Preparations for Initial Startup of a Process Unit

Here is what to do just after a new plant is built, to make sure it will have a smooth startup

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Work on a chemical project involves basic engineering, detail engineering, procurement, erection, precommissioning and startup. While each of these activities has its own importance, construction and precommissioning are the two crucial activities that determine a smooth startup.

Commissioning of a plant involves all activities from mechanical completion up to the certification of guarantees embodied in the contract between the EPC (engineering procurement and construction) contractor and the owner. In general, the commissioning costs, as a percentage of total plant investment, are:

- 5–10% for established processes
- 10–15% for relatively new processes
- 15–20% for novel processes

In order to ensure that a plant undergoes a smooth startup, it is important that the last phase of mechanical completion and the preparatory activities for commissioning are thoroughly performed. These include such activities as: cleaning, and leak-testing pipelines and vessels; loading lubricants, chemicals and catalysts; installing mechanical seals, and column and vessel internals; removing temporary bracings; aligning rotating equipment; and inerting the system. Other activities include closing (box-up) of columns and vessels, test runs of rotating equipment, drying of fired heaters, calibrating of instrumentation, and performing loop and functional checks. Once these activities are completed, the plant is ready for startup.

These and other procedures for preparing a typical process unit for startup are described below in greater detail. The term "process unit" can have wide range of definitions, depending on the industry; whether it is related to, for instance, petroleum refining, petrochemicals, fertilizers, plastics, pharmaceuticals, oleochemicals, detergents, pulp and paper, paints, metal refining, or beer brewing. While it is not possible to write instructions covering every type of process unit, the guidelines presented here cover typical activities that are required for a broad range of process industries.

Proper planning is essential

The precommissioning and operations personnel should be in touch with the construction staff at an early stage of piping erection in order to establish priorities for mechanical completion. Ideally, when construction activities have achieved about 75% completion, the construction team should be refocused according to the needs of the precommissioning team.

At the outset, the plant should be divided into various sections in the order in which mechanical completion is desired. For example, process gas compressor(s), if any, may have to be test run at a fairly early stage in order to rectify possible problems. Therefore, all process lines and equipment falling in the compressor loop will have to be precommissioned on a priority basis.

Similarly, reactors, which ordinarily have to be filled with catalyst, must normally undergo a drying cycle involving fired heaters. Therefore, equipment and piping included in the catalyst and fired-heater loop also need to be precommissioned at an early stage.

Refrigeration systems, which are used to chill a process stream or product, also fall under this priority category and need to be test-run at an early stage. It is therefore essential that a schedule be prepared, well before the commencement of startup activities. The schedule should take into account those activities that fall on the time-critical path. An example of such a precommissioning schedule is shown in Figure 1.

Personnel needs

Making sure the right personnel are in place is also critical. A typical structure for the organization of the precommissioning team is shown in Figure 2. The team, headed by the precommissioning manager, consists of process engineers who are, in turn, supported by instrumentation, electrical, machinery and piping engineers.

The number of engineers required from each discipline is determined by the scale and complexity of the plant. Vendor representatives for packaged items, such as refrigeration and compressors, also form part of the team and are called upon at appropriate times during test runs of respective packaged units. In addition, the availability of a dedicated skilled-labor force, with necessary tools and proper equipment, is very important to take care of temporary installations, such as replacing control valves by spool pieces, preparing and installing temporary lines, fabricating adaptable fittings for connecting temporary hoses, and similar activities. Typically, such a labor force should consist of welders, gas cutters, grinders, fitters and riggers. Some EPC companies prefer the erection sub-contractor to provide this labor force. However, precommissioning activities require such fabrication work only for temporary purposes. Some companies, therefore, hire such a team from the local market, usually at lower rates than they pay for permanent employees.

