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| KLM Technology Group<br><br>Practical Engineering Guidelines for Processing Plant Solutions | KLM Technology Group<br><br>Engineering Solutions<br><br>www.klmtechgroup.com | Page : 1 of 79<br><br>Rev: 01<br><br>Rev 01 Sept 2016 |
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## INTRODUCTION

### Scope

Every year people at work are injured, sometimes fatally, when a plant or piece of equpment is inadvertently activated. The unexpected energizing, start-up or release of stored energy during operation, servicing or maintenance work (e.g. inspection, repair, adjustment, cleaning), on machinery or equipment can lead to serious worker injuries. These injuries can be prevented by introducing and following correct isolation of plant procedures. It can prevent accidental release or transmission of energy.

All equipment and machinery shall be locked out and/or tagged out to protect employees against accidental or inadvertent operation during any servicing or maintenance activity. Lockout is the best and preferred method of isolating machines or equipment from energy sources and shall be used whenever possible. If a tagout system is used without a lock, additional steps (e.g. removal of an isolating circuit element, blocking of a controlling switch, opening of an extra disconnecting device, or the removal of a valve handle) shall be taken as may be necessary to provide the equivalent safety available from the use of a lockout device.

Lockout is always the preferred method of isolating machines or equipment from energy sources. However, when equipment is not capable of being locked out, proper tags maybe utilized with nylon/plastic lock-straps. The straps will be destroyed upon completion of the project and reactivation of the equipment

The safe and environmentally friendly commissioning of any new asset should always be of the highest priority and integral with every check-sheet and procedure written during the preparation and execution of the commissioning process. The safety of personnel plus the environmental implication must always be the first considerations of any commissioning activity and as such the documentation therefore must address and satisfy all the safety and environmental aspects at all times.

## General Design Consideration

Every year people at work are injured, sometimes fatally, when plant is inadvertently activated. The unexpected energizing, start-up or release of stored energy during operation, servicing or maintenance work (e.g. inspection, repair, adjustment, cleaning), on machinery or equipment can lead to serious worker injuries. These injuries can be prevented by introducing and following correct isolation of plant procedures. It can prevent accidental release or transmission of energy. In general, the standard requires that all energy sources for equipment be turned off, isolated (disconnected), and physically locked out. Bleeding, relieving, or blocking other stored and residual energy must also be done to achieve zero energy state.

The appropriate procedures must be implemented to deactivate the specific machine or equipment, to isolate it from its energy source, and to lock and tag out the energy isolating device (e.g. breaker, switch, valve, blocks, disconnect switch). Before any plant is inspected, repaired, maintained or cleaned it must, where practicable, be shut down and its energy sources locked out and tagged as part of an isolation procedure to ensure the safety of those doing the work. Finally, the last important function before service begins is to verify all energy has been deenergized and/or isolated.

