Startup and shutdown of chemical equipment

Davide Manca

Lecture 9 of "Dynamics and Control of Chemical Processes" – Master Degree in Chemical Engineering

POLITECNICO
MILANO 1863

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 inspect and maintain it. It is possible to classify the following typologies of shutdown:
  - **total or partial** shutdown to perform **ordinary** maintenance
  - **critical**, also known as **emergency**, shutdown due to malfunction, trouble, fault, abnormal situation, accident.

Introduction

More than **20%** of accidents occur during the startup or shutdown procedures.

In addition, several **accidents**, which occur during the **normal working conditions** of the plant, are caused by either thermal or mechanical stresses as a **consequence** of these operations.

- The following **issues** are quite important when running the startup/shutdown procedures:

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

Introduction

The hazards that are **most frequently** encountered during the startup/shutdown procedures 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.

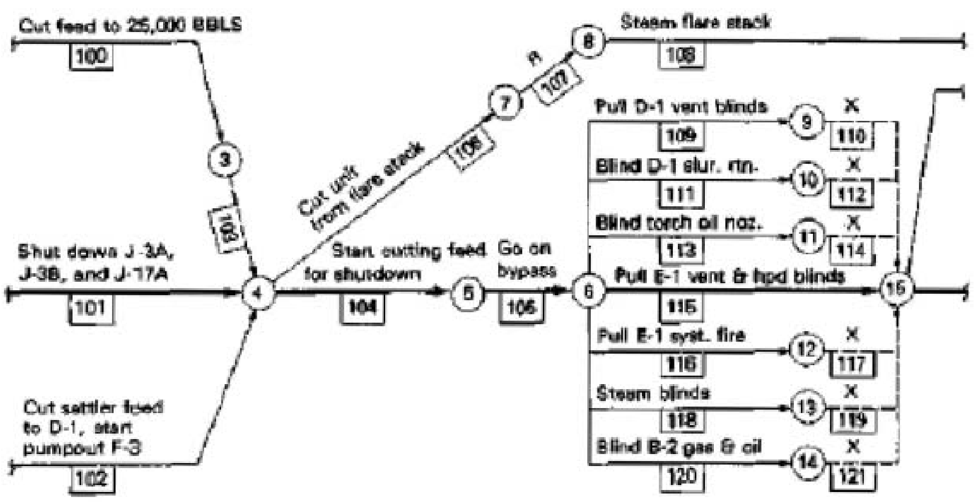

Figure 3 *Portion of a shutdown arrow diagram.*

Startup and Shutdown Preparation

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

Preliminary preparations

- Usually, commissioning operations are performed using **available liquids and gases**, such as air, nitrogen, steam, water, or oil. This may be problematic because process units are designed to work at nominal operating conditions.

Preliminary preparations are operations performed to prepare the process units to the startup/shutdown procedure. The objectives are:

- **to test the equipment and fix potential problems**
- **to take preventive measures against performance deterioration**

Preliminary preparations

- A pre-start-up practise consists in the **leak-test**, the most common technique is **pressuring up the units with inert gas**, with all vents and drains closed, and then monitor the rate of pressure loss.
  - When leaks are detected, bolts are tightened, if the leak persists, 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. Water makes **leak-detection easier**, but is more troublesome to use than nitrogen (hydrostatic loads problem).
  - Other techniques use an easily **detectable tracer gas**.

Preliminary preparations

- Another 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 operating capacity, relief capacity of the equipment, together with safe working temperature, and internal supports are adequate for the test.
  - Following the test, the **solvent must be removed**. However, if the solvent is acceptable/consistent with the final product(s), the removal 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.

Operations involved in shutdown procedures

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

1. Cooling
2. Pumping out
3. Residuals removal
4. Blinding and opening
5. Inspection for entering

1. Elimination of air
2. Tightness testing
3. Elimination of water
4. Bringing the unit onstream

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

1. Cooling

Cooling is performed at the initial phase of shutdown.

A possible way to **cool** the process units is to **wash** them.

In addition, units are also **washed** for one of the following reasons:

1. To remove **solids**, and corrosive products
2. To uncover **leaks** and check the **pumping** operation
3. To **dissolve undesirable materials**
4. To **wet column internals**
5. To **remove water**

- A water wash-up is effective for the first four reasons (1-4)
- A chemical wash-up is used for the last reason (5)
- Washing may help against resisting debris, so it is recommended a **water velocity of about 3.6 m/s.**
- Water washing should not be performed unless the unit is sufficiently cool, i.e. **cooler than 90 °C.**

2. Pumping out

- The **liquid materials**, once cooled to the assigned temperature, should be pumped out of the units.
- Materials should be **routed to some storage devices** (*e.g.*, vessels, tanks, pools) according to **their composition/purity, 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.**

3. Purging to remove residuals

When the process unit **separates combustible or hazardous materials**, they are usually purged with an **inert gas prior to startup, to remove air**. Then the process unit 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 (e.g., steam for distillation/coking units; inert gas for units with catalysts).

- Nitrogen is the most common inert gas; steam and carbon dioxide are also used. At shutdown, it is worth purging 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 hours.

3. Purging to remove residuals

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

- In case of very cold working conditions (*e.g.*, freezing weather) the use of steam or water for purging and washing purposes during shutdown, can introduce serious hazards.

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 damages and breakdowns.**

Pressurization and depressurization

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

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

- Pressurization and depressurization should be performed in **dry-units**, so it is recommended to drain liquid before these operations are carried out.

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

4. Blinding and Opening

Shutdown blinds and **slip plates** are usually installed in all lines which leave or enter the process units 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 opened **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 material specifications** of each **blind** should be checked to avoid any inconsistencies with the process unit or the input/output lines.

5. Inspection for entering

There are several precautions recommended and **required by law** before entering the unit for inspection:

- The officer responsible for safety, before allowing the personal to enter the process unit must:
  - Approve the work procedures and emergency plans
  - Check that the unit is safe
  - Ensure that work will be performed under **qualified** supervision
  - Then they can issue a written permit to inspect the process unit

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

5. Inspection for entering

- Any materials (*e.g.*, small amounts 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 % 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 injury.

- 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