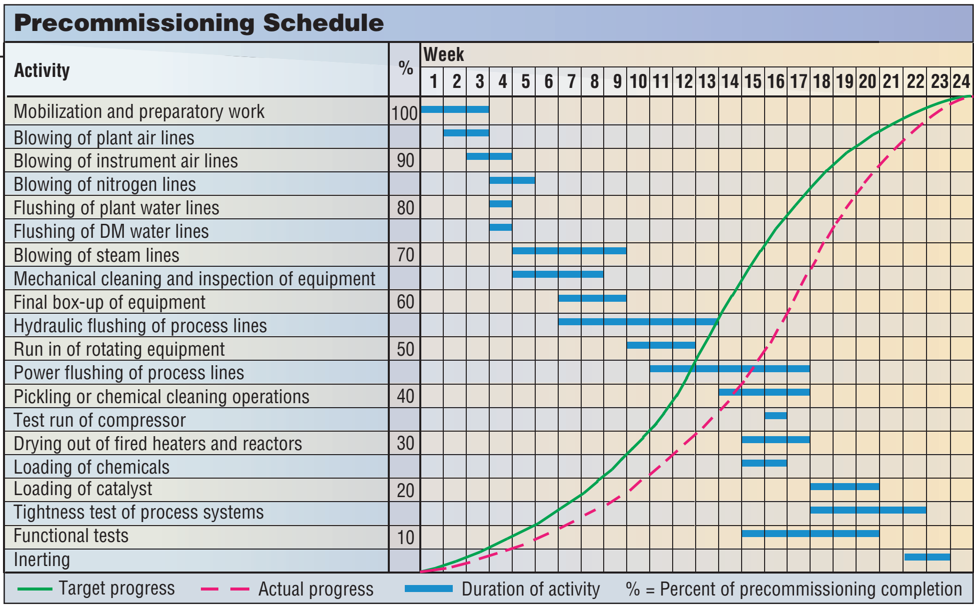

FIGURE 1. Proper planning is essential to make sure the different tasks are performed at the correct time. A schedule, such as the one shown here, should be drawn up in advance

Plant inspection

Before precommissioning operations begin, it is important that all equipment and pipes be thoroughly checked to ensure that they confirm to the detailed P&IDs and the project specifications. In this manner, mistakes committed during construction can be found and rectified. Inspection of the plant can be basically divided into the following areas:

- Personnel and safety
- Vessels and heat exchangers
- Reactors and columns
- Machinery
- Piping
- Electrical and instrumentation

For each of these areas, a checklist of the essentials is provided in the table on pp. 40 and 41. This checklist can be used as a "to do" list before commencing preparations for startup.

Commissioning of utilities

Soon after the plant is constructed, the utilities, such as steam, cooling water, and air, must be put in service. Once steam is available at the battery limits, the steam system can be warmed up and blown free of all debris. Three different categories of steam blowing are used, depending on the lines involved:

- For steam-tracing lines and hose stations, blowing steam through once (the "once-steaming" method) is usually sufficient
- For process-steam lines, the warming up operation is performed gradually, with the steam-supply valve opened by a few turns before every blowing cycle. In each cycle, steam blowing is generally performed for about 10 minutes. Thereafter, the valve is closed and the system allowed to cool for at least an hour. This cycle of warming up, blowing, and cooling down of the pipe, is carried out a number of times, and the repeated expansion and contraction of the pipe causes rust, weld slag or spatter to peel off the pipe surface. This leads to a more effective blowing
- For superheated steam lines that supply steam turbines, the "target-plate" method is applied. In this method, in addition to the heating-blowing-cooling cycle described above, a target plate is installed at the blow-off end, usually after the third cycle. A final blowing cycle is done for 10 minutes after the warming step, and the target plate is removed and inspected. If the number of minute particles deposited per unit area is not below a pre-specified value, the steam blowing must be repeated

Before putting steam into the system, all steam traps, control valves, turbines, heaters, instruments, vacuum ejectors and strainers should be removed or blanked off from the system. Condensate must be drained manually, as it forms, to prevent steam hammering. When blowdown of the steam system is complete, the traps and other equipment that were removed prior to the blow-off may be reconnected. The system is then reheated and placed in service.