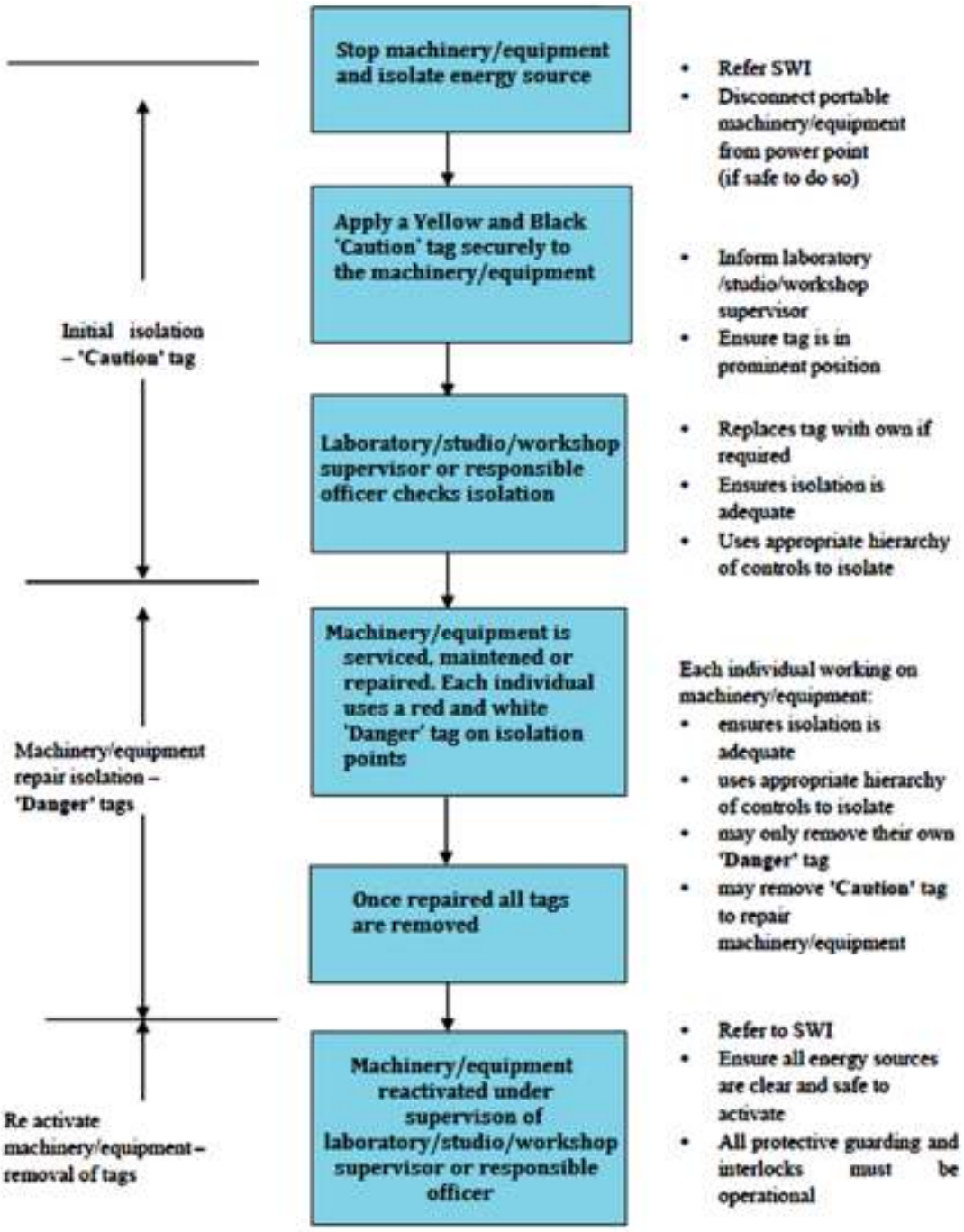


Figure 1: Flow chart for the isolation of machinery/equipment

If the condition of the equipment is considered unsafe it must be removed from service to prevent injury to staff, student and contractors. The following process should be followed to remove equipment from service:

- If safe to do so, stop equipment and isolate each energy source according to Safe Work Instructions (SWI) or isolation documentation for the equipment;
- Physical isolation, e.g. locking devices, cutting power cords, removal from service, must be put in place for equipment that presents a high risk to safety if used;
- A yellow & black, 'Caution', isolation tag must be completed, signed and secured to each isolation device at a prominent position. The laboratory/studio/workshop supervisor or responsible officer must be notified of the equipment failure and isolation;
- The laboratory/studio/workshop supervisor or responsible officer must check that machinery/equipment is isolated effectively and is de-energized for safe repair, service or maintenance work
- It is good practice to communicate to relevant personnel that the equipment is out of service and why; and
- The 'Caution' tag must remain on the equipment until equipment is fully repaired and ready to be re-energized.
- Machinery/equipment may then undergo repair, service or maintenance work by competent service providers or authorized personnel. These personnel must securely apply a completed and signed white & red 'Danger' tag and isolation device to each isolated energy source.
- A 'Danger' tag may only be removed by the person who applied and signed the tag, unless in an emergency.
- Until all tags are removed, the machinery/equipment must remain out of service. Once removed, any tags must be destroyed and not reused.
- Re-energizing of the machinery/equipment or section must be performed according to the reactivation procedure of the machinery/equipment or under the supervision of the laboratory/studio/workshop supervisor or responsible officer, ensuring all energy sources are clear, safe to activate and that protective guarding or interlocks are operational

The basic principle of isolation aim is to

- isolate all forms of potentially hazardous energy to ensure that an accidental release of hazardous energy does not occur;
- control all other hazards to those doing the work; and
- ensure that entry to a restricted area is tightly controlled.

**Basic isolation procedure**

An isolation procedure is a set of predetermined steps that must be followed to ensure that plant and related hazards cannot jeopardize the safety of those working on the plant.

There must be an isolation procedure for each item of plant, including the application of isolation devices, locks and tags, as practicable.

