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Commissioning of green field project for manufacturing of Agro-activities and speciality chemicals

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Abstract

The global demand for agrochemicals and specialty chemicals is on the rise, propelled by the ever-growing need for sustainable agricultural practices and innovative chemical solutions. In response to this demand, the commissioning of greenfield projects has emerged as a strategic approach to meet both market needs and environmental goals. This abstract presents a comprehensive overview of the commissioning process for a greenfield project aimed at manufacturing agrochemicals and specialty chemicals. The abstract begins by elucidating the rationale behind the greenfield approach, emphasizing its potential to integrate cutting-edge technologies and sustainable practices from the project's inception. Subsequently, it delves into the key phases of project commissioning, including feasibility studies, site selection, regulatory compliance, and resource allocation. Special attention is given to the incorporation of eco-friendly principles and circular economy concepts throughout these phases, ensuring minimal environmental impact and maximum resource efficiency. Moreover, the abstract highlights the significance of stakeholder engagement and collaboration in driving the success of greenfield projects. It underscores the importance of forging partnerships with local communities, government bodies, and industry stakeholders to foster a conducive operating environment and promote social responsibility. Furthermore, the abstract outlines the technological advancements and innovative processes integral to the manufacturing of agrochemicals and specialty chemicals within the greenfield setup. From sustainable raw material sourcing to energy-efficient production techniques, it underscores the pivotal role of technological innovation in achieving both economic viability and environmental sustainability.

Keywords: Greenfield commissioning; Industrial commissioning; Agro-industries; Plant layout; Sustainable operations; Process optimization; Process safety engineering

1. Introduction

A greenfield project is one that is built from the ground up, meaning it is unrestricted by previous work and involves the construction of a new industrial factory and infrastructure. It involves building on vacant property when remodelling or demolishing an existing building is not necessary [1].

1.1. Appraisal of Project

In the case of greenfield projects, banks typically want a technical and financial appraisal performed by an accredited organisation that can provide an unbiased judgement on "whether the project is technically and financially viable or not." The agency conducts a comprehensive analysis of the project [1]. The following could be the field or scope of research used to reach a final decision about the project in question: Project technical components, such as technical feasibility; management competency, which includes studying the following issues; and commercial, financial, political, and environmental viability [2].

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1.2. Commissioning of Green Field Project

The plant's commissioning is completed with a series of tests to demonstrate the operability and efficiency of its various systems. When these tests are successfully completed, initial acceptance takes place. Following initial acceptance, the O&M team usually takes ownership and control of the plant for operation.

Since commissioning is the final significant stage prior to operation, there is a chance that it will be done under extreme time constraint or that certain postponed commissioning procedures may persist after the facility has started up.

To guarantee safety and dependability during commissioning, more work is required. Commissioning, launch, and shutdown procedures deserve special attention because they have been linked to numerous mishaps, malfunctions, and other problems [2].

1.3. Pre-commissioning

Special efforts are required to assure the safety and reliability of the commissioning process. Commissioning, launch, and shutdown procedures deserve special attention because they have been linked to numerous mishaps, malfunctions, and other problems.

At this point, all controllers and motorised valves should have their actions examined. Every valve, including relief valves, needs to be examined and validated. In front of the commissioning crew, major equipment should also undergo a comprehensive inspection, be closely watched, and then be closed. Critical clearances should be measured initially for comparison and control purposes. Asking a maintenance engineer or engineers to attend the activities or even take part in the commissioning process for inspection and testing of any spinning machinery, including mechanical or electrical machines, is helpful for equipment inspection. Maintenance personnel should, after all, maintain these machinery and equipment while they are in use, and the commissioning phase is the ideal time to begin this duty [3].

1.4. Commissioning & startup

The commissioning phase includes day-to-day involvement in making critical decisions on-site. This everyday engagement involves many complexities and problems, including risk-taking, accepted deviations, financial control, and plant adjustments. When the unit or plant is first operated, the majority of the equipment and items are first put through their intended operating conditions.

