# Phosgene Safety Practices

for design, production and processing

## Part 2

## Key elements of safety practices - long version

## Section 2: Design criteria (basic engineering concepts)

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(Abbreviations and acronyms)


### III caveat

The information herein is presented in good faith, is believed to be accurate and reliable, but may well be incomplete and /or not applicable to all conditions or situations that may be encountered.

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# 2 Design criteria (basic engineering concepts)

## 2.1 Layout concepts

The following considerations are important when designing a plant using or generating phosgene:

- Optimisation of the location of a phosgene generation and processing plant with respect to other occupied areas of the larger overall plant site, the site fence line, any inhabited areas outside the fence line and high traffic areas.
- Consideration of the prevailing wind direction when locating the control room in relation to the phosgene section of the plant.
- Compliance of the plant layout with governmental regulations, company and local site standards and practices and adherence to good engineering practice as related to operation, maintenance, safety and future expansion are important considerations.
- Optimisation of the footprint of the plant sections that generate and process phosgene to minimize both the hazardous area and the phosgene hold-up inventory.
- That critical safety and control functions be remotely operable from safe locations.

## 2.2 Design concepts

Basic safety in this practice guide is the combination of primary followed by secondary measures and is important in the design of safe plant.

Consideration should be given to process conditions and primary and secondary containment (safety layers) to minimize the risk of phosgene being released to the environment.

For the design, consider provisions for all conceivable upset conditions.

### 2.2.1 Process conditions

- **No phosgene inventory:** in continuous processes, advanced process control can eliminate the need for phosgene storage. For batch processes, minimising the phosgene inventory will reduce the risk of a significant release.
- **Temperature and pressure:** elevated pressures and temperatures may potentially increase the amount of phosgene released in case of a leak, but may also reduce the phosgene hold-up in the process. By applying adequate engineering standards combined with appropriate segmentation and dump possibilities, these conditions are manageable.
- **Barrier fluid for heating and cooling**: instead of water / steam consider the use of inert or process-compatible fluids for heating and cooling to exclude the possibility of water getting into the process, resulting in corrosion and other dangerous process conditions. If aqueous media are used additional precautions are needed.
- **Continuous chemical analysis:** Monitoring impurities in raw materials continuously can avoid dangerous process upset conditions.

### 2.2.2 Primary containment - general

Primary containment is the hardware containing phosgene and its solution. Secondary containment is a second layer of protection preventing phosgene from harming people in case any of the primary hardware fails.

Primary containment relates to the hardware of the plant (vessels, towers, exchangers, rotating equipment, piping, instrumentation):

- Careful consideration should be given to the **temperature and pressure ratings** of process equipment, so that even under upset conditions their mechanical integrity is maintained.
- The choice of **materials of construction** is critical because water intrusion into the equipment can lead to severe corrosion and other hazardous conditions.
- To maximize mechanical strength **piping and nozzles** with minimum dimensions are good options. However **tubing** may not have the required strength to be used in phosgene service.
- **Tubing.** Except for analyzer connections, tubing may not have the required strength for phosgene service.
- **Screwed connections** may not be reliable enough to be used in phosgene service. Consider avoiding screwed connections, tubing and fittings in contact with phosgene, as non-threaded process connections provide less potential for leaks.

- **Hoses**, braided or otherwise, may not be reliable enough to be used in phosgene service
- Minimise use of **flanges** as they represent a leak potential.
- **Avoid using expansion joints** as they are subject to fatigue and have a limited life time. Expansion joints (bellows, compensators) can be used only when registered, inspected frequently and replaced following the manufacturer's recommendation regardless of their condition.
- **Avoid using sight glasses** as they are subject to mechanical and thermal stress.
- Minimize the use of **rotating equipment** (pumps, compressors, etc.) and consider gravity flow as an alternative.
- **Seal-less pumps** (magnetically driven or canned motor pumps) are preferred.
- **Valves** of the bellows type with a second barrier are preferred.
- Paint applied to **corrosion sensitive equipment** and piping will slow and reduce external corrosion.
- Regular **wall thickness** tests are recommended.
- Inspect and pressure test all **pressure equipment** at regular intervals to the extent required by state regulations and company requirements.

### 2.2.3 Fabricated equipment

#### 2.2.3.1 Pressure vessels

This section addresses metallic pressure vessels, which are used in non-corrosive applications such as isocyanate and polycarbonate processes.

A pressure vessel is a container designed to hold liquids or gases at either a positive or negative pressure and may be: reactors, ancillary vessels, heat exchangers or other equipment, used under pressure.

Some specific requirements for heat exchangers will be addressed in a separate section.

Vessels made out of plastic materials, which are required due to the corrosive nature of the process, are addressed in a separate section.

**Important considerations:**

- It is recommended that only manufacturers that have been audited and approved to fabricate equipment used in phosgene service be considered.
- It is advisable to design pressure vessels with a minimum number of connections to decrease the number of potential sources of leaks.
- It is important that vessels be designed for the pressure / temperature conditions determined in the process safety and analysis review. Also consider a corrosion allowance added to the calculated wall thickness for the equipment and nozzles.
- Good safety considerations require pressure vessels be protected with a pressure relief device that discharges to a phosgene destruction system in case the design pressure is exceeded.
- A minimal size for all flanged connections of DN 25 mm (1” nominal pipe size (NPS)) or greater (preferably DN 50 mm, 2” NPS) is recommended. Consider all forces applied to the flanged nozzles when designing the vessel.
- Manholes with a minimum diameter of DN 600 mm (24” NPS), preferably above the normal liquid level, will allow access by an individual wearing full respiratory protection if necessary for maintenance etc.
- The following flange facing styles are recommended for flanged body joints or flanged nozzles:
  - Tongue and groove
  - Raised face
  - Flat face
  - Special design (for body flanges only)
- Fabrication: All welds using at least 2 passes and butt welds that are full penetration welds welded with a cap weld pass if possible are optimal. Locating welds where they can be tested with non-destructive examination methods such as radiographic testing is optimal. Minimize the number of hidden welds. When storing equipment for a prolonged period, it is recommended that the item be blanketed with an inert atmosphere.
- Equipment designed for non-phosgene service may not be suitable for use in phosgene service unless rigorously inspected, tested, all of the documentation verified and the equipment formally approved for phosgene service.

- It is important that only materials of construction that are suitable for all process conditions including supplementary conditions such as cleaning using high pressure techniques are used. Vessels made of ductile materials that are capable of retaining their ductile properties at the lowest operating design conditions are optimal.
- Examination and testing: Initial examinations and testing and recurring inspections meeting applicable regulatory and company requirements are optimal with butt welds in contact with phosgene 100% radio-graphed. Good safety practices dictate that all repairs are executed as specified in regulatory and company guidelines, with inspection and testing as required.

#### 2.2.3.2 Heat exchangers

This section applies to all heat exchangers with at least one side in phosgene service. Phosgene generators should also comply with these requirements.