1. Identify the plant involved and the corresponding energy sources.
2. Identify all other hazards.
3. Shut the plant down.
4. De-energize all stored energy sources.
5. Isolate and lock out all energy sources.
6. Tag plant controls, energy sources and other potential hazards.
7. Control other potential hazards.
8. Test by ‘trying’ to re-activate the plant, without exposing the tester or others to risk, to ensure isolation procedures have been effective, before commencing any maintenance, cleaning, inspection or repairs on the plant.
9. Carry out the work on the plant.
10. Once remedial work is complete, the people who tagged the controls are to remove the tags before the plant is returned to operational status.

Written isolation procedures should be developed where plant is combined with other machinery or equipment and may involve different processes, hazards or power sources. Only people with the right skills should develop these procedures. The procedures should be developed in consultation with safety and health representatives, people doing adjustments, cleaning, maintenance, repairs or inspections and, if possible, plant manufacturers, suppliers and people who designed and installed the plant. Where practical, people experienced in operating the plant should also be consulted.

The effectiveness of isolation procedures relies on providing workers involved with the plant with information, instruction and training, and appointing an authorized person to supervise and ensure isolation procedures are rigorously applied. The isolation procedure should be displayed in a prominent position on or adjacent to the plant where possible.

## Commissioning

The safe and environmentally friendly commissioning of any new asset should always be of the highest priority and integral with every check-sheet and procedure written during the preparation and execution of the commissioning process. The safety of personnel plus the environmental implication must always be the first considerations of any commissioning activity and as such the documentation therefore must address and satisfy all the safety and environmental aspects at all times.

Commissioning shall refer to the process whereby equipment and systems are verified to meet functional specifications as control and responsibility are transferred from project or non-operational status to operational status in the following types of projects;

- Capital projects
- Major equipment assembly (new)
- Significant changes to operating facilities
- Restarting a mothballed process
- Post-turnaround start-up
- Start-up after major maintenance activity/rebuilds

Commissioning can fall under the jurisdiction of either the Project Manager or the Operating Unit depending on the application and needs to be determined by the

Project/Area Manager. Typically commissioning planning and execution will also include equipment vendor support.

A successful plant commission has at least three parts, which out which cannot be considered a success.

1. No Loss Time Accidents. No commissioning can be considered a success if it is not done safely. Safety has to be stressed from the very beginning of the design, construction and commissioning.
2. No equipment damage – this function of many disciplines, design, construction and commissioning team.
3. On-test product within a reasonable period. Less than two days would be considered very good, seven days would be acceptable, and above fourteen days would be less than acceptable.

Safe systems of work should be integral to all commissioning activities and procedures. The utmost care will be given to avoid a loss of process containment or environmental incident. The commissioning organization should be robust enough to establish or contribute to the development of safe systems of work at the work location if not already established. These safe systems of work may include permit to work systems, confined space entry permits and hot work permits.

Commissioning is best described when broken into three categories:

1. Pre-commissioning, activities carried out during construction that prepare and enable the unit to move to the main commissioning phase. The range of pre-commissioning activities include: installation of filters, packing of distillation columns, filling a reactor with catalyst, cleaning pipes and equipment, vendor and factory acceptance testing, punch listing and instrument, electrical and motor loop testing.
2. Commissioning, here the various systems and items of equipment are first put into initial operation. Utility systems, instrument air, cooling water and general purpose water are made live and the core process systems are first made operational, typically with safe chemicals, air or water. The unit is leak tested, started up, shut down, distillation columns and scrubbing columns put into use, all to gain the confidence that when process chemicals are introduced the plant will operate as designed and intended.

3. Start-up, the plant is brought into actual operation.

There are also two commissioning terms that are readily used which require explanation

1. Dry Commissioning. Tests and procedures that are conducted where there is no process or safe chemicals yet introduced to the plant. Examples of these activities would be interlock and emergency shutdown tests, control system sequence checks and potentially initial running of major motors and/or equipment and ancillary systems, such as compressor oil lubrications systems, uncoupled from the turning mechanism.
2. Wet Commissioning. Water or some other relatively safe medium has been introduced to the process and initial commissioning of the system and its major plant items can be undertaken, putting the process through its operating scenarios to replicate in the most suitable manner possible the normal operation of the unit.

Commissioning consists of several key functions including:

1. Selection of a Commissioning Manager / Lead

2. Assembly and approval of a Commissioning Team

   Making sure the right personnel are in place is also critical. A typical structure for the organization of the commissioning team is shown in Figure .. The Commissioning Team should consist of a cross-functional team representing Operations, Maintenance, Reliability, HSE, the Project, and Equipment Vendors as applicable. All stakeholder groups shall identify a representative responsible for participating in the commissioning process at the request of the Commissioning Manager / Lead.