It is advisable to carefully subject components to their planned working conditions because failures of equipment, components, or facilities at this time might result in significant revenue losses for the operator. It is necessary to follow the proper startup sequence and procedure with the greatest care and attention.

A precise set of spare parts is required for any machinery or equipment to be commissioned and started up. In order to prevent commissioning and startup from being delayed due to a shortage of tools or spare parts, large amounts of spare components should be supplied for this phase. All too frequently, the rapid deterioration of subpar equipment or goods, abnormal loads on equipment owing to design flaws, and malfunctioning operation for a variety of causes cause the consumption of spare parts to be abnormally high during commencement [4.5].

Commissioning in a Greenfield project ensures proper installation, testing, and readiness of all systems and equipment based on project requirements. Different types of commissioning processes are used depending on the nature of the system and the project requirements

1.5. Dry Commissioning

Dry commissioning tests equipment and systems without using process fluids or materials. It focuses on mechanical checks, electrical systems, and control functionality to ensure proper installation before operation.

1.6. Wet Commissioning

Wet commissioning introduces inert fluids like water or air to test pipelines, pumps, and valves. This phase verifies flow rates, leak detection, and cooling system performance before using actual process materials.

1.7. Inactive Commissioning (Cold Commissioning)

Inactive commissioning is conducted without live energy sources like electricity or steam. It includes equipment inspections and system verification to detect potential issues before full operation.

1.8. Active Commissioning (Hot Commissioning)

Active commissioning tests the plant under full operating conditions with actual process materials. It ensures stability, efficiency, and compliance before commercial production begins. [6]

1.9. Factors Affecting on Commissioning

Project type: Thus, situational variables are significant; that is, the circumstances that resulted in a successful (or unsuccessful) commissioning outcome in one case may not be transferable to another.

Who is responsible for the phase? Depending on the project, various organisations can finish the commissioning process. Depending on the project's size and needs, it could be the equipment manufacturers, the operating team, or a different commissioning team. Contractual duties also stem from the importance of these individuals' relationships.

Phase count and type: Depending on the complexity of the project, commissioning can also be divided into a number of stages, including planning, pre-commissioning, testing, integration, monitoring, documenting, and handover. Careful project planning is necessary for this.

Contractual sufficiency and project planning: In contrast to ad hoc therapy, commissioning necessitates intentional planning, as is commonly acknowledged in the literature. As a result, it must be properly taken into account when creating specialised operating procedures, allocating resources, transferring those expenses into the original contract, and structuring the project and work breakdown structure. This is in line with the project management approach's "integration" tasks [7].

The introduction should be typed in Cambria with font size 10. Author can select Normal style setting from Styles of this template. The simplest way is to replace (copy-paste) the content with your own material. In this section highlight the importance of topic, making general statements about the topic and presenting an overview on current research on the subject. Your introduction should clearly identify the subject area of interest.

Reference should be cited at appropriate point in the text by number(s) in square brackets in line with the text. e.g.: '..... was reported earlier [1, 2].'

The actual authors can be referred to, but the reference number(s) must always be given. e.g.: 'Barnaby and Jones [3] obtained a different....'

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2. Protocol of Commissioning / Proposed Methodology

Commissioning involves systematic steps to ensure that the systems, equipment, and facilities within a Greenfield project meet design specifications, regulatory requirements, and Commissioning involves systematic steps to ensure that the systems, equipment, and facilities within a Greenfield project meet design specifications, regulatory requirements, and operational objectives. A detailed protocol includes the following phases and activities:

User Requirement Specification (URS) defines the functional and non-functional requirements of the system, emphasizing the scope, performance parameters, regulatory compliance, and workflow. The scope includes a description of system objectives, processes, and applicable regulatory concerns. Performance parameters target efficiency, capacity, and output metrics. Regulatory compliance ensures adherence to environmental, safety, and operational standards, while the workflow specifies processes the system must support to ensure seamless integration with other operational elements [8].