Cooling-water lines should be flushed with cooling water, as is discussed in detail below. All condensers, sample coolers, lube oil coolers at pumps, and cooling water to case jackets of rotational equipment should be disconnected from the system. The inlet lines should be flushed one at a time, using flow from the cooling-water pumps. Flushing is next done through the users (the equipment) themselves. Thereafter, flushing is done through the users and through the outlet line from the users. Finally, the return line is flushed.

The plant air lines should be blown thoroughly with plant air. The instrument air lines should be blown with instrument air. Subsequent service testing should be carried out on these lines before putting them into service.

Potable-water lines to eyewash and safety showers and drinking water fountains should be flushed until debris and harmful substances are removed. The drinking water must be analyzed at each point of human consumption to ascertain whether the water is suitable for human consumption.

Regarding the fire-water system, each fire hydrant and turret should be flushed after removing all nozzles. Before flushing the sprinkler systems, all sprinkler heads should be removed. Before reinstallation, the heads should be inspected to ensure that they are clean.

Condensate lines should be cleaned with a strong flow of water from battery limits.

Cleaning lines and equipment

Pipelines must be cleaned to remove any foreign material that may have been left behind during the construction period or formed during piping work. Naturally, generated rust also needs to be removed. Otherwise, debris from uncleaned pipelines can lead to contamination, clogging of pipe or control valves, malfunctioning of equipment, or damage of rotating equipment.

Various types of cleaning methods exist. The common ones are hydraulic-pressure and power flushing, pigging, air blowing or blasting, steam blowing, oil flushing, acid cleaning, alkaline boiling and manual (mechanical) cleaning. One, or a combination, of these methods is applied, depending upon how critical the process is, and other site requirements.

Mechanical cleaning: Initially, equipment that is very dirty may need a round of mechanical cleaning with a wire brush or cloth to ensure that it is free from weld spatters, construction debris, welding rods and so on.

Water flushing and air blowing: After the initial round of mechanical cleaning, piping and equipment should be subjected to flushing or blowing operations, similar to those outlined above for the utility systems. These methods utilize the kinetic energy of a fluid to dislodge foreign materials, such as sand, rust and weld slag. In general, water flushing may be applied at the intake of pumps (usually connected to columns and vessels) as well as the discharge piping, which can be flushed with the pump in operation. It can also be applied to piping and equipment that can be conveniently cleaned by water flowing under gravity, using a water or fire hose. Air blowing can be used where the presence of water is not permitted. Reactors, for example, are items of equipment where air blowing should take preference over water flushing.

For water flushing, any of the following methods may be adopted:

- By injection of huge volumes of water (using any temporary device, such as a hose connection and pump), pipes are water-flushed
- By discharge of water filled in the column, drum, or vessel concerned, pipes connected downstream are water-flushed
- By flushing (with the pump operating with water), pipes connected downstream of the pumps are water-flushed. The pump used for power flushing is a permanently installed piece of equipment

Air blowing, using air from a utility air supply or a temporary compressor, can be carried out in the following ways:

- In the air-accumulation method, a column, drum, or vessel associated with the pipe is filled with compressed air. Then, the pipe at the downstream end is blown out by opening the valve. This procedure is commonly used for instrument-air, plant-air, nitrogen, fuel-gas, hydrocarbon, and cold-service lines
- In the direct-blowing method, the pipe to be air-blown is connected to the air supply source using a temporary pipe or hose. The method often is applied in chemical lines and instrument and plant-air lines
- In large-diameter pipes (8 in. or more), where it is difficult to get sufficient velocities for air blowing, the "cardboard-blasting" method is applied. First, one end of the pipe is covered by a thin polymer film. The pressure is slowly raised by connecting air through a hose or temporary connection. When the film bursts, the shock wave carries the dirt along with it. The blowing or blasting procedure is repeated until foreign particles are no longer visible in the discharge. If necessary, the thickness of the film can be gradually increased so that higher pressures can be used.

Chemical cleaning: For process reasons, certain units demand further cleaning beyond just flushing or blowing. A good example is a butadiene extraction unit. The cleaning operation is usually carried out by circulation of appropriate solutions (described below) through the piping and equipment. Such cleaning is usually subcontracted to specialists. As another example, suction lines of compressors need to be pickled. Pickling of pipes is carried out to remove piping scale, rust, weld slag, spatter and other foreign matter, which might, if dislodged, damage the compressors.

