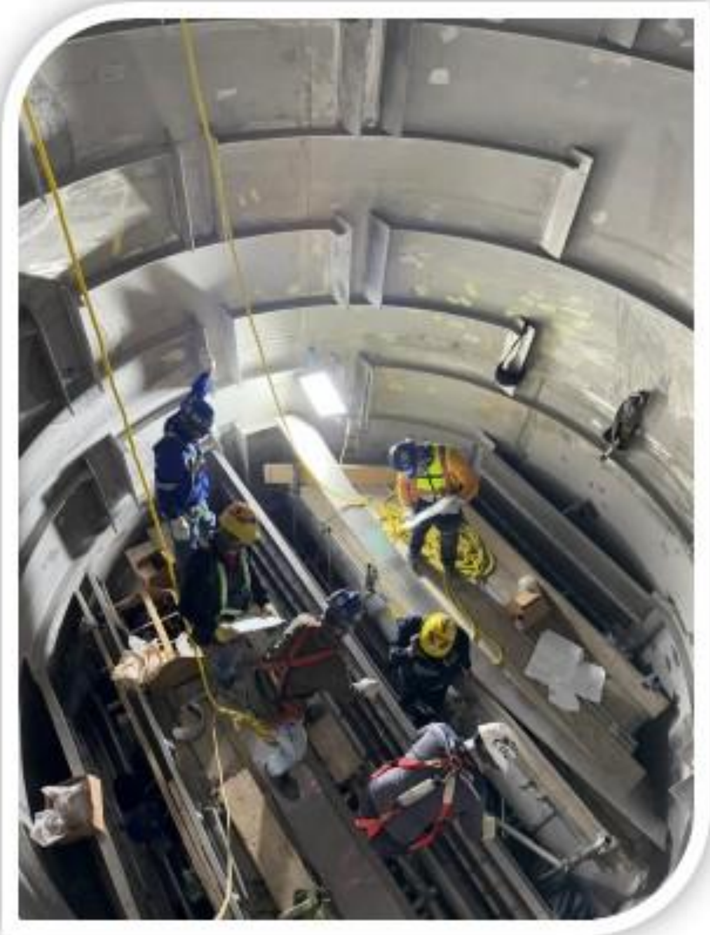

Figure 6: Scaffolding inside the column

Tray Installation. Tray installation was done on a level wise stage starting from the lowest level. Components were checked for cleanliness and completeness before installation. First, the pre-assembled parts on the ground were installed first on the internal of vessels. Components were carefully assembled and placed the same way it was assembled on the ground. Second, bolting the components was started to ensure stability. Once the assembly of tray on the first level was completed, third, the portion of the internal surface of shell where the second level of tray will be assembled was cleaned. A sheet of non-combustible material was placed on the completed first level tray to ensure its cleanliness of dust and other foreign particles. The same procedure was followed, until completion of tray installation. Tray identification and orientation was checked and verified to ensure continuity of installation work inside the equipment vessel. Finally, gaps and spacing of individual trays were ensured to be matching the approved drawing.

Figure 7: Tray Installation

Bolting Method. Once the assembly of individual trays were completed, bolts were tightened using a calibrated torque wrench. Prior to using torque wrench, bolts were initially tightened by using hands/fingers. Bolts were verified to be clear of any damage, that might have happened due to excessive force fit.

Welding Method on Vessel Internal Components. Welding method on vessel internal components was done with approved vendor WPS or WPS approved by the Company. Safety procedure was taken into consideration as always. Slags and fumes were removed in a safe manner during the course of the welding activity. All cables and materials for welding were inspected for any contamination in the assembled trays installed inside the vessels. Adequate fire blanket was provided for the entire duration of the welding activity.

Leak Test Method. Once the entire installation of vessel internals trays was completed, final inspection was done to ensure completeness of the tray installation. After inspection and acceptance of the responsible personnel, leak testing of assembled trays will commence. The following criteria shall be followed.

- Third-party certified demineralized water shall be used for the leak test.
- Chloride content of the demineralized water shall not exceed 50ppm.

- All tray assemblies shall be thoroughly cleaned.
- Trays shall be filled with water to overflow weir or chimney height to test the seal.
- Fully seal-welded trays shall have no leakage over one hour.
- The water level shall not drop by more than 25mm after 1 hour of testing to pass the acceptance criteria for leak test.
- If the actual leakage rate exceeds these requirements, weld repairs and gasket replacements shall be rectified and the tray is re-tested until a satisfactory result is obtained.
- All trays shall be thoroughly dried after the leak testing.