Design Qualification (DQ) ensures that the proposed design meets all predefined specifications. Key activities include reviewing Process Flow Diagrams (PFDs) to verify overall process design, analyzing Piping and Instrumentation Diagrams (P&IDs) for proper interconnection and flow, and cross-verifying critical parameters like pressure, temperature, and materials in equipment specifications. Risk assessments are conducted to evaluate potential hazards (HAZID) and ensure compliance with safety protocols [9].

The Factory Acceptance Test (FAT) is conducted at the manufacturer's facility to confirm that equipment meets functional and performance requirements. Operational testing is performed under controlled conditions, and calibration and mechanical components are verified. Detailed reports, including any deviations and corrective actions, are documented, and the owner's representative signs off on the system for shipment [10].

The Site Acceptance Test (SAT) is performed on-site after the equipment is installed to ensure equipment integrity and functionality. Key focus areas include inspection for transportation damage, testing under real-site conditions (such as temperature, humidity, and utility availability), and verifying installation parameters against predefined criteria. The SAT confirms readiness for integration into the commissioning phase [11].

Pre-commissioning involves preparation and readiness checks before full operational tests. Activities in this stage include system cleaning, such as flushing pipelines and cleaning filters to ensure contamination-free systems. Loop testing verifies electrical and instrumentation loops, while packing involves filling distillation columns, reactors, or similar equipment with the required packing materials. Catalyst loading is completed for applicable systems. Inspections to identify punch list items are finalized to address pending tasks [3,7].

During commissioning, equipment and systems are tested collectively to verify seamless integration. Utility systems, including instrument air, cooling water, and power, are activated. Leak testing ensures all pipelines and systems are free of leaks. Initial tests are conducted with inert materials like water or air to validate system functionality. Functional checks are performed to test startup, shutdown, and safety interlocks, while control system validation ensures that all signals and responses are accurate. Both dry and wet commissioning may be used, depending on the specific system [4,6].

Performance Qualification (PQ) verifies consistent performance under actual operating conditions. Trial production runs validate process parameters, and sampling and analysis ensure output meets specifications. Stability testing assesses long-term equipment performance over continuous operations. Detailed reporting of results and any deviations is essential for final approval.

Before full operational handover, personnel undergo training on operating procedures, equipment handling, monitoring, and safety protocols. Emergency response training equips personnel to manage leaks, spills, or system failures. Comprehensive system documentation, including manuals, maintenance logs, and operational records, is provided during the final handover. Additionally, training records ensure compliance with both regulatory and internal standards [12].

Post-commissioning ensures continued reliability and efficiency. Initial operational data is monitored to identify performance trends, and process parameters are fine-tuned for maximum efficiency. Preventive and predictive maintenance schedules are developed based on early observations. Documenting lessons learned creates a feedback loop for future commissioning activities. Periodic audits are also conducted to evaluate system reliability over time [4]

2.1. Additional Safety and Regulatory Measures

- Emergency Response Planning: Comprehensive evacuation plans, gas leak sensors, and fire safety equipment ensure preparedness during emergencies.
- Calibration of Equipment: All equipment must be calibrated regularly to ensure accuracy and minimize risks associated with measurement errors. Tank calibrations should be performed after installation and periodically thereafter.
- Blasting Wall Considerations: For hazardous processes, reinforced blasting walls should be installed to minimize the impact of explosions and protect personnel [6]

3. Layout of Commissioning Plant

The layout of a commissioning plant is a critical aspect of its design and functionality. Proper planning ensures efficient operations, safety, and compliance with regulatory standards. The layout encompasses the spatial arrangement of equipment, utility connections, and pathways for personnel and materials.

