Startup and shutdown of chemical equipment

"Dynamics and Control of Chemical Processes" – Master Degree in Chemical Engineering

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Introduction

- **STARTUP** is the initial procedure of a chemical plant that allows reaching the normal operating conditions. It is possible to classify the following typologies of startup:
  - Dry startup of the empty equipment.
  - Startup of the plant after some maintenance due to a partial shutdown.

- **SHUT DOWN** is the final procedure of a chemical plant that shutdowns the production and takes the plant to the atmospheric conditions in order to inspection and maintain it. It is possible to classify the following typologies of shutdown:
  - Total or Partial shutdown in order to perform ordinary maintenance.
  - Critical (also known as Emergency) shutdown due to malfunction or troublesome.

Introduction

- Why study these procedures?

  More than 20% of accidents occur during the startup and shutdown procedures. In addition, several accidents, which occur during the normal working conditions of the plant, are caused by either thermal or mechanical stresses due to these operations.

- The following issues are quite important:

  1. To save time and money thanks to the optimization of the startup/shutdown procedures.
  2. At the design stage, to devise all the services and dedicated units which are necessary to carry out those procedures.
  3. To train both control-room and field operators.

Introduction

The hazards encountered most frequently in shutdowns and startups of process units are:

1. Mixing of air and hydrocarbons.
2. Contact of water with hot oil.
3. Freezing of residual water in equipment.
4. Corrosive and poisonous liquids and gases.
5. Thermal and mechanical stresses.

These hazards can result in fires, explosions, destructive pressure surges, and other damages to the units, as well as injuries to personnel.

Startup and Shutdown Preparation

- The complete plan for a startup and shutdown should include previous preparation of the process units together with piping, valves, instrumentation, utility lines, and storage vessels.
- The startup and shutdown procedures must be written, formalized, agreed, and strictly followed.
- The critical path (arrow diagram) method has been used in recent years for planning.

Startup and Shutdown Preparation

- Startup and shutdown procedures must incorporate several initial measures, which include:
  1. Preparing adequate operating, startup, shutdown and maintenance procedures.
  2. Ensuring the startup team consists of workers who possess all the skills likely to be required.
  3. Adequately training the startup team, supervisors, and operators.
  4. Proper startup planning.
  5. Securing all the stuff required.
  6. Developing adequate procedures for last-minutes modifications.
  7. Developing individual tasks by members of the procedures team.
  8. Preparing checklist for each phase of the startup.

Operations involved in startup and shutdown procedures

- The startup and shutdown procedures usually include the following operations:

  1. Preliminary preparations.
  2. Cooling and heating.
  3. Pumping out.
  4. Pressurization and depressurization.
  5. Purging.
  6. Blinding and opening.
  7. Inspection for entering.

- The equipment involved in the shutdown and startup procedures should be tested regularly while the units are operative.

1. Preliminary preparations

They are operations performed to prepare units to startup. The objectives are:

- to clear the system of undesirable materials,
- to test the equipment and rectify potential problems,
- to take preventive measures against performance deterioration.

- Usually commissioning operations are performed using available liquids and gases, such as air, nitrogen, steam, water, or oil. This can be problematic because units hardware are designed to work at standard operations (steady state).

- A pre-startup practice is the blowing lines, it consists of flowed some inert substance to remove debris.
  - Line blowing can cause vapor flow rate higher than the design flow rates. This problem is best avoided by calculating expected flow rate in each line before blowing the line and then monitor the flow rate.

1. Preliminary preparations

- It's a good practice to clean the equipment before blow lines into it, some big debris can deposit in the column internal.
- Instrument, except for these that are directly required for monitoring the line-blowing operation, should be disconnected or at least blocked off.
- Any control or trip valves should be removed and replaced by pipe spools.
- It is recommended to blow at velocities of 60m/s.

- Another pre-start-up practise is the leak-test, the most common technique is pressuring the unit up with inert gas, with all vents and drains closed, and monitoring the rate of pressure loss.
  - When leaks are detected, bolt are tightened, if the leaks persist, it may be necessary to depressurize the system and correct the fault. The test continues until no more leaks are detected.
  - Alternative techniques, involve hydrostatic testing of the column or pressuring it up with steam. Steam or water make leak detection easier, but these fluids are more troublesome to use than nitrogen (hydrostatic loads problem).
  - Other techniques use an easily detectable tracer gas.

1. Preliminary preparations

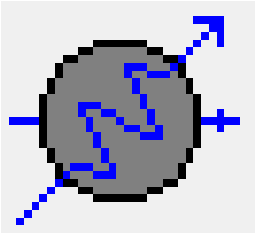
- One more pre-start-up practise is solvent-testing. Its purpose is to run the unit with a solvent, a “safe” fluid, whose properties are close to those of the feed.
  - Select the solvent closer to the process fluid to have a more meaningful test.
  - Pre-test checks must be carried out to ensure that the equipment operating capacity, relief capacity, safe working temperature, and internal supports are adequate for the test.
  - Following the test, the solvent must be removed, if the solvent material is acceptable in the product, removal, it is not necessary.
  - A major advantage of solvent testing is that it allows testing the reliability of instrumentation, alarms, trips, and emergency systems.
  - It is often beneficial for operator training.

2. Cooling and Heating

Cooling and heating are performed in the initial phase, they can be included in the preliminary operations.

