6.5 Instruments

Introduction

The Instruments section provides a general description of instruments and control systems utilized in phosgene service. It also provides information tips regarding operation and maintenance, as well as historical information. As with the rest of the Guidelines, the information presented is intended to be general guidelines, and is in no way intended to serve as a directive or to supersede any ISA (Instrument Society of America) standard, law, regulation or other applicable industry standard. This information is intended to supplement and not to replace the use of good engineering practices. As with other sections of the Guidelines, companies may need to adopt practices different from those discussed here, or employ practices that are not discussed herein, based on their factual situations, the practicality and effectiveness of particular actions, and economic and technological feasibility.

The primary focus of this document is on phosgene liquid and gas. Combinations of phosgene with another component or components (i.e., with a solvent) will necessitate additional considerations of the combined and/or unique properties of the mixture.

The information provided in this section should not be considered as a directive or as an industry standard that readers must adopt or follow. Instead, the information is intended to provide helpful ideas and guidance that users may wish to consider in a general sense (See Section 1.1 *Preface and Legal Notice*). Also included is a reference list of useful resources.

Contents

6.5 Instruments

6.5.1 Hazard Analysis and Safety Instrumented Systems

Evaluate manufacturing processes to determine the appropriate Independent Protection Layers (IPL) to control hazards, and to identify the need for a Safety Instrumented System (SIS) along with the integrity requirements of the functions the system performs. Safety Instrumented Systems are intended to provide protection for people, property and the environment against deviations in the manufacturing processes. Several industry standards, such as International Standard IEC-61511 and US Standard ISA S84-2004, address Safety Instrumented Systems. Examples of detailed guidelines on this subject are available through publications developed by the Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers (AIChE).[1]

6.5.2 General Description

Operate phosgene producing or phosgene processing units in a manner that provides protection for personnel and the environment. Instrumentation can help provide for safe and reliable operation.

It is expected that the process will be controlled and remain within the vessels, equipment, piping, instruments and/or analyzer systems. A goal of the instrument design effort is to help eliminate or minimize potential leakage points. Try to minimize leak paths in instrument installations with the use of inline instrument devices.

Other goals of instrument design efforts for phosgene service include providing for the reliability of instrument systems and devices, utilizing reliable technologies and methods, and providing for safe access and maintainability of the instrument system and devices to minimize personnel exposure to phosgene.

The goal of providing safe access for maintainability of the instrument system may sometimes create inconsistencies with the goal of minimizing leak paths. Maintainability is often enhanced with the use of flush/purge fittings or devices. These installations tend to add more valves and fittings, and hence possible leak paths. Minimizing leak paths without maintainability will often require removal of an instrument device with a small controlled release to a recovery system. Refer to individual company policies and/or practices for how best to achieve these goals.

The design/application of inline instrument devices or hardware utilized in phosgene service considers all the process conditions and other materials in the process stream in selecting the most suitable/appropriate materials of construction for the instrument device or hardware. Material selection for instruments in contact with phosgene varies depends on overall process stream requirements and other specific factors.

Design of the instrumentation system is impacted by instrumentation reliability and relevant safety classification requirements for the system and its components, which are defined by a Process Hazard Analysis Review. *(Refer to 2.0Training and Job Safety, Safety Review Section 2.2. for further information.)*

The frequency and methods for inspection/calibration of devices used in phosgene service are generally set by company policies and procedures.

6.5.3 General Design Installation Issues

As part of evaluating your company's own system needs, the following considerations may be of assistance:

- Evaluating the use of inline devices.
- Eliminating (minimizing) leakage points to the atmosphere for instruments in phosgene service.
- Minimizing screwed (national pipe thread, NPT) process connections and tubing and fittings in contact with phosgene or its reactants as non-threaded process connections can provide less potential for leaks.
- Evaluating common Mode Failure possibilities and how to eliminate them.
- Utilizing fail-safe components and methods whenever possible to drive the process to a safe state on loss of energy.

- Other considerations that phosgene users may find useful:

- Cleaning and degreasing for chlorine service may be beneficial for valves and inline instrument devices in phosgene service.

- Carefully evaluate the use of PTFE tubing, fittings or devices in phosgene services due to the potential for phosgene permeation of PTFE. Consider emphasizing a strong mechanical integrity program to help maintain safe usage in phosgene service. See Section 6.3 *Piping Items and Valves* for further information on PTFE piping-related issues.

- The use of a process isolation valve for all instrument devices in phosgene service that are not of inline design may allow for safe removal of instruments for maintenance.

- 1" – 300 # Raised Face (RF) flanging has been used as a guideline for consideration for instrument devices in phosgene service. However, 150 # flanging is being utilized on glass-lined reactor and PTFE-lined piping installations. For example, some PTFE-lined pipe is used in phosgene service and weep holes are monitored for signs of permeation. Glass-lined service (GLS) pipe has also been employed. Flow rates and/or process requirements could lead to an instrument connection size different than 1"-300 # RF.

- Review histories of reliability in technology selection. The use of smart transmitters, valves with smart positioners, etc., may assist online diagnostics and maintenance.

- Instrument devices can be installed to allow flushing and decontamination, purging and/or venting before removal of equipment for calibration and/or repair.

- Redundant systems, when used, often include redundant elements from sensor to control processing to final control elements.

- Support for instrument devices and their auxiliaries are designed to protect against mechanical damage. One example is a small bore extended branch trees with extended moment arms.

- Incorporating self-monitoring and/or error reporting elements ("smart instruments") into phosgene indication, control, interlocking, and/or alarming strategies can help identify some potential problems.