**Important considerations:**

Heat exchangers should follow the same considerations as outlined under section 2.2.3.1 “Pressure vessels” plus

- Special emphasis in the design to prevent tube bundle vibration is important.
- Seamless or certified welded tubes for tube bundle heat exchangers are recommended.
- Avoid expansion joints on the product side of heat exchangers.
- After welding and radiographic testing, it is recommended that the tubes be roller expanded in order to improve mechanical stability, reduce vibrations and prevent gap corrosion on the shell side.

**Protection against corrosion as a consequence of water intrusion into the process:**

- Layout and Design

  The use of tube bundle heat exchangers with conventional double tube sheets is recommended.

- Process Engineering Measures
  - Process pressure greater than that of the cooling water will cause the phosgene to leak into the cooling water rather than vice versa. An online analyzer with alarm function should monitor the pH of the cooling water.
  - Measures taken to assure that the cooling water is not corrosive, such as a closed secondary loop, padded with nitrogen are advisable.
  - Cooling water treatment with a corrosion inhibitor is a good practice.
  - Equipment for monitoring pH and/or conductivity can be installed.
- Monitoring for Water

  Continuous analysis for water on the process side is recommended.

**Air cooled heat exchangers (fin-fans)**

For new installations it is good practice to avoid fin-fans in phosgene service.

#### 2.2.3.3 Rotating equipment

Pumps, compressors, vacuum pumps and agitators are considered rotating equipment. Equipment with no seals (seal less) is preferred.

Canned motor pumps or magnetically driven pumps are the pumps most commonly used. Magnetic drives should be considered for the other equipment.

**Important considerations:**

- **Examination and testing:** It is a good practice to radiograph the "critical areas" of the casting. The critical areas are normally defined as regions of the casting that:
  - Have the highest stress during operation
  - Are most likely to have cast defects such as porosity or inclusions
  - Are areas that have the highest curvature or complexity
  - Are areas next to the flanges

  Consider testing both the internal and external surfaces of the casting using a dye penetration method. A helium leak test of the pump casting is another test to consider.
- **Mechanical seal**: A seal-less canned motor or magnetic drive design is the preferred design for rotating equipment. The use of double mechanical seals may be used but is discouraged since significant instrumentation is required for monitoring and failure cannot be excluded.
- Avoid using equipment with **dead zones** wherever possible. These zones are areas in the equipment, which can trap the process fluid and cannot be easily flushed or cleaned once the equipment is removed for service.
- It is important that the **material of construction** of all process-wetted sections of the pump is known to be compatible with the process conditions.
- It is important that **external auxiliary connections**, which may include drains, vents, bearing flush, valves, etc., are 1-inch nominal pipe size (DN 25) or greater. They should comply with the phosgene piping material specifications.

##### 2.2.3.3.1 Centrifugal pumps

It is important that seal-less magnetic driven / canned motor pumps, have instrumentation to monitor for:

- Bearing flush backflow
- Dead heading
- Dry running of pumps
- Motor winding temperature (canned motor pumps only)
- Excess thrust (canned motor pumps only)

Although seal less pumps are preferred, pumps with mechanical seals may be used with the following considerations:

- Double mechanical seals are a prerequisite if seal-less pumps are not used.

- Avoid using non-purged, single mechanical pusher seals.
- Using a seal buffer fluid circulated between the seal, which is compatible with the process and at a higher pressure than the process pressure, will ensure that any inner mechanical seal leaks will go into the process and not to the environment.
- If you are using a buffer fluid pot, monitoring of the level and pressure of the buffer fluid will indicate a seal leak. Dependent on the seal plan selection, you could do the same with a flow measurement.

#### 2.2.3.3.2 Compressors

Avoid the use of compressors in phosgene service but if necessary special design considerations and instrumentation may be required.

#### 2.2.3.3.3 Vacuum pumps

Liquid ring pumps, operated with a solvent as the seal fluid, are recommended for phosgene service, with the solvent used as the seal fluid compatible with the process conditions. Other requirements are defined in the pump section.

#### 2.2.3.3.4 Agitators

It is important that the mounting flange, considered as part of the tank wall, be made of same materials of construction as the tank.
Other requirements are defined in the pump section.

#### 2.2.3.4 Equipment made of non-metallic materials

**This applies for small scale isocyanate, carbamate and formamate units.**

**General:** Equipment made of non-metallic materials is suitable for handling aqueous liquids with organic components or other services that are corrosive to metallic materials.

Since non-metallic material applications are in a constant state of development, assessment of material for each application including testing of a representative sample under process conditions is recommended.

The temperature rating of lining material is critical.

**Materials of construction:** In order to minimize pipeline forces, avoid nozzles less than DN 50 mm (2" NPS) and minimize the number of flanged connections. Flanged connections with a flat surface designed for elastomeric gaskets are recommended. Consider thermal expansion of the materials when designing the plant.

**Examination and testing:** Consider testing the equipment including lining materials in accordance with the established testing procedures and guidelines established for the material used. Welds and the areas near the welds can be spark tested for defects.

##### 2.2.3.4.1 Vessels made of glass.

The use of equipment made of glass in phosgene service may not be suitable except in laboratory applications due to the possibility of catastrophic failure.

##### 2.2.3.4.2 Equipment made of glass-lined steel

Glass-lined equipment is typically used in fine chemicals and can be suitable for phosgene service.

##### 2.2.3.4.3 Vessels made of composite materials or equipment made of plastic-lined steel

**General:** Steel equipment lined with ECTFE (ethylene chlorotrifluoroethylene) is most suitable for phosgene service that may be operated up to 100 °C. Above 100°C this material may deteriorate.

PVDF (polyvinylidene fluoride) is considerably less suitable as a lining material for steel because of its poorer ability to process (higher stiffness), its high water vapour permeability and its high thermal expansion coefficient.

#### 2.2.3.4.4 Heat exchangers made of graphite

**Materials of construction:** Impregnated graphite is a good choice for the material of construction for heat exchangers due to its high chemical resistance, outstanding thermal conductivity properties and ease of mechanical processing. Due to its passive surface, it is also less susceptible to contamination than metal.

Heat exchangers made of graphite have been used for decades. The probability of a graphite heat exchanger becoming defective is extremely low when properly installed and operated.

**Examination and testing:** In addition to any shop testing, performing a pressure test after installation will confirm that nothing was damaged during transportation or installation. This applies especially if the equipment has been stored or has not been in operation for a longer period. To safely conduct a pressure test, all seals/gaskets (tie-rod, compression fittings, PTFE bellows) should be tightened following the torque requirements provided by the manufacturer. The pressure can be gradually increased to the required test level (again following the manufacturers' instructions). The graphite material normally does not undergo any changes. Periodic pressure tests are recommended.