3.1. Plant Layout Design

Plant layout involves the strategic positioning of machines, processes, and services to maximize output and minimize costs. An effective layout incorporates:

3.1.1. Equipment Arrangement:

Ensuring optimal placement of machinery to streamline operations, reduce piping and wiring complexity, and avoid interference between equipment.

3.1.2. Process Constraints:

Positioning equipment to align with process requirements, such as gravity-fed systems for materials and fluid flow.

3.1.3. Safety Considerations:

Ensuring adequate spacing for emergency access, fire exits, and safe operation. Fire zones must be clearly defined to contain potential hazards, with separation between high-risk and low-risk areas.

3.1.4. Operational Efficiency:

Simplifying the flow of materials, personnel, and products while reducing transportation and handling time within the plant [13].

Factors influencing the layout include site constraints, process needs, and regulatory compliance. For example, the location of cooling towers, furnaces, and stacks must consider prevailing wind directions to avoid contamination and maintain air quality standards.

3.2. Equipment Layout

The arrangement of equipment is guided by process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs). Key considerations include:

3.2.1. Horizontal vs. Vertical Arrangement:

Horizontal layouts, commonly seen in refineries, simplify construction, allow for easier operator access, and facilitate maintenance but require more ground space. Vertical arrangements save ground area, reduce inter-equipment piping length, and are suitable for compact facilities or processes requiring height for gravity-fed systems [19].

3.2.2. Access and Maintenance:

Providing sufficient space for cleaning, repairs, and replacements. Platforms, walkways, and ladders should be strategically placed to ensure safe and easy access.

3.2.3. Control Rooms and Storage:

Allocating dedicated, climate-controlled areas for operational monitoring, laboratories, and secure storage for critical materials such as catalysts and hazardous chemicals [14,15].

3.3. Piping and Instrumentation

P&IDs serve as a blueprint for connecting equipment. They include:

- Details of pipe routing, including slopes for drainage, insulation requirements, and support structures.
- Special materials for high-pressure or high-temperature systems.
- Placement of venting and safety valves to ensure system pressure remains within safe limits.

- Utility connection points for steam, water, air, and electrical systems, ensuring redundancy where necessary [16].

3.4. Safety Provisions

Safety is integral to plant layout. Key measures include:

- **Emergency Exits:** Clearly marked and unobstructed pathways for personnel evacuation during emergencies. Doors and exits must comply with fire and safety regulations.
- **Firefighting Systems:** Strategically placed fire extinguishers, sprinklers, alarms, and hydrants to ensure rapid response in case of a fire.
- **Assembly Points:** Designated safe zones for personnel to gather during emergencies. These should be away from hazardous zones and clearly marked [6].
- **Blasting Walls:** Reinforced walls or barriers around high-risk areas, such as reactors or hydrogen storage units, to minimize damage from potential explosions.

3.5. Utility Layout

Utilities like cooling water, electricity, compressed air, and inert gases must be efficiently distributed across the plant. Key considerations include:

- **Utility Racks:** Centralized racks for pipelines and electrical conduits to minimize congestion and allow for future expansions.
- **Trench Systems:** Underground trenches for water and electrical lines to avoid surface-level obstructions and enhance safety.
- **Redundancy:** Backup systems for critical utilities to ensure uninterrupted operations during failures [17].

3.6. Specialized Areas

- **Hazardous Zones:** Equipment handling flammable, toxic, or corrosive materials should be isolated with reinforced barriers and placed away from general operations.
- **Inspection Pathways:** Dedicated walkways and observation platforms for personnel to safely monitor operations without interfering with ongoing processes.
- **Storage Areas:** Separate zones for raw materials, intermediate products, finished goods, and waste. Hazardous material storage should include secondary containment to prevent spills and leaks.
- **Decontamination Zones:** Areas equipped with showers and wash stations for personnel exposed to hazardous materials.

