DI04019041: Fabrication Technology - Unit 6

GTU Course Presentation

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Course Contents I

Understanding Installation I

Installation refers to the placement, mounting, and connection of machinery or equipment to its final operating position, including foundation preparation, alignment, leveling, and hookup of utilities (piping, electrical, instrumentation) in accordance with engineering drawings and manufacturer specifications.

Understanding Installation II

Key Points

- Foundation preparation involves inspection of concrete foundations, checking anchor bolt locations (coaxiality and projection), and verifying strength using concrete core tests.
- Leveling and alignment are performed using precision spirit levels, dial gauges, or laser alignment tools to ensure shafts and axes conform to tolerances (typically within 0.05 mm).
- Grouting fills the space between the equipment baseplate and concrete foundation using non-shrink epoxy or cementitious grout to distribute operating loads.
- Utility hookups include connecting process piping (ensuring no piping strain is transferred to equipment nozzles), electrical power cabling, and control

Understanding Erection I

Erection is the physical assembly, lifting, positioning, and temporary securing of heavy structural components, pressure vessels, columns, or modular units using cranes, derricks, or gin poles. It is primarily a mechanical assembly and rigging operation before final alignment and tie-ins.

Understanding Erection II

Key Points

- Rigging planning is critical, involving calculation of the equipment's center of gravity (CG), selection of slings, spreader beams, and crane capacity (incorporating a safety factor of at least 1.25).
- Lifting operations utilize mobile, crawler, or gantry cranes, requiring detailed rigging studies, wind speed monitoring (typically capped at 10 m/s), and ground bearing capacity checks.
- Assembly involves bolting or welding structural sub-assemblies (e.g., columns, trays, external ladders, and platforms) at the site before or during lifting.
- Temporary securing uses guy wires, jacks, or temporary bolts to stabilize the structure until permanent anchor bolts are tightened or foundation welds are completed.
- Compliance with safety and rigging codes such as

Process Flow: Erection to Installation I

Process Flow: Erection to Installation II

Erection (Mechanical)
Lifting, positioning, rough alignment, structural assembly, securing columns/vessels

↓ Secure foundation and structural integrity

Installation (Integration)
Leveling, precision alignment, grouting, piping tie-ins, electrical hookups

↓ Utility connection and mechanical completion

Commissioning (Functional)
Pre-commissioning tests, loop checks, cold/hot runs, performance trial

Understanding Commissioning I

Commissioning is the systematic process of verifying, testing, and adjusting every component and system of the process equipment to ensure it operates in accordance with the design intent and safety regulations before handover to the operations team.

Understanding Commissioning II

Key Points

- Pre-commissioning: Includes clean-out (flushing, chemical cleaning, steam blowing), hydrotesting of piping (per ASME B31.3), and cold loop checks of instrumentation.
- Cold Commissioning: Involves dry runs, testing of interlocks, running auxiliary equipment (lube oil pumps), and functional testing of components using inert fluids (e.g., air or water).
- Hot Commissioning (Start-up): Involves introducing the actual process fluid, heating up the system to operating temperatures, and conducting dynamic testing of control loops.
- Performance Guarantee Run (PGR): Operates the plant at full design load for a specified period (e.g., 72 hours) to verify capacity, efficiency, and emissions compliance.

Installation vs. Erection: Core Differences I

While often used interchangeably in layman terms, installation and erection have distinct engineering scopes, tools, tolerances, and labor requirements in fabrication technology.