The cleaning procedure begins with a wash of cold water during which, the system is filled with water and circulated. This is followed by a degreasing cycle using measured quantities of caustic soda and detergent solution. In this cycle, oil, grease and lubricants that are insoluble in acid are removed.

An intermediate wash with demineralized (DM) water is then carried out. Then, citric acid and corrosion inhibitor are added to the circulating water. The temperature is raised to 60°C, and the pH is maintained at 3–3.5 by adding ammonia, as required. The circulation is continued and the iron concentration measured every half hour. When the iron concentration stabilizes, the circulation is stopped. The system is then drained under a blanket of nitrogen.

When this cycle has been completed, the system is filled with DM water and circulated. Draining and refilling is continued until the pH is neutral and the iron concentration is less than 100 ppm.

This is followed by a rinse with 0.2% citric acid at 60°C. After stabilization of iron concentration, ammonia is added to the system till the pH is raised to 9.5. Thereafter, sodium nitrite (0.5–1.0%) is added to the circulating solution, and circulation continued for 4–6 hours. The system is then drained under a blanket of N_2 and dried.

Finally, the chemically cleaned surface should be visually inspected. The internal surfaces of pipes and equipment should be uniform and free of deposits. If a steel-gray magnetite coating is observed on the surface, the chemical cleaning is deemed to be complete. The cleaned system should then be pressurized with N_2 and maintained under N_2 until startup.

During chemical cleaning or pickling, care should be taken to ensure that all control valves, orifice plates, venturi meters and other instrumentation are removed and replaced by spool pieces.

Calibration of tanks and silos

Level indicators must be calibrated against the tanks and silos onto which they are mounted, in order to determine the relationship between the level indication and the actual content. For tanks, a measured quantity of water is added stepwise, and the level readings recorded at each step. From the recorded values, a calibration curve is prepared. This calibration procedure also serves the additional function of flushing the vessel with water.

For levels in silos, three different measuring principles can be used: weighing, or capacitive or ultrasonic measurement. When one is using capacitive measurement, the chips used for calibration must correspond to those used later in production. If different material is used, differences in display can be expected later.