**Special Installation requirements:** Graphite is brittle and sensitive to pressure surges. Even while operating at relatively low pressures, high pressure peaks may occur, particularly due to the closing of valves and/or opening them instantaneously. The following is recommended:

- Use only slow opening/closing valves to avoid pressure surges.
- Control the flow rate at a point upstream of the heat exchanger. Free flow is preferable; however, if valves are necessary in the outlet, testing the valves before start-up is advisable. The media flow started against closed valves in the outlet can damage the heat exchanger.
- Avoid trapping the media in the exchanger. Thermal expansion may cause unacceptably high pressures. Providing safety valves as needed is recommended.

### 2.2.4 Piping systems

A piping system is defined as pipe, piping components including miscellaneous items contained within the system, up to equipment flange, instrumentation systems, etc.

#### 2.2.4.1 Piping design

Minimum requirements for the piping design in compliance with national regulations, as well as company engineering practices and standards are recommended. Consider using a piping system with pressure ratings exceeding the minimum standards.

- Important Considerations: A well defined pipe specification for phosgene piping is important.
- Metallic pipe and fittings that are either seamless or provided with certified welding are recommended.
- Carbon steel is the primary material of construction for piping systems handling dry phosgene but process conditions may require higher alloys be used.
- Phosgene piping with a minimum line size of DN 25 mm (1" NPS) or greater (preferably DN 50 mm or 2" NPS) is most suitable for mechanical stability. Avoid using threaded connections as they increase the possibility of a leak. Using only standard pipe sizes is also recommended.
- Designing piping systems to allow for thermal expansion by having adequate flexibility due to the pipe routing or by the use of expansion loops is important.
- Using full penetration butt welds made with at least 2 passes that are 100% tested (radio-graphically) enhances the safety of the piping system.
- Avoid the use of expansion joints and hoses.
- Instrumentation and sample-point connections equipped with at least a DN 25 mm (1" NPS) flange are preferred.
- Minimising the number of flange connections and valves to the lowest number practical, taking into consideration operation and maintenance requirements will reduce the possibility of leaks.
- Valves located in piping systems to provide proper isolation for maintenance tasks and normal operations. An emphasis on ease of access is recommended.
- Jacketed pipe for steam heating or cooling with water is not advisable.
- Phosgene may diffuse through the bonnet joint seal or gasket and may react with moisture. This leads to the corrosive attack which eventually may develop into leaks.
- Consider using either stainless steel or carbon steel with an appropriate coating for piping for vents, drains and miscellaneous connections which protrude through the insulation and are subject to icing and defrosting.
- Painting piping systems made from carbon steel, even if insulated, will slow and reduce external corrosion. Under certain conditions such as a location

near a marine environment it is best to coat stainless steel to reduce stress corrosion.

- Labelling and colour coding all piping, especially pipes used in phosgene service is good engineering practice.
- Close all flange openings (i.e. vents and drains) with a blind flange, when not in use, to reduce the risk of leaks.

Generally, the following systems are not suitable for phosgene piping in service for isocyanate or polycarbonate:

- Thermoplastic lined metallic piping systems (e.g. CS/PTFE, CS/PP, etc.) due to the increase in the number of flanged connections and the pipe venting requirements.
- Rubber lined metallic piping systems due to the poor performance of the liner when small traces of solvents are present.
- Solid thermoplastic piping systems such as PVC, CPVC are unsuitable due to the potential for external corrosive attack, as well as mechanical damage.

#### 2.2.4.2 Pipe routing and support

A good piping layout will contribute to the safe operation of the plant.

- Phosgene piping routed the shortest possible distance is consistent with good engineering practices.
- Design piping layouts to avoid low points where liquids can accumulate; this applies to liquid phosgene systems as well as gas lines in which condensation is possible.
- Avoid trapping liquid phosgene between valves and provide means to release pressure in case a line system is full of liquid between two valves.
- Avoid installing phosgene lines adjacent to lines carrying hot fluids or corrosive materials.
- Avoid routing piping through areas of high traffic density or protect the piping against mechanical impact
- Avoid routing piping underneath lifting equipment.
- To enhance safety provide piping in phosgene service with dedicated supports designed and installed to reduce vibration, stress and thermal expansion.

#### 2.2.4.3 **Expansion joints** (bellows / compensators)

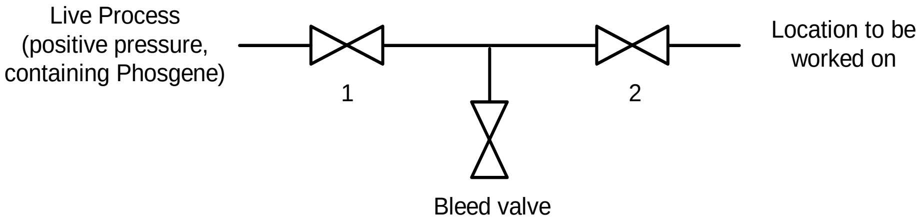
Designing piping systems to allow for thermal expansion by having adequate flexibility due to the pipe routing or by the use of expansion loops is important. Avoid the use of expansion joints.

If expansion joints are unavoidable, a piping design limiting stresses outside the design parameters, which is consistent with parameters used for phosgene service is advisable.
Following manufacturer's instructions for installation, inspection and replacement of expansion joints is important.

#### 2.2.4.4 Double block and bleed

It is advisable to have two independent barriers in a piping system between the live process and areas that will be maintained. This is usually achieved by the use of double block valves with a bleed valve, which ensures that leaks through block valves will be controlled within a work area. If this is not possible, it may be necessary to shut down the process and depressurize and clear the system prior to any work commencing.

**Example**:




In this typical example valves 1 and 2 will be closed, the liquid in between valves 1 and 2 drained and depressurised via the bleed valve.

In cases where a double block and bleed configuration is not installed, additional organisational or technical measures may have to be implemented to prevent phosgene exposure of personnel and to ensure destruction of any phosgene released.

#### 2.2.4.5 Non-metallic piping materials

**This applies only for small scale isocyanate, carbamate and formamate units.**

Piping made of non-metallic materials is suitable for handling aqueous and liquids with organic components or other services that are corrosive to metallic materials. When selecting non-metals such as plastics it is important that the piping system is resistant to solvents or other chemicals that may be used. Since non-metallic material applications are in a constant state of development, assessment of material for each application including testing of a representative sample under process conditions is recommended.

The temperature rating of lining material is critical.

### 2.2.5 Valves

Safety relief valves and instrument valves used in process analyzer systems are not within the scope of this section.
Block valves and throttle valves in phosgene service with two diverse seals to minimize the potential for emissions are important. The secondary seal may be adjustable but not necessarily independent of the primary seal.