Installation vs. Erection: Core Differences II

Key Points

- Scope: Erection deals with structural lifting, positioning, and heavy assembly of structural frames and major equipment. Installation deals with leveling, precision alignment, piping hookups, and cabling.
- Equipment & Tools: Erection requires heavy rigging gear (cranes, slings, shackles, derrick masts). Installation requires precision tools (dial indicators, laser aligners, torque wrenches, levels).
- Tolerances: Erection tolerances are typically in millimeters (e.g., structural plumbness of 1 in 1000). Installation tolerances are in fractions of a millimeter (e.g., alignment within 0.02 to 0.05 mm).
- Labor Specialization: Erection is executed by riggers, ironworkers, and structural welders. Installation is executed by millwrights, pipefitters, electricians, and

Commissioning Phase Sequence I

Commissioning Phase Sequence II

Pre-Commissioning
Flushing, Hydrotesting, Loop Checks

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Cold Commissioning
Utility Runs, Dry/Wet Runs, Interlock Tests

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Hot Commissioning
Process Fluid Introduction, Thermal Stabilization

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Handover and PGR
Performance Guarantee

Codes, Standards and Safety Protocols I

Erection, installation, and commissioning of process equipment are strictly governed by international engineering standards to ensure structural integrity, pressure containment, and human safety.

Codes, Standards and Safety Protocols II

Key Points

- ASME Section VIII Div 1 & 2: Governs the design, fabrication, and field assembly/inspection requirements for pressure vessels during erection.
- ASME B31.3 (Process Piping): Defines fabrication, assembly, examination, and testing (hydrostatic or pneumatic) of process piping connections.
- API 686 (Machinery Installation): Recommended practice for the design and installation of petroleum, chemical, and gas industry machinery (pumps, compressors).
- OSHA 1926 Subpart CC: Governs safety practices for cranes and derricks used during heavy lifting and erection operations.
- NEMA & IEC Standards: Define installation and testing criteria for electrical control panels, grounding, and

Static Process Plant Equipment: Pressure Vessels I

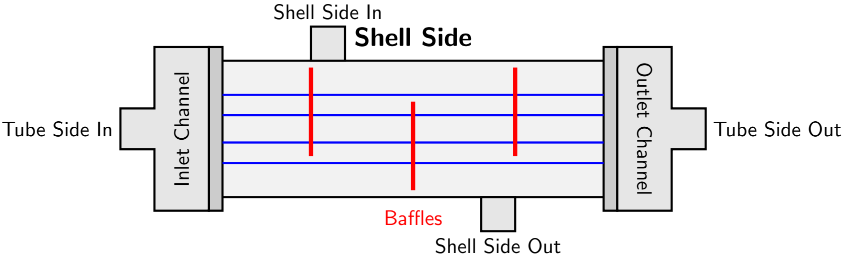
Pressure vessels are closed containers designed to hold liquids or gases at pressures substantially different from the ambient pressure.

Static Process Plant Equipment: Pressure Vessels II

Key Points

- Design Codes: Fabricated strictly according to ASME Boiler and Pressure Vessel Code (BPVC) Section VIII, which is divided into Division 1 (construction rules), Division 2 (alternative design-by-analysis rules), and Division 3 (rules for high pressure $>$ 10,000 psi).
- Materials of Construction: Commonly carbon steel (e.g., SA-516 Gr. 70 for moderate/lower temperatures) or stainless steel (e.g., SA-240 Type 304/316 for corrosion resistance). Clad plates are used to balance cost and chemical resistivity.
- Fabrication Process: Involves plate cutting (CNC plasma/oxy-fuel), plate rolling to shape, welding of longitudinal/circumferential seams (GTAW, SMAW, SAW), nozzle attachment, and Post-Weld Heat Treatment (PWHT) to relieve residual stresses.

Heat Exchangers & Distillation Columns I



Heat Exchangers & Distillation Columns II

Key Points

- Shell and Tube Exchangers: Fabricated according to TEMA (Tubular Exchanger Manufacturers Association) standards. Features include tube sheets, baffles to direct fluid flow and support tubes, and channel covers.
- Plate Heat Exchangers (PHE): Built using corrugated metal plates clamped in a frame, offering compact size and high heat transfer coefficient but limited to lower pressures and temperatures.
- Distillation Columns: Tall vertical static vessels used for separating chemical mixtures by fractional distillation. Contain inner components like distillation trays or structured/random packings.
- Column Internals & Erection: Tray support rings must be welded inside with strict leveling tolerances (usually within +/- 1 mm) to prevent liquid channeling and

Piping Systems and Process Valves I

Industrial piping networks transfer fluids safely between process equipment, guided by safety codes and flow control valves.