   The commissioning personnel must make themselves familiar with all site regulatory procedures and works instructions that they may have to consider during the execution of their activities at a particular jobsite. These could include environmental impact assessments, job safety analysis, major job reviews, job method statements, pre-task planning, safe and unsafe acts audits, there are many others. The commissioning manager must ensure that the commissioning team is actively involved with any audit regime that the project has instigated for the purposes of safe construction and commissioning phases.

3. Generation of a Commissioning Plan.

   The Commissioning Plan should also be generated well in advance of actual commissioning activities to allow for adequate preparation. The Commissioning Plan will vary in scope depending on the project and at a minimum the plan should include:

   - Resource Plan (Commissioning Team members)
   - Detailed Scope of Work and Schedule.
   - Custody Tagging, Dry and Cold Testing, Hot and Wet Testing.
   - Field Walk-Thru checklist
   - Pre-Startup Safety Review checklist (see Table…)

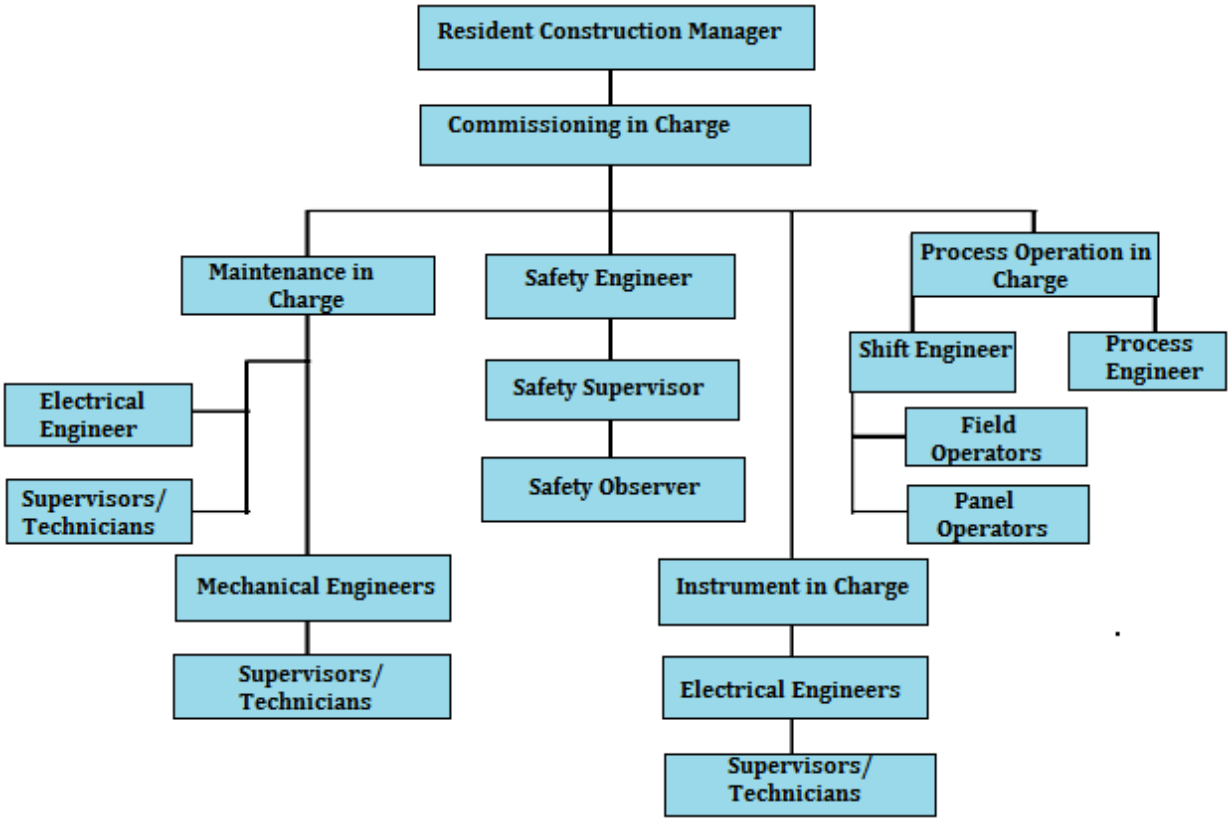


Figure 2: Commissioning Team

Commissioning is divided into three phases

1. Prepare. Activities to be taken to set commissioning up, gather information, select the commissioning team, develop the schedule and create documentation.
2. Implement. This phase, traditionally perceived as “commissioning”, examines the facets that address the installation, checking and start-up of the new equipment.
3. Close-out. The final stage of the commissioning process and the one most neglected, ensuring that all paperwork systems and trials are complete, and that the plant or equipment has met its acceptance criteria, enabling the plant to be handed to the ongoing operations group.