3.7. Modern Layout Tools

Advanced computer-aided design (CAD) tools assist in optimizing plant layouts by simulating workflows, ensuring compliance, and facilitating real-time adjustments. These tools allow engineers to:

- Visualize equipment placement and identify potential inefficiencies.
- Simulate emergency scenarios and test evacuation plans.
- Optimize resource allocation and piping routes for cost and energy efficiency [17].

3.8. Typical Layout Configurations

3.8.1. Grade-Mounted Horizontal Arrangement:

Equipment is placed at ground level, simplifying construction, operations, and maintenance. However, this requires significant land area and may limit future expansions.

3.8.2. Structure-Mounted Vertical Arrangement:

Equipment is stacked vertically in steel or concrete structures, saving ground space. This configuration is commonly used in chemical and petrochemical plants where gravity-fed systems are advantageous [18].

3.8.3. Hybrid Layouts:

A combination of horizontal and vertical arrangements tailored to specific plant requirements, balancing accessibility and space constraints.

3.9. Environmental and Regulatory Compliance

The plant layout must comply with environmental regulations, including:

- Managing stormwater and wastewater discharge points.
- Minimizing emissions by positioning chimneys and vents appropriately.
- Ensuring green buffer zones around the facility for noise and pollution control [19].

A well-designed plant layout enhances operational efficiency, safety, and adaptability. By incorporating process requirements, regulatory compliance, and modern design tools, commissioning plants can achieve sustainable and cost-effective operations. Thorough planning ensures that the plant not only meets immediate production needs but also remains scalable and adaptable for future demands.

4. ASME Standards in Equipment and Plant Design

The American Society of Mechanical Engineers (ASME) establishes critical guidelines and standards for designing, fabricating, and maintaining mechanical and process equipment used in industrial plants. Compliance with ASME standards ensures safety, reliability, and efficiency in chemical, pharmaceutical, and specialty chemical manufacturing facilities.

The ASME Boiler and Pressure Vessel Code (BPVC) governs the design, manufacturing, and inspection of boilers, pressure vessels, and related components. These regulations ensure that high-pressure steam and chemical reaction systems operate safely. BPVC Section VIII is particularly crucial as it ensures pressure vessel integrity and prevents failures due to overpressure conditions. Pressure vessels designed according to this standard undergo rigorous testing and quality assurance procedures before they can be put into operation.

ASME B31.3 – Process Piping defines safety and material requirements for chemical processing pipelines. Given the highly reactive and hazardous nature of certain chemicals, this standard ensures that piping systems in hydrogenation, herbicide, and pharmaceutical plants withstand extreme temperature and pressure variations. It mandates the use of high-grade materials, proper welding techniques, and non-destructive testing to prevent leaks and failures in the piping infrastructure.

Another critical standard, ASME B73.1 – Chemical Process Pumps, establishes mechanical specifications and performance standards for centrifugal and diaphragm pumps used in chemical processing. These pumps must be designed to handle corrosive, abrasive, and high-viscosity fluids commonly found in agrochemical and specialty chemical production. The guidelines ensure that pumps are equipped with appropriate seals, bearings, and materials to extend their operational lifespan while maintaining efficiency and safety.

The ASME BPE – BioProcessing Equipment standard focuses on the hygienic design of equipment used in pharmaceutical and specialty chemical manufacturing. This standard ensures that reactors, dryers, filtration systems, and other process equipment maintain sterile conditions and prevent contamination. The requirements emphasize cleanability, surface finish, and material selection to meet stringent pharmaceutical and bioprocessing needs.

Additionally, ASME Section IX – Welding and Brazing Qualifications specifies welding and brazing standards for equipment fabrication. It ensures that pressure vessels, piping systems, and plant infrastructure are structurally sound by setting procedures for material testing, heat treatment, and post-weld inspections. Compliance with these guidelines is crucial in industries where welding defects could lead to catastrophic failures.