Piping Systems and Process Valves II

Key Points

- ASME B31.3 Process Piping: The standard design code regulating piping material specifications, pipe wall thickness calculation, thermal expansion analysis, and testing limits.
- Piping Fabrication & Standards: Involves cut-back preparation, welding of pipe spools under ASME Section IX certifications, and flange fittings standard ASME B16.5 for pressure ratings up to class 2500.
- Isolation Valves: Gate valves (used for full-flow isolation, low pressure drop) and Ball/Plug valves (quarter-turn, quick-acting bubble-tight shutoff).
- Regulating & Non-Return Valves: Globe valves (used for flow throttling and high pressure drop), Butterfly valves (compact throttling for large lines), and Check valves (swing or lift type to prevent backflow).

Rotary Process Equipment: Pumps & Agitators I

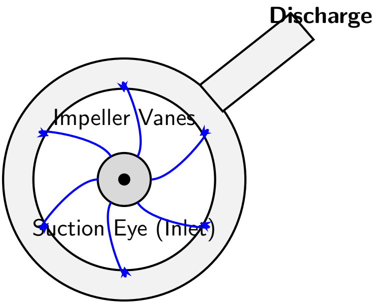
Rotary equipment uses dynamic forces and rotating shafts to add kinetic energy, move fluids, or mechanically mix process fluids.

Rotary Process Equipment: Pumps & Agitators II

Key Points

- API 610 Centrifugal Pumps: The primary rotary machine for transporting liquids. Features single or multi-stage impellers, dynamic wear rings, and mechanical shaft seals.
- Positive Displacement Pumps: Plunger, piston, diaphragm (API 674/675) or rotary screw and gear pumps. Used for highly viscous fluids, high discharge pressure, or precise metering.
- Agitators & Mixers: Vertical rotating shaft equipment with impellers (hydrofoils, turbines, anchors) used inside reactors and blending vessels to ensure mixing homogeneity.
- Sealing and Balance: Requires high-integrity mechanical seals (API 682) to prevent process fluid emissions, and dynamic balancing of rotor components to prevent

Fans, Blowers, and Compressors I



Centrifugal Compressor / Fan Volute

Fans, Blowers, and Compressors II

Key Points

- Industrial Fans: Move huge volumes of air/gases at very low pressure rises (< 0.07 bar). Classified into axial (propeller-like) and centrifugal (radial flow) fans.
- Industrial Blowers: Work in the pressure range of 0.07 to 2.0 bar. Common types include Roots rotary lobe blowers and centrifugal blowers, used in pneumatics and aeration.
- Process Compressors: Deliver extremely high pressure rises. Centrifugal compressors (API 617) handle high flow rates, while Reciprocating compressors (API 618) handle low flows at massive pressures.
- Critical Operations: Compressors require dedicated surge detection/anti-surge valve systems and auxiliary API 614 lubrication oil systems to prevent mechanical failure during surges.

Advanced rotary machinery includes solids-liquids separation equipment and prime movers that extract work from process steam or gas expansion.

Agitators, Filtration Equipment & Turbines II

Key Points

- Agitation Internals: Comprises motor-gearbox assembly, rigid shafts, steady bearings (to prevent shaft whip), and impellers designed for axial or radial flow profiles.
- Industrial Filters: Rotary Vacuum Drum Filters (RVDF) provide continuous filtration, utilizing a rotating drum under vacuum to collect and scrape off dry filter cake.
- Steam Turbines (API 611/612): Convert thermal energy of high-pressure steam into mechanical shaft rotation. Used as economic prime movers for massive compressors or backup generators.
- Gas Turbines & Expanders: Heavy industrial gas turbines combust fuel to drive electric generators, while turboexpanders recover cryogenic cold energy and generate power from high-pressure gas streams.

Erection, Alignment & Commissioning of Equipment I

Proper field installation determines the operational life and vibration behavior of static and rotary equipment.