**Important considerations:**

- Minimising the number of valves will reduce the risk of leaking.
- Valve size greater than DN 25 mm (1" NPS) (DN 50 mm, 2" NPS is preferred) are most suitable for phosgene service.
- Process Control Technology (PCT) connections for sensors or sample collection systems can use the DN 25 mm (1" NPS) process block valve.
- Valves designed to operate at maximum process pressure and full vacuum are advisable. Design conditions for valves are normally compatible with the overall piping design.
- Valves can have either flanged ends or butt weld ends.
- Valve housings made of ductile materials, which are either cast or forged are preferred. Avoid using welded housings.
- Threaded connections in a valve body are not suitable for phosgene service.
- Three way valves may not be used safely as block valves and should be avoided.
- Valve hand-wheels or actuators that protrude through the insulation that are subject to icing and defrosting may require extra long stems or stem extensions to prevent frostbite injuries to the operator.
- Single body style valves are preferred over split body valves.

#### 2.2.5.1 Recommended valve types

The four basic valve types recommended for phosgene service are:

- Bellows sealed globe valves
- Plug valves

  Plug valves have pressure and temperature limitations.
- Butterfly valves

  Butterfly valves are sometimes used to meet the large diameter valve requirements for phosgene piping systems but modifications to the standard valve may have to be made to make it an acceptable for phosgene service.
- Ball valves

  Ball valves can be all metal and are ideally suited for streams where solids may easily deposit. The metal seated ball allows breaking off the solids and maintaining the sealing quality. Before disassembling the valve, drain the ball and leave it in an open position since phosgene may be trapped behind the ball.

#### 2.2.5.2 **Jacketed valves** (secondary containment)

The design of jacketed valves requires special considerations for monitoring of the packing gland and bonnet joint. Standard jacketed valves normally supplied for heating systems may not be suitable for phosgene service but jacketed valves can be an integral part of the secondary containment of the phosgene plant.

### 2.2.6 Gaskets

**Important considerations:**

- Compatibility with the process fluid
- Operating pressure and temperature parameters compatible with the overall piping design.
- The type of flanged assembly (tongue and groove, raised face)
- Blow-out resistant gaskets unless contained in a confined joint.

Typical examples for gaskets in **metallic systems**:

- Graphite gaskets with or without metal-reinforcement
- Spiral wound gaskets with poly-tetrafluoroethylene (PTFE) or graphite filler
- Kamm-profile gaskets with PTFE or graphite layers
- Purgeable gaskets for purging from one section to the next for use in fully jacketed systems. These gaskets are a combination of a grooved metal gasket with a PTFE or graphite lining for the primary seal and a spiral wound gasket with PTFE or graphite filler for the secondary seal

Typical examples for gaskets for use on **non-metallic** or lined piping and equipment systems:

- Rubber gaskets with metal inserts
- Restructured PTFE gaskets with non-asbestos fillers
- 100% Expanded PTFE gaskets with multidirectional strength
- PTFE gaskets with a memory insert
- Graphite gaskets without metal fillers
- PTFE tape (for equipment only)

**Installation**

Prior to gasket installation the following are good practices to follow:

- Clean and examine for damage nuts, bolts and flange surfaces.
- Ensure alignment of the mating surfaces and centring of gasket.
- Lubricate the working surfaces such as nuts and bolts.
- Install and tighten bolts in incremental rounds using a criss-cross pattern, using a torque wrench
- Bolted assemblies leak tested after installation.

### 2.2.7 Secondary containment

Secondary containment is to prevent the dispersion of phosgene in case of a failure of the primary containment. This is to protect personnel in the plant, in neighbouring plants and in the community beyond the site fence line.
Phosgene destruction systems can be located outside the secondary containment because of the low concentration of phosgene in gaseous form.

Options for secondary containment are:

- A ventilated, air tight **containment**, also called chamber or enclosure, housing the phosgene containing equipment.
- **Fully jacketed** equipment and piping.
- **Steam–ammonia curtain**.
- Combinations of the three options above

#### 2.2.7.1 Containment / chamber / enclosure

A ventilated, completely enclosed **containment chamber** or enclosure housing all of the equipment containing phosgene and equipped with a phosgene detection systems, which can be used to contain any release of phosgene. In the case of a release into the containment chamber the gases can be diverted to a phosgene destruction system. With the right equipment in place, such as analyzers for various chemicals (phosgene, carbon monoxide, etc.), cameras and safe entry procedures the containment chamber can be made accessible for personnel.

**Design and operational considerations**:

- atmospheric or pressure resistant
- air tightness
- ventilation for temperature control
- slight negative pressure
- phosgene analyzers with alarms
- analyzers for other air contaminants, such as carbon monoxide, chlorine, flammables, oxygen with alarms
- ventilation management system in case of phosgene detection
- functionally tests at regular intervals
- connection to a phosgene destruction system
- fire protection
- TV monitoring
- accessibility for personnel
- communication system
- access doors with alarms, consider air lock system
- larger opening for moving large pieces of equipment
- procedures and permits for controlled access, buddy system
- procedures and permits for executing work inside the chamber
- specifications of personal protective equipment (PPE)

#### 2.2.7.2 Jacketed systems

This is a system with an outer jacket enclosing phosgene containing equipment, piping, flanges, valves and PCT systems.
Jacketed piping, for example, is a piping system consisting of one pipe inserted within another pipe. The inner pipe (the core) is in contact with liquid or gaseous phosgene and the space between the inner and outer pipe (the annulus) is filled or purged (under pressure or vacuum) with a dry gas such as nitrogen or instrument air.

The gas in the annulus is monitored, analysed for phosgene and connected to a destruction system. This is used to identify leaks in the entire phosgene system. Monitoring can be achieved by purging the annulus to an analyzer system, padding the annulus with pressure and monitoring or applying a vacuum to the space and monitoring.

There are two typical jacketed systems:

- Fully jacketed systems
  This is a system with an outer jacket enclosing **all** equipment, piping, flanges, valves and PCT systems. A system typically consists of a double wall pipe construction, flow through flanges, flow through gaskets, jacketed valves and PCT systems.
  This system allows for the monitoring of pipe leaks, leaks at flange connections and leaks at inline components.

- Partially jacketed systems:
  This is a system consisting of a double wall pipe construction, with standard phosgene flanges, gaskets, valves and PCT items. The jacket typically ends on the hub of the flange, which will contain the pipe to flange weld within the jacket.
  This system uses flanges and valves from single wall systems and does not allow the monitoring for leaks at flanges and valves.
  Partially jacketed piping systems are usually used as primary measure and are only regarded as secondary measure in combination with an additional measure like a steam-ammonia curtain.

**Design and operational considerations**:

- phosgene containing equipment that needs to be enclosed
- outer jacket should have same pressure rating as equipment enclosed
- monitoring of the jacketed space, as the inner pipe wall can no longer be inspected visually
- the annulus be purgeable
- the gas in the annulus should be dry, consider inert gas rather than air
- the annulus is pressurised or under vacuum at all times
- analyse for phosgene
- functionally tests at regular intervals
- able to divert automatically to a destruction system in case of phosgene detection

#### 2.2.7.3 Steam-ammonia curtain

This is a system designed to destroy phosgene released from the primary containment in open air structures.