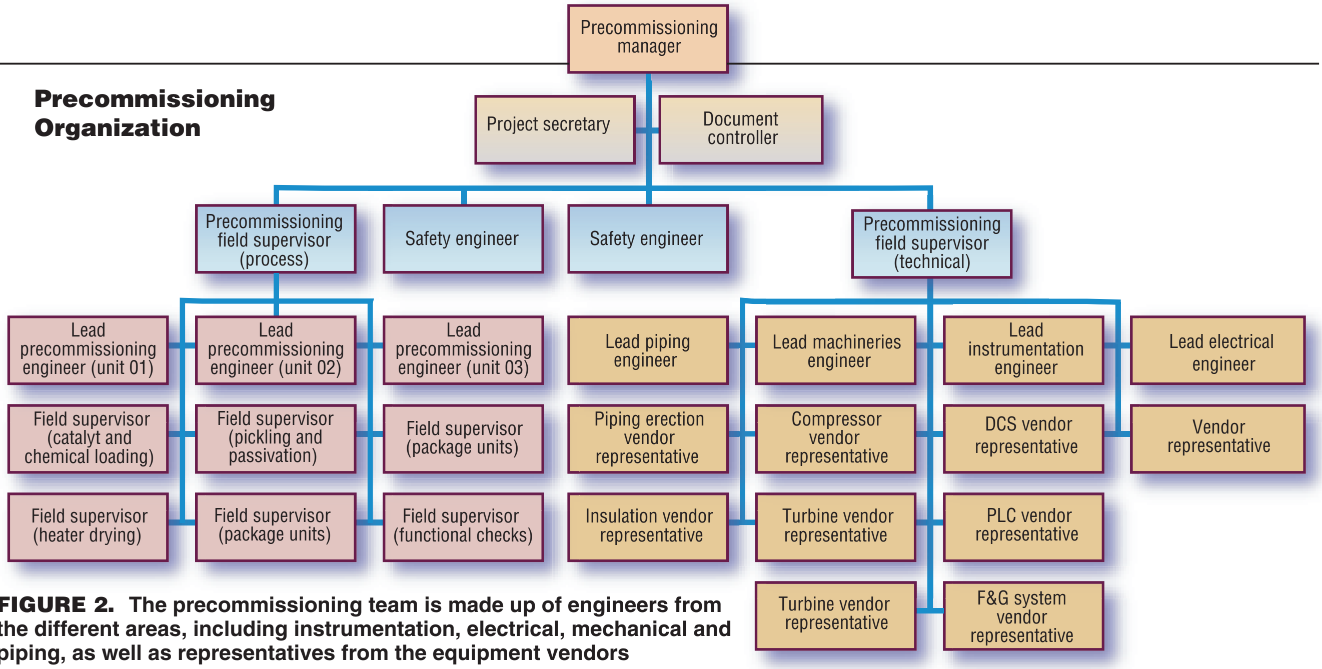

FIGURE 2. **The precommissioning team is made up of engineers from the different areas, including instrumentation, electrical, mechanical and piping, as well as representatives from the equipment vendors**

Inspection and boxup

Process licensors normally like to carry out a check of the column internals, vessels, and heat exchangers before final boxup since these internals are directly linked to their process guarantees. The best time to involve the licensor is immediately after the plant inspection has been carried out by precommissioning personnel, and cleaning of lines and equipment is in progress. The EPC contractor should effectively coordinate with the owner to have licensor's personnel at the site on time, since several activities are linked to each other at this stage. After each piece of equipment is mechanically cleaned, the licensor's personnel are invited to carry out a check of the internals to ensure compliance with specifications. Any errors can be rectified at this stage. Thereafter, the equipment are boxed up and flushing or blowing continued.

Run-in of rotating equipment

Before motors are coupled to their respective drives, they are usually run for three to four hours under the supervision of an electrical specialist to check and verify the machines for smooth operation. The following checks are carried out during mechanical run-in:

- Rotational direction
- Bearing temperature
- Vibration
- Other necessary gage readings

Prior to a unit startup, all centrifugal pumps should be thoroughly checked and, if possible, properly run-in. Test runs of agitators are also carried out at this stage. Often, pumps are used for water flushing of the discharge lines after flushing of the suction line. During that flushing procedure, the pump runs for several minutes, which is often sufficient to serve as the test of the pump. However, one must be aware that many high-head pumps are not designed to pump water. To do so can result in damage to the pump or the motor, or both. Vendor's specifications should be checked before attempting to run-in pumps with water.

Calibration is carried out for metering pumps. At various pump speeds, the pumping rates are measured by the amount of liquid collected in a measuring vessel in a given time, using a stop watch. Calibration curves are generated for pumping rate against the pumping speed.

In plants where handling of solid materials is involved, the conveying equipment, such as belt conveyors, should be given trial runs. If possible, these runs should be made with material, to detect bottlenecks in chutes or other critical points. This work should be started early to avoid unnecessary delays in plant startup.

Other material handling equipment, such as vibrating screens, is also tested at this stage. The usual method begins with starting up the screen, following the manufacturer's instructions. While the material is poured, the product distribution and vibrating behavior are observed, typically over eight hours of operation. Checks are performed to determine whether the product has flowed, via the screen, evenly in the proper direction and that the product conforms to specifications.

Process systems drying

Equipment and piping of the plant may still hold residual water from hydro testing, or moisture if blowing was carried out with air that was not dry. In either case, the moisture needs to be removed, especially from systems where its presence could cause problems during normal operation. Typical examples include refrigeration systems, and carbon steel pipes that handle dry chlorine; beyond a certain humidity, Cl_2 is aggressive to carbon steel, and corrosion becomes rapid.