Erection, Alignment & Commissioning of Equipment II

Key Points

- Foundation & Grouting: Checking concrete foundation for cracks, verifying anchor bolt coordinates, leveling equipment with steel shims, and pouring non-shrink epoxy grout.
- Precision Shaft Alignment: Using reverse dial indicator or laser alignment systems. Target tolerances for coupling alignment are typically within 0.05 mm for parallel and angular deviations.
- Piping Strain Prevention: Piping flange connections must be aligned to the equipment nozzles without applying external torque or stress, checked using dial gauges during final bolting.
- Commissioning Steps: N2 purging to eliminate oxygen,

Pump Foundation & Pre-Installation Checks I

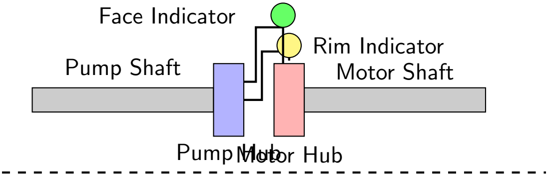
Civil foundation preparation and leveling standards under API RP 686 requirements.

Pump Foundation & Pre-Installation Checks II

Key Points

- Concrete foundations must cure for a minimum of 28 days and achieve 75% of design compressive strength before equipment placement.
- Concrete surface laitance is removed by chipping/scabbling to expose sound aggregate and ensure robust epoxy grout bonding.
- Baseplate or soleplate leveling is done using stainless steel shims or leveling jackscrews on flat metal plates.
- The baseplate must be leveled to within 0.4 mm per meter (0.005 in/ft) across longitudinal and transverse planes before grouting.

Shaft Alignment & Dial Indicator Method I



Shaft Alignment & Dial Indicator Method II

Key Points

- Rim and face dial indicator method isolates parallel offset (rim) and angular misalignment (face) across the coupling hubs.
- Reverse dial indicator method uses indicators mounted on opposing shafts to eliminate indicator sag errors on long-span couplings.
- Standard field tolerance limits parallel offset to 0.05 mm (0.002 in) and angular deviation to 0.05 mm per 100 mm coupling diameter.
- Thermal growth compensation adjusts the driver (motor) shaft height lower than the pump to account for thermal expansion at operational temperatures.

Piping Connections & Pipe Strain Management I

Guidelines for pipe fit-up to prevent static and dynamic nozzle loads as per API 686 Chapter 6.

Piping Connections & Pipe Strain Management II

Key Points

- Suction and discharge piping must be independently supported, guided, and anchored to prevent weight transfer to pump nozzles.
- To check pipe strain, dial indicators are mounted on coupling hubs while the suction and discharge flange bolts are fully torqued.
- Allowable shaft deflection at the coupling during flange bolt tightening is strictly capped at 0.05 mm (0.002 inches).
- Temporary suction strainers (witch's hat type, minimum 40 mesh) must be installed to capture debris during initial line flushing.

Grouting Procedures for Pump Baseplates I

Execution of baseplate epoxy grouting to ensure rigid, vibration-damping mechanical support.

Grouting Procedures for Pump Baseplates II

Key Points

- Epoxy grout is preferred over cementitious grout due to high compressive strength (90+ MPa), chemical resistance, and zero shrinkage.
- Grout pour must be continuous from one side of the baseplate to the other using a headbox to maintain hydrostatic head and prevent air voids.
- Baseplates require vent holes (12-25 mm) at corners and compartments to verify complete grout flow and release trapped air.
- A post-cure hammer-tap test checks for hollow spots; any detected voids are vacuum-injected with low-viscosity liquid epoxy.

Erection of Process Vessels at Site I

Lifting and vertical alignment of heavy industrial columns, reactors, and storage vessels.