**Design and operational considerations:**

- a piping ring system surrounding the phosgene containing area at one or multiple elevations depending on the height of the structures
- phosgene analyzers with alarms
- possibility to inject ammonia into the steam
- activation procedure, automatic or manual
- functionally tests at regular intervals
- procedures for protecting personnel from ammonia exposure

**Phosgene decomposition systems:** These can be located outside the steam ammonia containment because of the low concentration of phosgene in gaseous form.

#### 2.2.8 Phosgene destruction

Regulatory bodies across the globe have criteria regarding the quantity or concentration of phosgene that may be emitted to the atmosphere (legal limits). It is critical that a phosgene plant has a device or devices that are able under upset conditions to decompose phosgene before it can be emitted to the atmosphere. A risk assessment based on a worst case scenario is normally used to design the capacity for the phosgene destruction system.

It is important that phosgene destruction systems be functional both during normal operation and during shutdown operations, as long as there is phosgene in the plant

**Sources of phosgene during normal operations:** The following phosgene-containing streams may need to be neutralised during normal operations:

- Off-gas from phosgene generation facilities
- Off-gas from phosgenation areas
- All other off-gas streams in the unit: e.g., off-gas from tanks, analyzers and other equipment
- Vacuum off-gas from distillation areas
- Other vent streams not mentioned above

Phosgene destruction systems can be located outside the secondary containment because of the low concentration of phosgene in gaseous form.

The number of phosgene decomposition systems required and their distribution depends on the plant concept. For safe operation, at least one destruction system will be available as long as phosgene is in the plant.

To avoid releasing phosgene to the atmosphere even when the primary decomposition system fails, consideration of a redundant system may be necessary or a system could be employed to recycle the phosgene within the primary and secondary containment systems until the process can be safely shut down.

##### 2.2.8.1 Design of phosgene decomposition systems

To ensure maximum reliability of the phosgene destruction system it is advisable to install redundant systems with emergency backup where possible failure could lead to failure of the entire system. It is prudent that some lines to the decomposition systems be made of acid-proof materials due to the possibility of water backflow and that these lines are installed without sag and on a downward slant toward the decomposition system.

Protection of equipment in cold areas against freezing is advised.

Since solvent vapour may be sucked into the spot ventilation system it may be equipped as a Zone 1 system and the suction lines are electro-statically conductive and grounded.

Blowers installed with horizontal exhaust nozzles are more easily drained. It this is not possible, the blower housings should have drainage systems, which are protected against freezing, as necessary.

Recycling water or diluted hydrochloric acid is desirable. The maximum acid concentration in the concentrated recycle stream should not exceed 5%, above which the capability of the system to decompose phosgene reduces very quickly.

Positive flow toward the decomposition towers is essential: if not, backflow or diffusion of water or diluted hydrochloric acid can cause corrosion.

### 2.2.8.2 Destruction systems

#### 2.2.8.2.1 Caustic soda scrubber

This system is comprised of a single or series of scrubbing towers with a circulation loop containing dilute caustic soda. A second redundant system is advisable. The phosgene streams counter-current to the flow of caustic soda solution, which flows by gravity down the column. The adsorbent flow can be assured using an overflow with flow meter

The reaction of the phosgene with caustic soda forms sodium carbonate, sodium chloride and water. It is advisable that the circulation pumps have redundancy and are connected to an emergency power supply and that an adequate inventory of caustic soda be available. A cooling system for the caustic loop to remove the heat of reaction is important.

Caustic soda reacts with atmospheric carbon dioxide leading to a reduction in its alkalinity and thereby, the efficiency of scrubbing. Consequently an automated system to replenish caustic soda is desirable.

A further factor to be assessed is blockage of the system (‘plugging’) due to the build up of insoluble sodium carbonate formed in the reaction between caustic soda and phosgene.

#### 2.2.8.2.2 Trickle bed tower with active carbon

The equipment comprises two or more towers packed with activated carbon with a system to distribute water or dilute hydrochloric acid evenly through the carbon bed. A second redundant system is advisable. The phosgene streams counter-current to the flow of liquid, which flows by gravity down the column. The phosgene is catalytically decomposed to carbon dioxide and hydrochloric acid. The reaction is exothermic; the heat generated is removed by the water or hydrochloric acid solution, which must be cooled. The distribution of water on the activated carbon is very important, to prevent hot spots. Therefore, the water distribution should be monitored through sight glasses during operations. It is advisable that the circulation pumps have redundancy and are connected to an emergency power supply and that an adequate inventory of hydrochloric acid be available.

Active carbon decomposition systems can be an operated with slight positive pressure or under vacuum. With vacuum operation, phosgene emission is improbable: however, if air is sucked into the system at leaking flanges and blowers, explosive gas mixtures maybe formed in the decomposition system. The risk can be reduced by monitoring oxygen. With positive pressure operation, leaks are more easily recognised and the formation of explosive gas mixtures in a decomposition system is improbable. On the other hand, phosgene and/or explosive gas mixtures in this case can be anticipated outside the decomposition system, close to the leak points.

The efficiency of the tower is affected by several factors. If hydrochloric acid is use, it is prudent to monitor the pH since the efficiency declines as the acidity rises above about 5%. Further, there is a drop in efficiency if there are high loadings of solvents or of inert materials.

The following general principles apply:

- In general, activity of the carbon (e.g. to phosgene destruction) is an inverse function of mechanical stability. Replacement of the carbon is important since the activity of the carbon is diminished as the particle size is reduced.
- Activated carbon with high activity has good phosgene decomposition properties, but is easily oxidised by oxygen and chlorine and this is to the detriment of its chemical properties.
- Demineralised water or condensate is preferred, to avoid the risk of blocking active sites on the carbon due to the deposition of minerals or suspended particles.
- Activated carbon can be contaminated by algae or bacteria, especially if ground water is used or if there is high oxygen content to the system, as could be the case with spot ventilation. This contamination can be minimised by operating with dilute acid and/or by occasional heating of the tower with steam or condensate, however without exceeding the operational temperature limits.
- A tower already contaminated with the types of biomass above, can be decontaminated by targeted addition of hydrochloric acid.
- A particular problem may arise when the off-gas contains isocyanates, which react with water to form highly insoluble, waxy polyureas.

## 2.3 Support / auxiliary systems

### 2.3.1 Segmentation (blocking-in procedures)

Segmentation is the practice of dividing large units into smaller sections by the use of shut-off valves which can be remotely activated from the control room. This practice minimizes the quantity of liquid phosgene which needs to be transferred into the dump tank in the case of a leak. The vapour space of each segmented area will probably be connected to a phosgene destruction system to ensure that no phosgene will be released to the environment.

Designing the phosgene handling unit in a way that allows the unit streams to be evacuated and subsequently diverted to a phosgene destruction system is an established practice. Segmentation minimizes the amount of effort necessary to clean and prepare the area around the leak for repair.

### 2.3.2 Dump tank

A dump tank system designed to contain the maximum quantity of the largest process segment and which is connected to a phosgene destruction system is normally incorporated into the design of the plant.