A possible way to cool units is to wash them, in addition units are also washed for one of these reasons:

- To remove solids, and corrosion products
- To uncover leaks and check the operation for pumping
- To dissolve undesirable materials
- To coat column internals
- To remove water

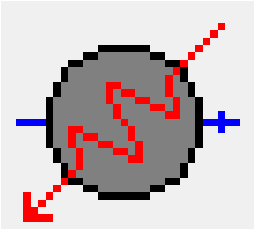


- A water wash is effective for the first three reasons; a chemical wash is used for the last two reasons.
- Washing may come up against resisting debris, a water velocity about 3.6 m/s is recommended.
- Water washing should not be admitted unless the unit is sufficiently cool (less than 90°C).

2. Cooling and Heating

Usually steam is used to heat units, they may be steamed during commissioning to:

- drive out the air.
- Heat the unit.
- Clear blockages.



At shutdown, units are steamed to:

- strip out and drive out residual chemicals.
- Prepare it for operators entry.

- Whenever possible steaming should be replaced by nitrogen purging, even if nitrogen is usually ineffective for heating up the column, vaporizing heavy liquids, or clear blockages.

- The most critical periods for steaming is when steam is introduced into cold units and when steaming is finished.

2. Cooling and Heating

- Before steaming is completed the effectiveness of operation should be checked, it is recommended to continue steaming for 20 to 30 minutes, since a pure flow of dry steam comes out from all vents.

- Steaming should be avoided when an acid solution may form in the unit upon condensation and when the unit contains an explosive mixture (steam may generate static electricity), so firstly it is recommended to purge it with inert gas.

- Steaming may accelerate stress corrosion in carbon steel unit containing residual alkaline solution.

- During shutdown if units contain combustible or pyrophoric deposits or liquids, they should be open to atmosphere only at the conclusion of steaming.

3. Pumping out

- The liquid materials, once cooled to the assigned temperature, should be pumped out of the unit.
- Materials should be routed to suitable storage devices (e.g., vessels, tanks, pools), as a function of their composition, by using dedicated lines/pipes.
- Inert gases or steam should fill in the unit during the pump out operation for two reasons:
  - firstly, to prevent leakages of air into the unit (and possibly enter the explosivity region);
  - secondly, to prevent the collapse of those process units that were not designed to withstand vacuum conditions.

4. Pressurization and depressurization

These operations are performed during commissioning, startup, and shutdown.

- They are used in order to:
  - reach the atmospheric or operative unit pressure.
  - remove air or inert gas.
  - prepare the unit for entry by personnel.

- Pressurization and depressurization should be carried out at a controlled rate, sufficiently slow to avoid unit damage and breakdown.

4. Pressurization and depressurization

- Location of relief valves, bursting disks and major vents should be carefully reviewed. These normally should be at the top of super-atmospheric units and at the bottom for vacuum units.

- Excessive vapor flow rates may cause flooding and gas lifting of the liquid, resulting in a liquid discharge into relief valve (champagne bottle effect).

- Pressurization and depressurization should be done in dry-unit, so it is recommended to drain liquid before starting these operations.

- When the equipment is located between intermediate stages of a compression train, the effect of compressor surging on unit internal should be considered. Bypassing the column during compressor startup often overcomes this problem.

5. Purging

When the unit separates combustible or hazardous materials is usually purged with an inert gas prior to startup, to remove air. Then it may be purged with the process gas to remove the inert gas. The reverse steps are performed at shutdown.

- The unit typology determines the appropriate purging substance.

- Nitrogen is the most common inert gas; steam and carbon dioxide are also used. This because atmospheric condensation of the residual steam can pull a vacuum which may suck air. At shutdown, it is best to purge the column with nitrogen prior to steaming, to eliminate combustibles.

- Purging often requires installation of special purge lines or purge connections, one rule is to size them to deliver a purge gas volume four times the volume of equipment to be purged over 10 hour period.

5. Purging

- Isolation valves should be opened and remain open during the purge period to avoid trapping of liquid or undesirable components.

- In the case of you are working in freezing weather the use of steam and water for purging and for washing during shutdown, can introduce serious hazards.

6. Blinding and Opening

Shutdown blinds and slip plates are usually installed in all lines which leave or enter the unit in order to eliminate leakage of material into the column when air is introduced.

- Extreme caution must be exercised when flanges for blinding or opening are operative, flanges should be open slowly and valves should not be closed until the unit is empty.

- Blinds should be properly tagged , a checklist of them should be made and the sequence of blinding must be planned and defined in the operating procedure, it is mandatory to check the lines prior to start the sequence.

- The pressure, temperature, and the material specifications of each blind should be checked to avoid any inconsistency with the unit or the line.

7. Inspection for entering

There are several precautions recommended and required by law before entering in the unit:

- The officer responsible for safety, before permitting personal entry must:
  - Approve the work procedures and emergency plans.
  - Check that the unit is safe.
  - Ensure that work will be performed under qualified supervision.
  - Sign a written permission to enter into the unit.

- The equipment must be isolated from any chemicals or service lines (by valves is not satisfactory, they can leak) . Any lines connected to the unit must be blinded or fully disconnected. It is a good practise to post a “danger: workers inside the unit” notice. Any electrical equipment or any radiation sources should be removed.

7. Inspection for entering

- Any materials (small quantity of solvent for weld-testing) should be critically examined. Their evaporation may generate an hazardous atmosphere inside.

- The atmosphere inside the unit must be analyzed to contain 19.5 to 23.5 percent of oxygen. The test should be repeated at regular intervals.

- The appropriate Individual Protection Devices must be worn inside the unit at all time to avoid injuries.

- Adequate and reliable lighting must be provided inside the unit.

- A proper communication system must be devised.

Bibliography

- BP Process Safety Series, Safe Ups and Downs for Process Units;