Box Up/ Vessel Final Closure. After completion of the inside vessel tray installation and leak testing, final inspection shall be made by concerned parties. Once inspection is completed and accepted, manholes to be closed immediately. The required torque value on the bolts of manhole flange to be applied. The equipment to be purged with nitrogen until required pressure is reached.

Case Study: Lessons from Field Experience

The case study of the Jafurah Gas Processing Facility's Amine Regeneration Column installation illustrates the deep link between technical precision and project management in industrial construction. At Jafurah Gas processing Trains Facility, the site construction team encountered alignment issues in the Tray Support Ring (TSR) assembly between levels TSR-13 and TSR-14 during the final phase of the mechanical installation of trays within the Amine Regeneration Column. The improper leveling between each TSR exceeded the permissible tolerance, resulting in the need to install shim plates in order to fill the gaps, and reach the required leveling.

Figure 8: Shim Plates

Due to difficulties in field execution, such as restricted access and scheduling limitations, shim plates where installed and tightened by the use of clamps, rather than welding.

Figure 9: Clamped Shim Plates

This deviation from the initial design has resulted in some confusion between stakeholders, whether shim plates could be tightened by clamps, or welding is required. After partial inspection, misalignment in the tray supports was observed.

Figure 10: Support Rings Misalignment

The root cause lay not in the field execution alone but in a manufacturing-stage defect that went undetected during pre-shipment inspections. During fabrication, the TSRs for levels 13 and 14 were misaligned due to inadequate quality control at the vendor's shop, where dimensional tolerances were not rigorously verified.

The technical repercussions of this misstep were profound: uneven TSR alignment increased the likelihood of tray deformation during operation, while the clamped shims introduced vulnerabilities to vibration-induced loosening, potentially leading to catastrophic failure under process conditions. From a PM perspective, the incident underscored systemic gaps in risk mitigation, quality assurance, and stakeholder communication.

The corrective actions undertaken—phased dimensional surveys to revalidate TSR alignment and the enforcement of licensor-approved modifications—demonstrated the interplay of technical and PM disciplines. By mandating formal communication for design changes and embedding quality checkpoints into installation phases, the project team addressed both the immediate technical flaw and the systemic PM gaps that enabled it. Preventive measures, such as pre-installation dimensional audits and digital alignment tools, were proposed to align field execution with engineering specifications. This dual focus on technical accuracy and PM discipline not only resolved the immediate crisis but also established a framework to mitigate similar risks in future projects.

Ultimately, the case study reveals that technical excellence in industrial construction cannot exist in isolation from project management rigor. Technical failures often stem from PM oversights—be they in risk assessment, communication, or quality control—and addressing both dimensions is essential to achieving operational safety, cost efficiency, and schedule compliance. For project managers, this reinforces the imperative to embed technical validation into every phase of execution, ensuring that technical and managerial objectives are pursued as symbiotic priorities.

Conclusion

This paper demonstrates that successful execution of industrial column installations hinges not only on technical precision but also on robust project management practices. The Jafurah Gas Processing case study illustrates how deviations from design standards—such as clamped shim plates instead of welded ones—stemmed from inadequate risk assessment, poor stakeholder alignment, and insufficient field verification. These issues underscore the cascading impact of construction-phase decisions on project timelines, budgets, and operational safety.

To mitigate such risks, project managers must prioritize:

1. **Quality Assurance Protocols:** Enforce pre-installation dimensional surveys, vendor-approved changes, and third-party leak testing to ensure compliance with technical specifications.
2. **Stakeholder Communication:** Align engineering, construction, and client teams on installation standards, especially when deviations arise due to field constraints.
3. **Risk Management:** Proactively identify construction risks (e.g., restricted access, scheduling pressures) and integrate contingency plans into project execution.
4. **Change Control:** Mandate formal approval processes for design modifications, balancing field feasibility with long-term operational safety.

By embedding these PM practices into industrial projects, teams can reduce rework, enhance safety, and align technical execution with project objectives. Future research should explore digital tools for real-time construction monitoring and PM frameworks tailored to high-risk industrial environments. This work positions project management as the linchpin of technical and operational success in complex engineering endeavors.

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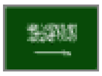

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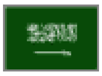

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