Ideally, phosgene will drain by gravity into the dump tank without the use of pumps. Valves located in the discharge lines from the process equipment to the dump tank are best activated from the control room. Equipment discharge lines to a dump tank can be flushed with solvent after use to decontaminate and to prevent blockage.

It is advisable that the dump tank and ancillary equipment be kept empty and ready for use.

### 2.3.3 Blow down vessel

Discharge lines from pressure relief devices are best discharged to a vessel where the liquid and vapour phases can be separated. This vessel will be connected directly to a phosgene destruction system to treat the vapours.

### 2.3.4 Evacuation or maintenance system

This is a permanently installed evacuation system connected to a phosgene destruction system. Normally the evacuation system is separated by double block-and-bleed valves from the process and is used for the following activities:

- clearing of the equipment in preparation for maintenance work
- evacuating the vapour area of a segmented section in case of a phosgene leak

### 2.3.5 Elephant-trunk or spot-ventilation systems

A vacuum system designed to remove any residual fumes when opening lines or other equipment during maintenance activities. It consists of a flexible hose with a large cone shaped opening connected to a phosgene destruction system. It is used when opening equipment which could possibly contain traces of phosgene. The system is independent and is not connected permanently to other units in phosgene service. It is important that the hose be chemically resistant to phosgene and other chemicals in the process.

### 2.3.6 Breathing air system

A dedicated, permanent breathing air supply system with numerous connection points from a safe and secure air supply to airline respirators to be used when opening lines, breaking into equipment or doing maintenance where exposure to phosgene is possible.

### 2.3.7 Dedicated nitrogen system (Protection of the nitrogen network)

A dedicated nitrogen system will prevent any phosgene from entering the plant nitrogen system in case of backflow.

The design pressure ensures that nitrogen can enter the equipment with the highest pressure.

If the general plant nitrogen system is connected to the phosgene unit, provisions are needed to prevent phosgene from flowing back into the general system. Such provisions may include interlocks controlled by pressure differential measurements. Check valves may not provide adequate protection in phosgene service.

### 2.3.8 Backflow prevention

**Protection of the solvent flushing systems:** If a solvent flushing system is an integral part of the phosgenation process and is permanently connected to the process, it is possible for the phosgene-containing media to flow back into the flushing system.

The backflow hazard can be eliminated by ensuring proper pressure differential between the solvent and the process. Provisions include interlocks controlled by pressure differential measurements. Check valves may not provide adequate protection in phosgene service.

## 2.4 Instrument and process control systems

This section summarizes the engineering and operational considerations for process control systems and online analyzers in phosgene producing or processing units.
It is advisable to use only process control equipment that conforms to all technical, plant and legal standards and that is purchased from approved vendors.

### 2.4.1 Important considerations:

**Construction principles and materials:**

Electrical and Instrumentation (E&I) equipment designed to meet the operational requirements of the piping and equipment, on which it is mounted, is important. This includes temperature limitations, pressure/vacuum ratings, chemical resistance of materials of construction in contact with the process media (including seals/gaskets, etc.) during normal operations, start-up and shutdown operations and any during cleaning procedures.

It is advisable that instruments are designed so that the electronic components are protected from external damage, i.e. that delicate components be enclosed in a structurally stable housing.

Instruments having active sensor systems and enhanced diagnostics are preferred such that if a sensor part is damaged a diagnostic alarm (e.g. maintenance needed, failure, etc.) is generated.

The following are general construction and material considerations for E&I equipment:

- Welds situated so that they can be easily tested after assembly of the instrument are optimal.
- Minimize (preferably eliminate) dead spaces.
- Deterioration due to corrosion and/or erosion can be minimised by selecting the appropriate material of construction and by correctly sizing the device. Suitable materials of construction are carbon steel and stainless steel; however, thin components (e.g. remote seal membranes and bellows) are best made of tantalum or Hastelloy C. Parts in contact with the phosgene process made of titanium may not be suitable due to the potential of pitting corrosion.
- Process connections welded or flanged consistent with the pipe design are preferred. The instrument mating flange and the E&I instrument flanges are most reliable when surfaces of each matched.
- Avoid using threaded connections to seal the process fluid from the environment, either when making connections or as a component of the instrument.
- When E&I devices consist of parts fastened by bolts, a static gasket seal or a chambered o-ring seal are the best option. When selecting the gasket and sealing materials consider all aspects of the process including solvents, temperatures and possible impurities.
- When choosing the materials of construction for the fasteners used to hold the parts of the instruments together consider potential corrosion, thermal and embrittlement effects caused by cold process temperatures, including icing and de-icing.

- Any necessary lubricants may require testing for compatibility with process conditions unless they are pure mineral oil.
- Be aware that PTFE can be permeated by phosgene meaning that it cannot be completely decontaminated. Properly dispose of PTFE components (gaskets, seals, lining, etc.) before the device can be sent outside of the plant for maintenance.
- Ductile cast material (e.g. ferritic cast steel, austenitic cast steel, spheroidal graphite cast iron) are good options for phosgene services.

**Selection criteria:** In general, it is best that the following PCT equipment be considered and only purchased from qualified vendors.

PCT equipment, for the purpose of this section, includes:

- Level Measurement by
    - Vibration (Tuning Fork)
    - Radar
    - External nuclear measurement
- Flow Measurement by
    - Coriolis
    - Vortex
    - Ultrasonic
    - Variable area (rotameter)
- Pressure Measurement
- Temperature Measurement (consider welding thermowells into the equipment)

The quality requirements for automated valves are the same as those for manual valves as described in Part 2 section 2.2.5.

It is recommended that all pressure bearing butt welds, which are exposed to the phosgene medium during normal operations, be 100% radiographed wherever practical. If the exposed butt weld cannot be radiographed (e.g. due to a thin wall thickness or small diameter) then the weld can be 100% tested using either a dye penetration test (for stainless steel and nickel based alloys) or magnetic particle test (for carbon steel and low alloy steel materials). It is good practice to test 100% of pressure bearing welds, other than butt welds (e.g. fillet welds), that are exposed to the phosgene medium by either dye penetration or magnetic particle testing. The extent of testing can be reduced depending on the quantity of the item purchased when the following criteria are fulfilled:

- The butt welds are performed by an automated welding process.
- The manufacturer has an established verification system (e.g. on a statistical basis) which shows that the required quality has been continuously met.

If there is additional examination and testing required by the end user, it is good practice to include it in the equipment specification.

**Installation considerations:**

PCT field equipment is installed in a self draining position. Avoid installation of measuring equipment on vessels below the normal liquid level.

All process connections for PCT (and PAT) with a minimum of DN25 (1-inch diameter) are preferred for mechanical stability. This connection can be made in one of three possible methods:

- No process block valve. This is a poor option as it requires process shut down for maintenance of PCT and is not reliable enough for PAT applications
- A single process block valve. This option also requires process shut down for maintenance of PCT and is considered the minimum requirement for PAT applications.
- A double block and bleed valve arrangement (either with process piping and valves, or a mono-flange valve for clean service only). This option is the best option as it allows maintenance of instrumentation to be done while the process is running.