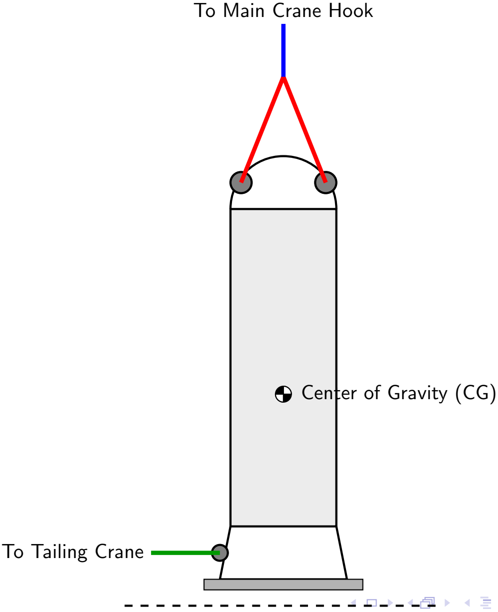
Erection of Process Vessels at Site II

Key Points

- A detailed lifting plan must specify crane load charts, rigging configurations, center of gravity, and maximum allowable wind speed.
- Lifting is conducted using the tail-dogging method, where the main crane lifts the top head and a tailing crane manages the skirt rotation.
- Vertical plumbness tolerance for column erection is set at 1 in 1000 of the height, or a maximum of 25 mm as per ASME Section VIII.
- Foundation anchor bolts are torqued in a cross-pattern sequence according to ASME PCC-1 guidelines to prevent uneven stress.

Vessel Erection & Lifting Hookup Schema I

Vessel Erection & Lifting Hookup Schema II



Pre-commissioning Checks and Handover I

Final field testing, cleaning, and documentation requirements prior to start-up.

Pre-commissioning Checks and Handover II

Key Points

- Pump pre-start checks include bearing lubrication, mechanical seal flush plan alignment (e.g. Plan 11/53), and shaft rotation direction (motor solo run).
- Vessels must undergo final internal inspection for cleanliness, tray levelness verification, and demister pad installation.
- Cold and hot alignment reports, torque logs, and field weld NDT records must be compiled into the final installation dossier.
- Piping systems undergo hydrotesting, followed by air blowing or chemical cleaning, before final removal of isolation blinds.

Piping Spool Erection: Workflow & Pre-requisites I

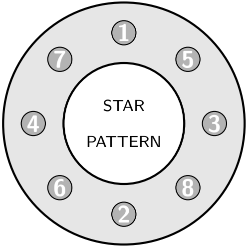
Piping spool erection involves lifting, positioning, aligning, and temporary securing of prefabricated spool sections according to Isometric drawings (Isos) and Piping & Instrumentation Diagrams (P&IDs).

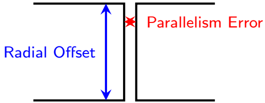
Piping Spool Erection: Workflow & Pre-requisites II

Key Points

- Verify foundation/structural supports are complete, grouted, and inspected before spool placement.
- Inspect spool fabrication records: check non-destructive examination (NDE) clearance, hydro-test reports, and internal cleanliness certificates.
- Use temporary gaskets and fasteners for initial alignment; preserve permanent gaskets (e.g., spiral wound, RTJ) for final bolt-up.
- Apply proper rigging procedures using nylon slings instead of steel wire ropes to prevent damage to coated/alloy surfaces.

Flange Alignment & Bolt Tightening Sequences I





Flange Alignment & Bolt Tightening Sequences II

Key Points

- Flange face parallelism must be within 0.5 mm/m and axial offset should not exceed 1.5 mm under free-state conditions.
- Tighten bolts using a star-pattern sequence in incremental stages (30%, 60%, 100% torque) to ensure uniform gasket compression.
- Verify flange gap alignment before applying torque; never use excessive bolt force to pull misaligned piping together.
- For high-pressure or critical services, use hydraulic tensioners or calibrated torque wrenches based on ASME PCC-1 guidelines.

Piping Supports and Spring Hangers I

Piping supports transfer gravity, thermal, and dynamic loads to the civil structure while permitting designed thermal expansion.