The plant should be divided into sections and dried sectionwise using instrument air or N_2. Dead corners and line ends should be dried with particular care. In cases where a fired heater is part of the loop, the drying out becomes very effective if a mild firing is maintained so that the hot air is available.

Furnace drying

Furnaces need to be dried in order to remove water or moisture trapped inside the refractories. This excess moisture can be slowly expelled from the insulating concrete or refractory by gradually raising its temperature before any appreciable load is put on the heater. This work must be done with extreme care to be assured of a long heater life with minimum maintenance.

Before commissioning the fuel-gas lines, the furnace firebox must be thoroughly purged with steam until a steady plume of steam can be seen rising out of the stack. Thereafter, a gas-

TABLE. CHECK LIST FOR PLANT INSPECTION

	Personnel Safety	Vessels/Heat Exchangers	Columns/Reactors
1.0	Medical checkup of all site personnel prior to commencement of work	General cleanliness	General cleanliness
2.0	Copies of accident prevention regulations are available	Internal baffles: type, orientation, levelness	Column trays level
3.0	First aid kits are available	Dip pipes correctly installed	All internals proper fit
4.0	Emergency telephone numbers for accidents, fire, etc. are displayed at important places	Vortex breakers as per specifications	Trays liquid tight
5.0	Fire extinguishers available	Demisters correctly installed	Type and height of packings correct
6.0	Necessary safety clothing used by all personnel at site	Location and orientation of instrument nozzles verified	All boltings and clips tight
7.0	All necessary safety equipment available	Insides of tubes inspected to check possible fouling	Catalyst bed correct height
8.0	Guidelines for handling of dangerous materials are available	Motor switches located near exchangers for air coolers	Feed pipe or distributor direction/orientation correct
9.0	Procedure for issue of work permits agreed with owner	Proper motor rotation	Type and size of vortex breakers correct
10.0	Make spark-free tools available at site	Tube fin surfaces in good condition with no construction debris	Distributor trays leak tested
11.0	Gas and fire alarm systems functioning properly	For water-cooled exchangers, checked for location of thermal-relief valve, vent and drain inside the outlet block valve	Support plates securely fastened
12.0	Area demarcated for precommissioning and commissioning cordoned off	Instrumentation easily accessible from grade	Valve caps and other contact devices move freely
13.0	Safety and eye wash showers functioning properly	Drains connected to safe location	Instrumentation easily accessible from grade
14.0	All gratings firmly anchored	Relief valves bench tested and correctly installed	Drains connected to safe location
15.0	All construction debris removed from site	Insulation provided as specified	Relief valves bench tested and installed correctly

free test is carried out before lighting the pilot burners.

After the pilot burners are lit, the arch temperature is raised to 120°C at the rate of 25°C per hour by lighting a few main burners. The temperature is held at 120°C for about 24 hours. The temperature is next increased to 200°C at the rate of 25°C per hour and held for about 12 hours. At this temperature, steam, air or N_2 is circulated through all process tubes in order to prevent overheating. Thereafter, the temperature is increased to 400°C and held for 24 hours. Finally, the temperature is increased to 500°C and held for 12 hours.

During the dry-out period, the operation of the burners is rotated frequently in order to distribute the heat evenly. Further, during the final dry-out period, it is advisable to try out all instruments and controllers on automatic control and see that all alarms, warnings, and other safety features are functioning properly.

At the end of the dry-out period, the temperature is reduced at a rate of 50°C per hour. Flow through the tubes is also reduced. At temperatures of about 200°C, the firing may be cut off and the fuel-gas lines are blinded. When the firebox is cool enough, the refractory is inspected for any signs of failure.

Loading of catalysts

Some process licensors prefer to be present to supervise the loading of the catalyst. Generally two types of catalyst loading are followed, namely, low-density and high-density.