The connection method can be different for each type of instrument depending on specific circumstances.

It is good practice to include instrumentation and automated valves in piping and equipment pressure/ leak testing programs unless the testing could damage the instrument. If not included in the pressure testing, the instrumentation should be installed before leak testing of the equipment is complete.

### 2.4.2 Analyzer instrumentation

Analyzer instrumentation for phosgene operating units can be classified according to their purpose as follows:

- monitoring of vent gas
- fence line / perimeter monitoring and leak detection
- air monitoring of rooms
- stream composition monitoring

Analyzers discussed in this section are the process/stationary type designed for continuous field operation. Portable devices do not meet these requirements and are not in the scope of this section.

#### 2.4.2.1 Monitoring of vent gas

Good options for measurement of phosgene are by infrared absorption or colour reaction with reagent solution on paper tape.

Note: Paper tape devices have negative cross sensitivity interference with HCl.

#### 2.4.2.2 Fence line / perimeter monitoring and leak detection

The design of the monitoring system is based on the detection sensitivity, response time and monitor location.

Monitoring a unit for gas emissions using a number of sample points or analyzers distributed around the unit has been proven effective. The degree of monitoring is determined by the number and spatial distribution of the sample points or analyzers. In principle there are two basic designs:

- The "**detector tube** concept" where the gas samples are conveyed to one or more central analyzers via one or more lines, each having a number of sample points for monitoring certain areas of the unit or critical equipment.

  The test method is colour reaction with reagent solution on paper tape.

Note: Paper tape devices have negative cross sensitivity interference with HCl.

- The "**individual analyzer** concept" where each measurement point is an individual sensor or analyzer.

  Measuring method is with an electrochemical sensor.

  Cross sensitivities to other substances are possible. Details can usually be found in the manufactures documentation.

#### 2.4.2.3 Air monitoring of rooms

- **Room air monitoring for intermittently manned rooms**: Monitoring of air in closed rooms that contain phosgene bearing apparatus and where personnel are only present on an intermittent basis (e.g. analyzer rooms and decontamination rooms) can be done with phosgene analyzers, directly installed in the room.

- **Monitoring of incoming air for manned rooms**: For ventilation systems in rooms that are manned with personnel on a continuous basis or for extended periods of time, a phosgene analyzer installed with the sample point in the fresh air inlet duct is advisable.

  If phosgene is detected in the air intake, the safest option is to automatically shut off the air intake. And evacuate the personnel in the room to safety following the appropriate emergency procedures.

#### 2.4.2.4 Design requirements for process analyzer systems

The tubing in sampling systems consisting of stainless steel tubing (316 or higher alloy) joined by welding or double ferrule compression tube fittings (for example Swagelok) have been shown to be reliable. Threaded connections (that are not double ferrule fittings) may not be reliable enough for phosgene service.

Designing and installing sample lines that allow for flushing the tubing back into the process or to a controlled disposal system is important. Using valves with a high quality stem seal such as bellows sealed valves and diaphragm sealed valves (membrane sealed valves) is recommended.

#### 2.4.2.5 Leak detection for analyzers

Process analyzer systems have many connections, which can develop leaks. Purging analyzer components, which use non-metallic seals and are in contact with the product (e.g. a glass window in a photometer sealed with an o-ring) continuously with a gas that is monitored for toxic substances (phosgene) and flow is a good safety practice.

It is important to design backflow prevention into the purge gas system to prevent toxic materials flowing back into the purge gas supply.

#### 2.4.2.6 Sample disposal requirements

Two options for handling analyzer exhaust streams are: a) to be returned to the process or b) disposed of in a phosgene decomposition system. Consideration should be given in the design of disposal lines to the potential for corrosion and the potential of over pressure conditions from the process or decomposition system.

#### 2.4.2.7 Analyzer rooms

Potential leaks in the complex analyzer tubing systems could lead to a hazardous situation. These potentials can be minimised by engineering design such as the use of high quality sealing components. Process analyzer equipment is generally not available in an explosion proof design (EEx rating). In the case of a leak, ventilation of the room is a widely used and accepted practice.

Analyzer rooms constructed away from other rooms will reduce the risk of contaminating those rooms with phosgene or other hazardous substances.

It is good practice that ventilation of analyzer rooms meets the following:

- Avoid exhaust air from the analyzer room contaminating air leading to other rooms (recycle).
- The air intake is located away from sources of hazardous chemicals.

Equipping analyzer rooms, which handle phosgene, with the following items is advisable:

- Monitors for phosgene.
- An alarm panel showing alarm / status signals from each of the room air sensors and a status indicator for the ventilation system is recommended at the entrance to the room with these alarms transmitted to the control room.

#### 2.4.2.8 Audible and visible plant alarm signals present inside the analyzer room. Calibration

If possible, use phosgene free gas for calibrations. When measuring phosgene as one component in a mixture, substitute methods are best used, especially if higher phosgene ranges will be calibrated. Reliable substitute methods include the use of surrogate gases or optical absorption filters.

## 2.5 Electrical supply

Two independent 100% power supply lines coming from different sources with automatic switch over are an important consideration to ensure safe, uninterrupted plant operation.

If there is only a single electrical feeder power supply for critical systems and pumps, (i.e. rotating equipment necessary to safely shut down the plant, pumps for the scrubber systems, the process control system, phosgene alarm system, critical lightning), a backup supply provided by either diesel operated generators or/and batteries is encouraged.

## 2.6 Phosgene emission control (monitoring)

It is advisable to install a reliable phosgene monitoring system with multiple, strategically installed, detectors throughout the plant giving an audible and optical alarm in the control room if phosgene is detected.

It is advisable that a system is established that revokes all work permits in the event of a phosgene alarm, stopping all work immediately and providing all personnel in the plant with emergency instructions which typically includes information about predefined safe assembly points where all employees, contractors and visitors gather and be accounted for.

Since wind direction and velocity is important for proper response in the event of a release, installation of wind indicating equipment in strategic locations is advisable. As part of evaluating your company's needs, the following considerations may be of assistance in case of a plant emergency:

- One or more safe assembly points.
- Emergency coordinators to direct all personnel on the plant to a safe assembly point.
- A weather vane indicating wind direction and velocities in the control room.
- Additional weather vanes installed on high points in the plant.
- A system to quickly account for all personnel (operations, maintenance, lab personnel, service personnel, contractors, visitors) on the plant in case of a plant emergency.

## 2.7 Building design

### 2.7.1 Control rooms and safe rooms

Some sites have their control room as the only clean-air refuge in the case of a chemical release: others have an additional safe area, which is called a “safe room” or “safe haven”. The same basic design criteria could apply to both types of refuge areas.