Piping Supports and Spring Hangers II

Key Points

- Types of supports: Rigid (anchors, guides, directional stops) and Flexible (variable and constant effort spring hangers).
- Spring hangers must remain locked using travel stops/pins during erection, pressure testing, and chemical cleaning.
- Unlock spring hangers only during pre-commissioning (hot-alignment stage) and verify cold settings match the piping design.
- Check that sliding supports (e.g., PTFE or graphite pads) are clean, properly aligned, and have sufficient clearance for slide travel.

Mechanical Clearance & Punch List Management I

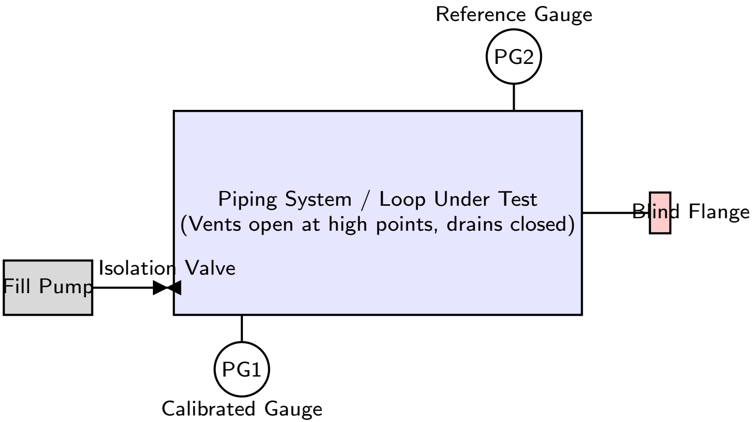
Mechanical clearance signifies that the physical construction of a piping system is complete, verified against drawings, and ready for pressure testing.

Mechanical Clearance & Punch List Management II

Key Points

- Establish a structured Punch List system categorized into Category A (critical for safety/testing) and Category B (can be resolved post-test).
- Verify all permanent supports, guides, and anchors are installed in accordance with the support drawings.
- Ensure flow direction of check valves, control valves, globe valves, and strainers matches the P&ID process flow.
- Confirm vents are provided at high points (for air displacement during hydro-test) and drains at low points (for complete dewatering).

Hydrostatic Pressure Testing Setup I



Hydrostatic Pressure Testing Setup II

Key Points

- Hydrostatic testing must be performed at minimum 1.5 times the design pressure (ASME B31.3) or as specified by the engineering spec.
- Use two calibrated pressure gauges (one at the lowest point, one at the highest point) to monitor pressure changes accurately.
- Hold test pressure for a minimum of 10 minutes, followed by a thorough inspection of all joints, welds, and connections at design pressure.
- Ensure testing medium temperature is compatible with the piping material to prevent brittle fracture; use demineralized water for stainless steel to prevent chloride stress corrosion cracking.

Pre-Commissioning: Flushing, Blowing, and Reinstatement I

Pre-commissioning prepares the piping system for operational fluids by removing construction debris, dust, slag, and temporary test components.

Pre-Commissioning: Flushing, Blowing, and Reinstatement II

Key Points

- Perform water flushing or air blowing at velocities sufficient to dislodge loose scale and debris (typically min 3 m/s for water).
- Use steam blowing for high-pressure steam lines, employing target plates to check for particle impingement before turbine connection.
- Reinstate the system: remove temporary blinds, replace test gaskets with permanent ones, reinstall control valves, flow orifices, and strainers.
- Conduct a nitrogen purge or helium leak test on systems carrying toxic or flammable media to guarantee zero leak emissions.

Commissioning of Process Plant I

Commissioning is the final phase where the plant is brought from a static state to dynamic operation, culminating in performance testing and handover.

Commissioning of Process Plant II

Key Points

- Stages include mechanical completion, pre-commissioning (dry runs/cold tests), commissioning (hot trials/introducing feed), and start-up.
- Perform loop checking of all instruments, DCS interlocks, and emergency shutdown systems (ESD) prior to feedstock introduction.
- Establish a tight nitrogen blanket and complete oxygen exclusion protocols for hydrocarbon-processing units to avoid explosive mixtures.
- Conduct dynamic trials of rotary equipment (pumps, compressors) to verify shaft alignment under operating thermal conditions.