Low-density catalyst loading: A stationary hopper fitted with a slide valve is mounted on top of the reactor manhole. Fitted to the hopper is a canvas sleeve that extends down to the reactor bottom. A mobile hopper that can contain three or four drums of the catalyst is kept at ground level and is lifted by a crane to the top of the stationary hopper and its contents emptied. First, inert balls are added to the bottom of the reactor through a canvas sleeve. Thereafter, the catalyst is introduced into the reactor. For large reactors, a person is stationed inside the reactor who ensures that the correct levels are maintained and that the levels of the bed are uniform. As the catalyst height builds up inside the reactor, the length of the canvas sleeve is progressively reduced by chopping off the extra portion. Once the lower bed is complete, distributors and other internals are installed and the procedure is repeated for successive beds.

High-density loading: The loading method described above is the technique most industries follow. However, catalysts can be loaded using a high-density loading technique, which enables operators to load, in a given volume, a higher quantity of catalyst. A transportable kit is used, which consists of a rotating distributor that is introduced into the reactor from the top flange. The function of the distributor is to sprinkle catalyst evenly over the bed, allowing it to be distributed uniformly on the surface. This more uniform distribution reduces the risk of channeling.

Technical audit, plant handover

The concept of a technical audit has become popular nowadays when large projects are handled on the basis of lump-sum-turnkey contracts. Before handing over a plant to the owner, the contractor is required to offer various sections of the plant (normally in the order of their completion) to the owner for an audit. In the course of this audit, the owner's personnel carry out a thorough check of the unit before taking over. The check is mainly carried out with respect to the P&IDs. In addition,

Piping	Machinery	Electrical/Instrumentation
Correct gasket types installed	NPSH requirements met	Control system configuration correct
Insulation provided as specified	Discharge-pressure guage readable from discharge-block valve	Instruments correctly located
Steam/electrical tracing provided as specified	Suction strainer easily removable for cleaning	Flow instruments and control control valves correctly installed
Check valves installed in correct flow direction	Minimum flow bypass provided if required	Measuring ranges and scales correct
Slopes provided as per requirements	Check valves installed in correct direction	Temperature sensors have correct length
Requirement of no pockets adhered to as specified	Venting and draining the pump casing adequate	Orifice plates have correct bore diameter and installed in correct direction
Insulation provided as per specification	All drains and vents routed to safe location	Interlock sysyems checked
Field instruments visible from grade	Pulsation dampeners provided for reciprocating pumps	Emergency shutdown systems checked
Valves to be operated accessible from grade	Relief valves provided for reciprocating pumps	Functional checks carried out
Pressure relief valves bench teated and correctly mounted	Warm-up lines provided across discharge check valve when pumping hot liquids	Analysers calibrated
Vents and drains properly located	Suction/discharge valves and auxilliary piping and controls easily accessible and operable	Emergency and redundant power supplies checked
Insulation provided wherever required	Pumps and drivers correctly aligned	Insulation, screening, earthing of power lines checked
Piping requirement for special procedures correctly done	Cooling water to mechanical seal (centrifugal pumps) provided with sight flow indicators	Switching devices, motor controls, setting of protection relays checked
Spectacle blinds installed in the correct position	Reciprocating pumps calibrated	Direction of rotation of all electrical drives checked
Locked open/closed valves locked in proper position	Alignment properly performed	Lightening protection and grounding systems checked

they also check compliance with all relevant specifications with respect to piping, instrumentation, electrical, and structural requirements. Following an audit, the owner generates a list of whatever defects, or areas of noncompliance with respect to specifications, were discovered during the audit. At this stage, defects (if any) are normally minor. For example, undersized studs or bolts may have been used occasionally in some equipment, or the painting may not be correct, or a check valve may have been mounted in the reverse direction. The contractor should rectify any errors, after which, the owner performs a final check. Once the owner is satisfied, the audit is considered complete.

Tightness test

Many process units handle combustibles or toxic substances (or both), the leakage of which could result in disaster, damage, or economic loss. To prevent the occurrence of such incidents, it is necessary to confirm that the plant complies with the required tightness before startup. Tightness test can be carried out by one of the following methods:

Air or nitrogen bubble test: In this method, the system is isolated and pressurized with air or N_2 to the test pressure, typically the operating pressure of the component. Possible leaks through flanges, screw connections and valves are checked with a soap solution. Any leaking connections, which show up as tiny bubbles, are retightened until the foam disappears. Normally, such test results are deemed acceptable when the leakage rates fall below the agreed specified value.