These activities of these phases are summarized in table 1 and figure 3.

Table 1: Commissioning activities (Killcross, 2012)

| PREPARE | IMPLEMENT | CLOSE-OUT |
|---|---|---|
| • Appoint the Commissioning Manager<br>• Define the commissioning scope<br>• Systemize the plant utilizing the project Piping and Instrument Diagrams (P&IDs) and other relevant documents including layout drawings and mechanical flow diagrams, into commissioning systems<br>• Integrate commissioning systems into the engineering documents, line tables, instrument index, P&IDs, equipment lists and procurement plans<br>• Input to design:<br>• The commissioning team upon agreement with the Project Manager and Commissioning Managers will attend the following reviews: P&ID, Piping isometric, Plant Layout, Constructability, 3-D model, Schedule, SIL, LOPA and action | • Attend factory equipment acceptance and pre-delivery tests<br>• Computer Hardware Factory Acceptance Tests (HFAT), Software Factory Acceptance Tests (SFAT), review<br>• Functional Design Specification (FDS) for the DCS<br>• Attend Site Acceptance Tests (SAT) for a DCS control system<br>• Be involved with management and decommissioning and/or decontamination of existing plant if required<br>• Check construction progress and quality<br>• Start commissioning log<br>• Test and clean pipe work<br>• Punch list<br>• Commence training of plant and | • Update to “as commissioned” all commissioning documents and Standard Operating Procedures<br>• Manage post-start-up modifications<br>• Update to “as commissioned” training documents<br>• Run and manage plant to pre-determined design production rates and initial output for the required duration |

| PREPARE | IMPLEMENT | CLOSE-OUT |
|---|---|---|
| upon alarm<br>• Compile the Commissioning Schedule<br>• Compile the Commissioning Estimate/Budget<br>• Agree interface/handover procedure with project, client and construction groups<br>• Obtain pertinent and relevant documents and establish electronic libraries<br>• Attend Hazard Study<br>• Compile Initial Commissioning Plan<br>• Set-up site base and compile commissioning consumables list<br>• Determine initial fill chemicals, simulants and procure<br>• Create Commissioning Manual<br>• Compile Standard Operating Procedures (SOPs)<br>• Compile training packages<br>• Agree Safe Systems of Work with all interested parties<br>• Compile Commissioning Procedures<br>• Give input as required to the User Requirement Specification (URS) for a Distributed Control System (DCS)<br>• Compile Decontamination Procedures | maintenance personnel<br>• Manage handover construction to Commissioning and/or Operations<br>• Attend and/or manage pre-start-up safety checks<br>• Complete all leak testing<br>• Pre-commission the systems<br>• Manage post-start-up modifications<br>• Manage the introduction of safe and process chemicals<br>• Move team to shift management role if required<br>• Issue first draft of the Standard Operating Procedures (SOPs)<br>• Start-up plant<br>• Validate plant performance with the Quality Team | |