By adhering to ASME standards, manufacturers and plant operators can ensure equipment reliability, enhance workplace safety, and meet global regulatory requirements. These standards not only facilitate safe operations but also optimize plant efficiency by reducing downtime caused by mechanical failures and maintenance issues [20,21].

5. Plants and Equipment Used

The commissioning of a Greenfield project involves various specialized plants and equipment essential for the manufacturing of agrochemicals and specialty chemicals. These facilities and machinery are designed to optimize efficiency, maintain safety standards, and comply with regulatory requirements. The selection of equipment and plant layout is crucial to achieving streamlined production, minimizing operational risks, and ensuring regulatory compliance.

5.1. Herbicide Plant

Herbicide plants play a fundamental role in the chemical industry by manufacturing weed control solutions. The setup of such plants involves comprehensive planning, incorporating considerations like site selection, safety measures, operational efficiency, and environmental impact mitigation.

Chemical reaction units within the herbicide plant facilitate the synthesis of active ingredients through controlled chemical reactions. These units must be equipped with safety interlocks to prevent hazardous chemical interactions. Once the active ingredients are synthesized, mixing and formulation systems blend them with solvents, stabilizers, and surfactants to ensure uniform dispersion. To enhance stability and ease of handling, granulation and drying units convert liquid formulations into solid granules. Finally, packaging units automate the filling of herbicides into bottles, cans, or drums, ensuring compliance with quality and safety standards [22].

5.1.1. Safety and Security Measures in Herbicide Plants

Security protocols are implemented to protect personnel and prevent environmental contamination. Restricted entry and exit policies ensure that only trained and authorized personnel handle hazardous chemicals. Surveillance systems, fencing, and automated access control prevent unauthorized interference with production. Emergency exit pathways are clearly marked and maintained to facilitate rapid evacuation in case of accidental exposure or chemical leaks. To safeguard workers, personal decontamination facilities, including showers and eyewash stations, are strategically placed within the plant [23].

5.2. Hydrogenation Plant

Hydrogenation plants modify organic compounds through hydrogen addition, a crucial step in chemical synthesis, pharmaceuticals, and agrochemical production. These plants require robust safety systems due to the flammable nature of hydrogen gas.

Hydrogenators, which are cylindrical or spherical reactors, facilitate reactions under controlled pressure and temperature. These reactors are often lined with specialized materials to withstand high-pressure hydrogen exposure. Catalyst systems, including metals like palladium, platinum, or Raney nickel, improve the efficiency and selectivity of hydrogenation reactions. Hydrogen storage and distribution systems maintain a steady supply of gas, ensuring uninterrupted operations. Heat exchangers regulate process temperatures to prevent overheating and ensure energy efficiency. Since hydrogen is highly explosive, reinforced blasting walls are integrated into the facility design to contain potential hazards [24].

5.2.1. Safety Considerations

Hydrogenation plants deploy gas leak detection systems that continuously monitor for leaks and trigger alarms if abnormal concentrations are detected. Adequate ventilation systems ensure that hydrogen does not accumulate in confined spaces. Emergency response protocols include fire suppression systems, explosion-proof electrical fixtures, and designated safe zones for workers [25].

5.2.2. Casket Assembly

Casket assembly involves the precise construction and integration of various components to create a durable and aesthetically pleasing final product. The process typically includes forming the base, attaching side panels, and securing the lid using reinforced hinges and locking mechanisms. High-quality materials such as hardwood, stainless steel, or composite materials are used to enhance durability and appearance. Interior lining, often made of velvet or satin, is carefully fitted to provide a dignified presentation. The final assembly undergoes thorough inspection to ensure structural integrity, smooth operation of closing mechanisms, and compliance with industry standards [26].