Service test: Such tests are performed for all N_2, water, compressed air, and steam piping and equipment with normal operating fluids. The system is first pressurized with operating fluids and then checked for leakage. For air and N_2 lines, leaks can be found using soap solution. For water and condensate lines, the leakage can be observed visually. Leakage points found during the test are retightened. The test is deemed successful if no foam is observed from soap solution, or if no water or condensate is observed visually.

Vacuum hold test: All vacuum systems must be leak tested. Air inside the system is first evacuated to attain the required vacuum. Then, the valve to the vacuum pump is closed and the system's pressure is monitored to determine the leak rate (in millimeters of mercury per hour). If the vacuum loss falls below the agreed specified value, the test is normally deemed accepted.

Tightness testing is usually performed on one section of the unit at a time rather than the whole plant at once. Otherwise it is difficult to pinpoint the source of a leak.

During the leak check, it is important that personnel be organized and ready to document any leaks found. The best way is to start at one end of the section and work through to the other end, checking flanges, valves, fittings, instruments, and other equipment. Each leak is tagged, making it easy for the maintenance team and personnel of the next shift to continue with the work. The maintenance crew should work together with the leak-check team as far as possible.

It is preferable to do the leak check shortly before startup. This minimizes the chances of new leaks developing. for example, after additional maintenance has been performed.

Inerting

This is an activity that is especially required when hazardous process materials, such as hydrocarbons, are involved, to prevent the formation of explosive mixtures. Once a system is mechanically complete and all preliminary checks have been carried out, purging is done to remove air (oxygen) from the system before the introduction of process materials. The following methods are normally used for inerting:

Evacuation and N_2 filling: In this method, air from the system is first evacuated by means of a steam ejector and then N_2 is introduced up to slightly positive pressure. This evacuation-filling cycle is repeated until the system's O_2 content in the system is reduced to acceptable limits.

A simple way to assess this is to place the O_2 monitor inside a clear plastic bag, and attach the bag to one of the vents in the system. A small hole at the end of the bag (which acts like a bellows) lets the purge gas flow through while the O_2 concentration within is monitored.

Steam out: In this method, steam is introduced into the system, with the vent-valves opened, to displace the air. Steam out is continued for four to six hours, depending on the system volume. After this, the steam flow is reduced, the inlet and outlet valves are closed, and N_2 is introduced into the system until the desired pressure is reached. Periodically, any condensate that accumulates is drained.

Pressurization and depressurization: In this method, N_2 is introduced into the system up to a pressure of 1 to 2 barg. The system is allowed to stand for about 30 minutes to allow the gases to homogenize. Then the system is vented (rapidly depressurized) down to a pressure of 0.1–0.2 barg. The cycle is repeated until the O_2 content meets the specifications.

Nitrogen sweeping: In this method, N_2 is continuously introduced from one end of the system or equipment and it displaces the air as it sweeps through the system to the other end. The vent gas is composed of a N_2-air mixture with gradually decreasing O_2 content. The process is stopped when O_2 concentration in the system meets the specifications. This method consumes a large volume of N_2, so it should be used as the last option, especially when the N_2 availability is limited.

Commitment & communication

Aside from the technical issues just discussed, the successful completion and timely handover of a plant to its owner depends upon the following factors:

- Proper selection of team personnel based on qualification and experience
- Preparing written procedures before commencing any precommissioning activity
- Proper emphasis on personnel safety, to minimize accidents and maintain a high team morale
- Proper overlap between the construction and the precommissioning team to avoid repetition of work
- Active interest of members of the management, without overriding the responsibilities of the lead engineers, and providing advisory help wherever necessary
- Holding regular meetings between the EPC contractor's and the owner's personnel regarding the activities planned on a day-to-day basis. This ensures a smooth functioning and unhindered progress
- Effective coordination with licensor personnel, since activities may get delayed if they are not at the site at the right time
- Finally, maintaining a good relation with owner's personnel, to foster good cooperation and a healthy team spirit ■

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