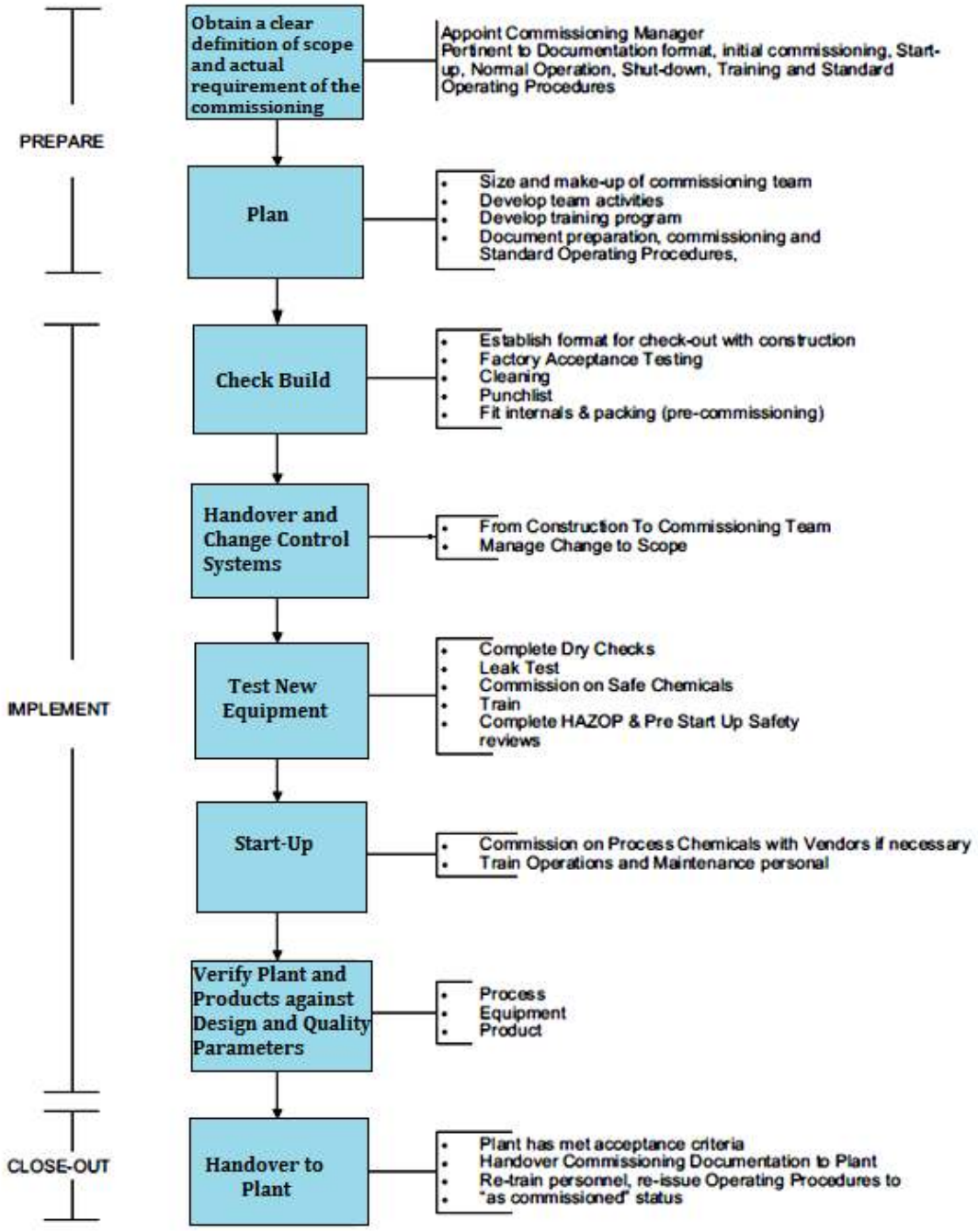


Figure 3: Overview of Commissioning Stages

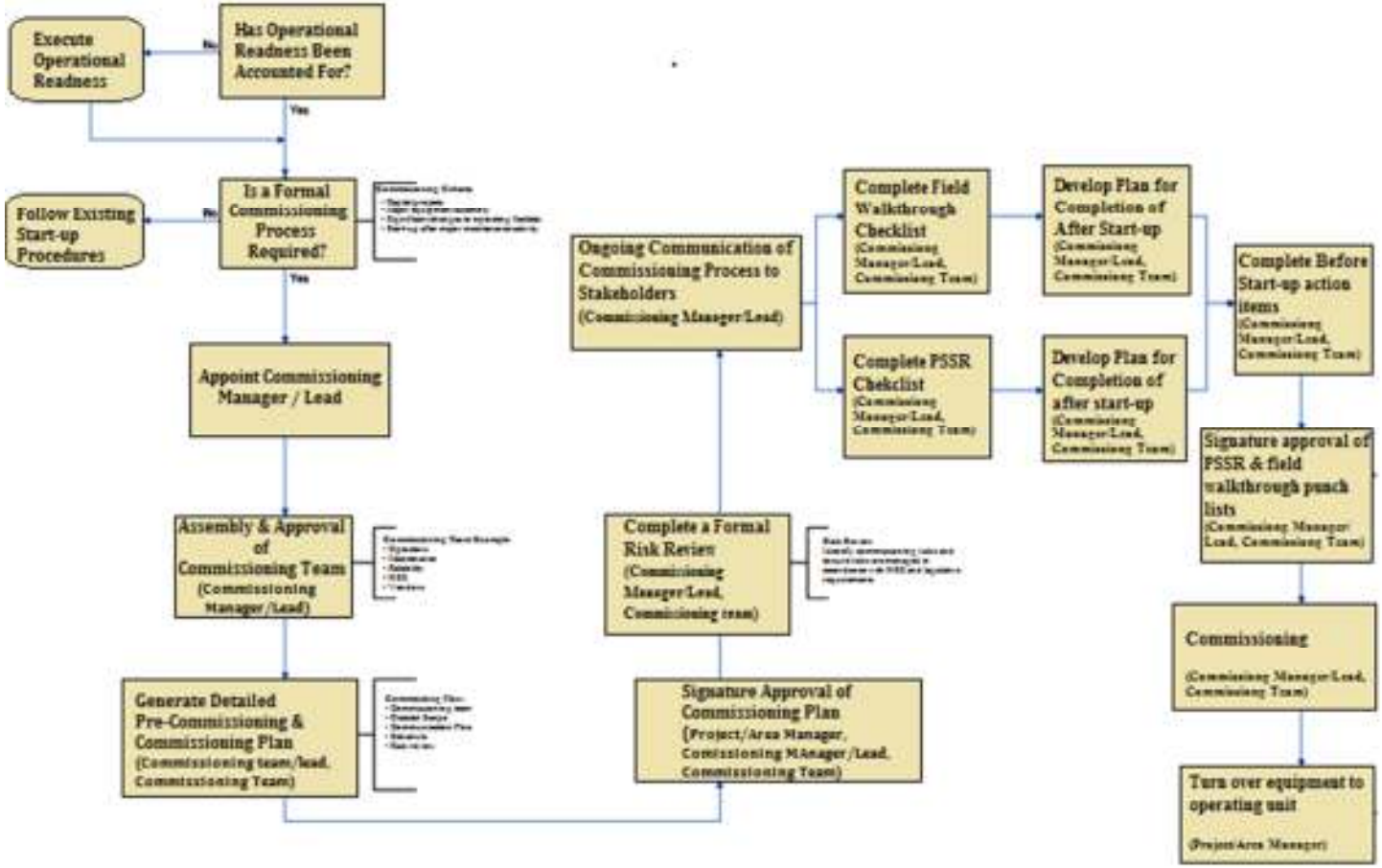


Figure 4: Commissioning Process Flow Diagram

## DEFINITIONS

**Affected Employee** - an employee whose job requires him/her to operate or use a machine/equipment on which servicing or maintenance is being performed under lockout or tagout. Affected Employees must receive training on the purpose and use of the energy control procedure.

**Authorized Employee** - an employee who locks out or tags out machines or equipment in order to perform servicing or maintenance on that machine or equipment. Authorized Employees must receive training on the recognition of applicable hazardous energy sources, the type, and magnitude of the energy available in the workplace, and the methods and means necessary for energy isolation and control.

**Caution tag** - a yellow and black tag that is used to indicate out of service equipment. The tag may be removed by appropriate service people, technical staff, or supervisor once the equipment is deemed safe and fit for purposes.

**Commissioning** - a verification process used to confirm that a facility has been designed, procured, fabricated, installed, tested, and prepared for operation in accordance with design drawings and specifications.

**Dry Commissioning** - Tests and procedures that are conducted where there is no process or safe chemicals yet introduced to the plant

**Danger tag** - a red, white and black tag that is used to warn people of the danger to an individual working on the equipment. It can only be removed by the personnel who placed and signed the tag.

**Energy source** - any form of energy that has the potential to damage property, injure or kill personnel. Energy sources may be in the following form: electrical, mechanical, hydraulic, pneumatic, chemical, thermal, gravitational, radiation, and other forms of stored or kinetic energy. Isolation of energy source is preferred both locally and at the source of the energy where practicable.

**Equipment** - defined as a system or device for doing work together with a power source and any associated auxiliary equipment. This includes pressure equipment, powered equipment, hoists, powered mobile plant, lasers, turbines, explosive-powered tools, scaffolds and temporary access equipment in laboratories, studios and workshops.

**Equipment isolation** - the isolation and safe removal of the energy sources from an item of equipment in such a way as to prevent the possibility of inadvertent energising of the whole or specified section of the equipment

**Isolation devices** - used to prevent energy from re-entering equipment during repair and servicing. They include locks, clasps, tags, closing and blanking devices, removal of mechanical linkages, blocks, slings, and removal from service.

**Lockout** - The placement of a lockout device on an energy isolating device, in accordance with an established procedure, ensures that the energy isolating device and the equipment being controlled cannot be operated until the lockout device is removed.