5.3. Boiler System

Boilers are indispensable in chemical plants for generating steam required in various heating, power generation, and chemical process operations. Efficient boiler systems contribute to operational sustainability by optimizing fuel consumption and reducing emissions.Water-tube boilers are commonly used in industrial applications due to their ability to handle high pressures and produce large volumes of steam. Biomass reciprocating grate boilers utilize renewable fuel sources like rice husk, promoting sustainability and reducing dependency on fossil fuels. Fuel storage and supply systems ensure uninterrupted fuel feeding, while condensate recovery systems enhance energy efficiency by recycling steam condensate back into the process [27].

5.4. IBR Rules for Boilers

The Indian Boiler Regulations (IBR), 1950, govern the design, manufacture, installation, and operation of boilers in India to ensure safety and efficiency. These regulations apply to all boilers operating above 22.75 liters in capacity and 1 kg/cm^2 pressure and are enforced by the Central Boilers Board (CBB) under the Indian Boiler Act, 1923. Boilers must meet strict material, fabrication, and inspection standards, as specified in IBR Part 1. They must be manufactured in IBR-certified facilities and undergo third-party inspection. Before operation, boilers must be registered with the Boiler Directorate and obtain an IBR certification. Safety valves and controls, including pressure relief systems and emergency shut-off mechanisms, are also required. Steam piping connected to IBR boilers must also comply [28].

5.4.1. Water Treatment Measures

To prevent scaling and corrosion, boiler systems incorporate water treatment processes such as demineralization and deaeration. Chemical dosing systems introduce corrosion inhibitors and oxygen scavengers to maintain optimal water quality, extending the boiler's operational lifespan [29].

All boiler systems should comply with ASME Boiler and Pressure Vessel Code (BPVC) standards, ensuring the design, materials, fabrication, and testing procedures adhere to internationally accepted safety regulations.

5.5. Key Equipment Used Across Plants

A variety of specialized equipment is employed across different processing units to facilitate smooth and efficient operations.

5.5.1. Stainless Steel Reactors (SSR):

These corrosion-resistant reactors operate under controlled temperature and pressure, making them suitable for the synthesis of agrochemicals, pharmaceuticals, and specialty chemicals. Their durability ensures long-term operational reliability. Reactors should comply with ASME Section VIII standards for pressure vessels to ensure safety and performance under high-pressure conditions [30]

5.5.2. Glass-Lined Reactors (GLR)

Ideal for handling highly corrosive chemicals, these reactors feature a protective glass coating that prevents contamination and enhances purity. They are commonly used in reactions requiring precise temperature control. These reactors must conform to ASME BPVC and API 660 standards for material compatibility and pressure handling [31].

5.5.3. Agitated Nutsche Filter Dryer (ANFD)

ANFDs perform solid-liquid separation, filtration, and drying within a single unit, improving efficiency and reducing material handling risks. They are widely used in pharmaceutical and specialty chemical manufacturing. Equipment design should follow ASME BPE (BioProcessing Equipment) standards for hygienic processing [32].

5.5.4. Vacuum Tray Dryer (VTD):

This equipment is designed for drying heat-sensitive materials under vacuum conditions. It minimizes thermal degradation, ensuring uniform drying and high-quality end products. Vacuum drying systems should comply with ASME Section VIII for pressure vessels to ensure safe operation [33].

5.5.5. Rotocone Vacuum Dryer (RCVD)

RCVDs are employed for drying hygroscopic and heat-sensitive substances. They enhance solvent recovery while reducing drying time, making them ideal for fine chemical production. These dryers must meet ASME and cGMP (Current Good Manufacturing Practice) standards for pharmaceutical applications [34].

5.5.6. Air-Operated Double-Diaphragm (AODD) Pumps

These pumps are used for transferring high-viscosity fluids and abrasive materials. Since they operate without electrical components, they minimize explosion risks, making them suitable for hazardous environments. AODD pumps should comply with ASME B73.1 standards for chemical process pumps [35].

5.5.7. Centrifugal Pumps

Designed for high-volume fluid movement, centrifugal pumps are essential in cooling systems, chemical transfer processes, and water circulation. They are available in single-stage and multi-stage designs, catering to diverse industrial needs. These pumps must meet ASME B73.1 and API 610 standards for industrial applications [36].