**Design features:** it is advisable that control rooms and safe rooms/ safe havens be designed with the following features:

- Location upwind of the plant and as far as possible from sources of phosgene or other hazardous chemicals, which are toxic, flammable or explosive. Any entrance from an area with the potential for phosgene contamination having the characteristics of an air lock (two sealed doors in series in a small enclosed area) is good practice.
- Gas-tight windows designed such that they may not be opened (except if designated as a fire escape) and preferably installed on the side of the building facing away from the unit.
- No chemical lines, including compressed air or nitrogen, running through the room, under the floor or in false ceilings.
- Alarms and warning systems that are audible and visible in all rooms and buildings in a phosgene unit that announcement systems and alarms be operational at all times so that they are always available during emergencies.
- It is prudent to maintain a slight positive pressure in control rooms with a reliable and safe fresh air intake monitored for toxic gases including phosgene and other applicable chemicals. Activating an automatic shut down of the ventilation system based on the toxic gas monitor output is a good practice. Control rooms can also serve as safe havens in case of a phosgene release.
- Adequate and sufficient personal protective equipment, which has been periodically inspected and well maintained, will normally be provided for all personnel operating or shutting down the plant and for evacuation purposes.
- Self-contained breathing apparatus or breathing air manifold supplied with compressed breathing air, sufficient for all personnel during the period of a safety shutdown of the plant and complete evacuation.

### 2.7.2 Ventilation system

It is good practice to locate the fresh air intake for the ventilation system upwind of the prevailing wind direction and away from potential sources of phosgene or other toxic and/or flammable substances.

Analyzers to detect hazardous chemicals in the air intake that can activate an automatic shut down of the ventilation system and an alarm to the control room if toxic gas is detected are advisable. Duplicate analyzers could also be considered for increased safety.

Visual indication should be provided in the control room for monitoring of the status for all unit ventilation systems with automatic shutdown. It is prudent that the control room has a manual means controlling the ventilation units to allow maintenance of the analyzers.

### 2.7.3 Elevators

It is important if elevators are used in buildings in process areas that they are equipped with:

- Breathing air equipment for all occupants.
- An alarm, which may be audible or visual, unless the external alarm can be heard or seen at all times in the elevator
- External signs at all elevator levels saying "Do not use in the event of an emergency".

### 2.7.4 Alarm systems

#### General requirements

It is advisable to inform and warn all personnel inside a unit when a phosgene emission is detected and, if necessary, to evacuate the plant. It is prudent, in an emergency situation that personnel outside the unit not be allowed to enter the unit without proper PPE.

Consequently consider equipping units with acoustic and optical alarm and warning systems.

This section describes phosgene alarm systems, used to alert personnel in and around a phosgene unit of potential and immediate danger of phosgene releases. They normally consist of a visual part (lights) and an audible part (horns and/or announcements).

It is understood that there may be needs for additional warning, alarm and protection systems (fire alarms, explosion protection, etc.) but these are not specific to phosgene units and thus are not addressed here.

Ideally phosgene alarm systems will have a back-up power source (batteries, uninterrupted power supply, generators, etc.) to provide power for operating at least one hour after loss of the normal external power source.

It is prudent to have a secure method (always powered and not able to be blocked) transmit phosgene alarm signals (as required by Safety Procedures) to a central site alarm station (such as the Plant Fire Brigade Control Centre, Incident Command Centre or Public Fire Department with a clear identification of the location initiating the alarm.

#### Area Alarm Lights and Sound

It is prudent that phosgene producing and consuming facilities be equipped with area alarm lights.

The location of the lights depends on the unit structure (open structure or chamber) and would be determined in consultation with safety experts.

Enough lights are positioned in such a way, that anyone approaching the phosgene containing areas from outside be able to see them before entering. This usually means lights positioned at chamber entrance doors, unit corners or stair wells and, if necessary, at appropriate distances down each side of the unit.

Installation of the same style of lights just inside exits of buildings within and directly adjacent to the phosgene unit to alert occupants of the danger outside should be considered.

The lights may be activated by automated sensors (perimeter monitors, process analyzers, etc. as defined in the Safety Procedures), but could also be manually activated in the Control Room.

In units with open structure, alarm lights and sound could also be activated manually from the field by one of the following methods:

- Activation buttons positioned at strategic locations throughout the unit such as at the entrance to stair wells and normal exit points. Activation by these buttons would also initiate an alarm in the Control Room.
- An intercom system may be positioned at strategic locations throughout the unit, which can be used to alert the control room of an alarm situation. (The control room then activates the alarm lights and sound using the button in the control room.)

It is prudent that any activation of the alarm system be designed causes an audible alarm to sound in the control room.

Consider providing cross-unit coordination in complexes with multiple units in close proximity. Announcement boards with text to identify the area(s) involved in an emergency situation may be required. Traffic control lights could also be activated.

**Announcement System**

A system of speakers should be provided to allow a unit announcement from the control room to detail the unit status (suspected release, release, action being taken, all clear, etc.) keeping affected personnel informed.

This speaker system is not to be confused with any plant wide announcement system, which provides audio coverage of all plant units and facilities, including non-phosgene production units and offices. The different announcement systems (e.g. site versus phosgene unit) could be coordinated on a site wide basis into a unified warning concept. If a phosgene unit announcement system is tied into a site announcement system covering a larger combination of units, it would be prudent to coordinate between safety systems. Precedence in case of competing announcements would be given to the safety announcement of higher importance as defined by Safety Procedures.

It is important that the phosgene alarm announcement system provide clear audio coverage in all phosgene production areas including auxiliary areas such as tank farms, motor control centres, instrument rooms, offices and warehouses. Recorded messages are recommended to provide better understanding and consistent wording.

## (Abbreviations and acronyms)

| | |
|---|---|
| CPVC | chlorinated PVC |
| CS/PP | Carbon Steel / Polypropylene<br>A component with a CS outer shell lined with PP. |
| CS/PTFE | Carbon Steel / Poly-tetrafluoroethylene<br>A component with a CS outer shell lined with PTFE. |
| DN xxx | Diameter Nominal is xxx mm. |
| E&I | Electrical & Instrumentation |
| ECTFE | Ethylene chlorotrifluoroethylene,<br>Fluoroplastic commonly known as Halar® [Registered Solvay S.A.]). |
| EEx | equipment rating for electrical equipment in hazardous areas |
| Hastelloy® | Prefix name of 22 highly corrosion-resistant metal alloys.<br>[Registered Haynes International]. |
| NPS | Nominal Pipe Size, North American set of standard sizes for pipes |
| PAT | Process Analyzer Technology |
| PCT | Process Control Technology |
| pH | Measure of the acidity of a solution (potential of Hydrogen) |
| PTFE | Poly-tetrafluoroethylene<br>Commonly known as basic Teflon® [Registered DuPont] |
| PVC | Polyvinyl chloride, Thermoplastic polymer. |
| PVDF | Polyvinylidene fluoride<br>Thermoplastic polymer commonly known as Kynar® [Registered Elf Atochem] |