**Lock-out device** - a locking device that provides a means for rendering a switch, valve, or any energy source inoperable. The device may be a padlock, chain, or any device that positively prevents a machine or piece of equipment from becoming "energized" or from releasing stored energy.

**Maintenance and Repair** - Workplace activities such as constructing, installing, setting up, adjusting, inspecting, modifying, and maintaining machines or equipment. These activities include but are not limited to lubrication, cleaning of machines or equipment and making adjustments or tool changes, where the employee may be exposed to the unexpected start-up of the equipment or release of hazardous energy.

**Mechanical Completion of systems** - all installation works of the system have been completed in accordance with approved construction drawings, approved specifications, applicable code as defined in the bid package and following accepted International good engineering practices and all the activities have been completed in a comprehensive manner.

**Other Employee**- is an employee that may be in the area where lockout/tagout is being applied. Other Employees must be informed of the LOTO procedures being performed in their work areas and must be instructed not to energize equipment being serviced

**Pre-commissioning activities** - those activities which are required to be performed after completion / installation, inspection, hydro testing etc of an equipment / system to make ready for commissioning. This shall include but not be limited to activities such as system checking as per P&ID's, site modifications, internal inspection of tank / equipment / vessel, flushing, air blowing of pipelines including gasket blowing, purging of system using nitrogen, leak test both for low pressure and high pressure systems,

calibration of instruments, checking of the electrical equipment for proper earthing, continuity, insulation resistance, secondary inspection of relays after insulation resistance, conducting operability test on individual equipment / systems, charging of lubes and other chemicals.

**Start-up** - the point in a project where process fluids and conditions are established with the intent of making products

**System** - A section of the plant or facility that can be Pre-Commissioned and commissioned independently, but in parallel, with other sections of the plant or facility under construction.

**Tagout** - the placement of a tagout device on an energy isolating device, in accordance with an established procedure, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed.

**Tag-out device** - a means of identifying who locked out the machinery, the date and time of day the lockout took place, and the department for which the person works. Tags must be durable and be securely fastened to the locking mechanism so as not to fall off.

**Zero Mechanical State -** The mechanical potential energy of all portions of the equipment or machine is set so that the opening of pipes, tubes, hoses or actuation of any valve, lever or button, will not produce a movement which could cause injury

## THEORY

### The Lockout/Tagout LOTO

The Lockout/Tagout (LOTO) covers the servicing and maintenance of machines and equipment in which the unexpected startup of the machines or equipment, or release of stored energy could cause injury to employees. Machines that start up unexpectedly while being serviced can cause severe injury or even death. Energy sources may include: electrical, mechanical, hydraulic, pneumatic, chemical, nuclear, thermal, or other energy.

“Lockout” is the placement of a locking device on an energy isolation device (circuit breaker, slide gate, line valve, switch, etc.) to insure the energy isolating device and equipment being controlled, cannot be operated until the lockout device is removed. A lockout device utilizes a positive means such as a lock (key or combination type) to hold an energy isolating device in a safe position and prevent the energization of a machine or equipment. The lockout device must be substantial enough to prevent removal without use of excessive force or unusual techniques.

“Tag out” is the placement of a tag out device (a tag or other prominent warning device and a means of attachment) on an energy isolation device to indicate the energy isolating device and equipment being controlled may not be operated until the tag out device is removed.

Below are the difference of lockout and tagout device

Lockout Devices

- A “lockout device” is a device that uses a positive means such as a lock to hold an energy isolating device in a safe position to prevent the energizing of a machine or piece of equipment
- Only authorized employees can affix lockout devices
- Lockout devices must be able to hold energy isolation devices in a “safe” or “off” position
- An energy isolating device is “capable of being locked out” if

- it has a hasp or other means to attach a lock
- it has a built in locking mechanism
- it does not have to be dismantled or rebuilt to achieve lockout

Tagout Devices

- A “tagout device” is a prominent warning device, such as a tag and a means of attachment, which can be securely fastened to an energy isolating device in accordance with an established procedure, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed
- Only authorized employees can affix tagout devices
- Tagout devices must be affixed in such a manner as will clearly indicate that the moving of energy isolating devices from the “safe” or “off” position is strictly prohibited
- An employer can use a tagout system when

  - When an energy isolating device is not capable of being lockout, or
  - When the employer can demonstrate (prove) that using a tagout system will provide full employee protection.

The lockout device must be used unless the employer can demonstrate that the utilization of a tag out system will provide full employee protection. The tag out device must be non-reusable and attached by hand. The tag out program must provide a level of safety equivalent to a lockout program. Use flow chart below for guidance.