5.5.8. Additional Utility and Storage Equipment

Plants also require support systems to store and transport raw materials and chemicals. Hydrogen cascade storage systems ensure the safe handling of high-pressure hydrogen gas. Process data sheets (PDS) and general arrangement drawings (GA Drawings) provide detailed documentation for plant layouts and equipment specifications, assisting in maintenance and future expansions.

The careful selection of plants and equipment in a commissioning project is crucial for ensuring operational efficiency, regulatory compliance, and workplace safety. By integrating advanced safety mechanisms, sustainable designs, and high-performance machinery, these plants can optimize production while minimizing environmental impact. Compliance with ASME, API, and cGMP standards further enhances equipment reliability and safety, ensuring long-term operational success [37].

5.6. Tank Farm

A tank farm is a specialized storage facility for bulk liquids such as chemicals, petroleum, and industrial fluids, typically occupying 70-80% of a plant’s total area. These storage systems play a critical role in managing raw materials and finished products while ensuring safe handling and environmental protection. Proper design and maintenance of a tank farm are essential to prevent leaks, spills, and fire hazards.

Tank farms must comply with ASME, API, OSHA, and EPA regulations to ensure safety, structural integrity, and environmental sustainability. ASME Section VIII governs the design and fabrication of pressure vessels used in storage systems, while API 650 and API 620 provide guidelines for constructing above-ground and low-pressure storage tanks. OSHA and NFPA safety codes establish fire protection measures, emergency response protocols, and personnel safety guidelines. Additionally, the EPA Spill Prevention, Control, and Countermeasure (SPCC) rule mandates secondary containment systems to prevent leaks from contaminating the environment.

Tank farms consist of above-ground storage tanks (ASTs) and underground storage tanks (USTs). ASTs are used for bulk storage of crude oil, chemicals, and water, featuring secondary containment systems, corrosion-resistant coatings, and leak detection mechanisms. USTs, primarily used for hazardous materials like petroleum and methane, are buried underground to minimize risks and comply with strict environmental regulations.

To enhance safety, tank farms incorporate dyke enclosures, firewalls, overfill prevention systems, and real-time leak detection technologies. Compliance with ASME and API standards ensures structural durability, while environmental regulations help mitigate potential risks. A well-maintained tank farm improves operational efficiency, regulatory compliance, and environmental safety, ensuring secure storage and distribution of critical materials [38].

6. Conclusion

The proper selection, design, and implementation of plants and equipment play a fundamental role in the success of Greenfield commissioning projects. By ensuring compliance with industry standards such as ASME, API, and cGMP, manufacturers can achieve operational excellence, safety, and regulatory adherence.

The integration of specialized facilities, such as herbicide and hydrogenation plants, requires meticulous planning to optimize efficiency, safety, and environmental impact. Modern advancements in equipment technology, including stainless steel reactors, vacuum dryers, and precision pumps, contribute to high-performance manufacturing while reducing maintenance costs and operational downtime. Additionally, adherence to ASME standards ensures the structural integrity and safety of pressure vessels, process piping, and welding procedures, mitigating risks associated with high-pressure and hazardous materials.

Furthermore, safety measures such as gas leak detection, fire suppression systems, and personnel decontamination facilities enhance workplace security, ensuring the well-being of operators and technicians. Sustainable practices, including condensate recovery systems and renewable fuel boilers, contribute to energy efficiency and environmental responsibility.

In conclusion, the success of a commissioning project relies on a comprehensive approach that integrates high-quality equipment, stringent safety protocols, and compliance with global engineering standards. By adopting best practices and leveraging technological advancements, industries can establish efficient, sustainable, and compliant manufacturing facilities, ensuring long-term operational success and market competitiveness.

Compliance with ethical standards

Conflict of interest statement

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no other interest to report.

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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