- Periodic checks, calibration procedures (including function check), and reporting methods have been used for instrument devices deemed critical to safety of the process (as identified by PHA analysis or other method).

- Instrument devices are often specified and installed with consideration given to maintenance, calibration and testing requirements, both on line and off line.

- Transmitters specified for phosgene applications can be designed to handle vacuum service required f or equipment evacuation.

6.5.4 Instrument/Device Connections for Phosgene

Tubing and fittings

Tubing used in phosgene service is supported and protected to prevent a failure in the tubing system. The selection of seamless heavy wall tubing for use in phosgene systems involves important considerations. One consideration is a minimum thickness for example. Under certain circumstances, dual ferrule compression tubing systems can be utilized. Individual tubes installed in a tube track or suitable tubing bundles have been used previously. In either case, address whether the tubing is suitably protected from mechanical damage and marked.

All welded small diameter piping is being used in lieu of tubing systems in some applications. If this method is adopted, consider whether suitable routing, marking, flanging and support have been incorporated to help ensure its integrity. *(*Refer to *Piping Items and Valves Section 6.3* for further information).

NOTE: Some phosgene users minimize the use of tubing and fittings for phosgene service in any concentration, as their goal is to eliminate or minimize the total number of the leak points, and/or screwed connections.

Threaded (Screwed) fittings

Evaluate the use of welded or flanged connections whenever possible and the minimization of screwed fitting(s) in phosgene service. Also consider minimizing the use of screwed or threaded fittings downstream of process isolation valves.

Pipe connections for instrumentation

Select pipe connections appropriate for a company's specific needs and circumstances. As part of selecting pipe connections appropriate for their own needs, common options used by companies have included the following:

- A vessel nozzle or process piping connection size that is 1" diameter or larger.
- A flange connection that is rated for 300# or higher, if equipment/piping design permits.
- All welded construction to minimize leak potentials.
- Phosgene service valves for primary isolation.

Inline connections
With regard to instruments for inline services, users may wish to consider:

- Avoiding the use of a wafer style in-line device that fits between flange bolt circle diameter.
- Using flanged devices rated for 300# or higher.
- Incorporating lug-style end connections for direct bolting to the device. This design has been used with butterfly valves and some flush ring connection designs.

6.5.5 Pressure Management

Pressure gauges
There are several considerations relevant to the selection of pressure gauges including:

- Whether gauge is to be mounted on lined piping or equipment;
- Whether gauge is installed on solid plastic pipe;
- What are the process operating conditions – pressures and temperatures; and
- Whether phosgene is pure liquid or gas, or contains other impurities.

One example for consideration, which may be useful for pure phosgene producers, is a pressure gauge with attached diaphragm seal consisting of specific-alloy diaphragm, steel or SS upper and lower housing, compatible synthetic oil fill fluid, and appropriate tubes, with SS gauge internals. 300# flanged diaphragm seals have been used, as well as 150# flanges at GLS reactors, as appropriate.

Pressure Gauges (for PSV/RD combinations)
Refer to Relief Devices, Section 6.6

Pressure gauges with specific pressure elements and connection sockets have been used for rupture disk burst indication (i.e., not normally subjected to process conditions) in phosgene service. Pressure gauges used for rupture disk burst indication are typically equipped with a "tell-tale" maximum pointer.

Pressure Transmitters
Steadily evolving designs to minimize possible leak paths continue to be utilized for pressure measurement applications. In this respect, it is helpful to keep updated on new approaches. There are several approaches that have been previously used which users may consider.

One approach that has been used in a number of cases is the following: transmitters with attached diaphragm seals, consisting of welded, specific-alloy diaphragms, stainless steel body with appropriate vent plug, stainless steel backup flange and bolting, glass-filled PTFE O-rings when needed, fill fluids suitable for process composition (some companies have used nitrogen or monochlorobenzene (mcb) purged with synthetic oil fill for their own situations) and site practices, and cleaning for chlorine service. When used with remote capillaries, other modified approaches have been used. Once again, in pure phosgene applications, steel has tended to be the material of construction used.

In high phosgene concentrations one might consider using in-line seal pressure transmitter arrangements utilizing similar metallurgy. Some other examples of approaches that users may wish to consider as they evaluate their own needs are listed below:

- A gauge or absolute pressure transmitter fitted with special body flange cast with an integral flange adapter, no vent port and a socket weld connection fitting. Specific material may be required. A 1” nipple is welded to the casting and a 1” 300# RF flange is then assembled to the pressure transmitter.

  NOTE: This unit offers two (2) possible leak paths.

- Gauge or absolute transmitters are also utilized with remote diaphragm seals and capillaries. When utilizing this method, consider designing for decontamination and removal for maintenance. (See Section 6.5.14*, Instrument Device Flush Connection Systems*).

  NOTE: This method offers remote mounting of the transmitter from the process, but yields concerns with calibration, fill fluid and capillary protection.

  CAUTION: Back welding of bleed screws on transmitter housings has not been successful. In many cases, the use of specific alloy pipe plugs with PTFE tape, or the use of a PTFE

O-ring gasket seal plate has been an alternative to back welding these bleed valves.

CAUTION: Remote mounting of pressure transmitters from the process isolation valve may raise potential leak sources if utilizing tubing or piping with screwed fittings. If remote mounting is necessary, consider utilizing remote seal systems and/or an all welded piping system with flush/decontamination capability.

Pressure Switches
Pressure switches are not often used in a service containing phosgene. A live measurement with continuous monitoring of the process pressure is a method often applied for pressure monitoring and switch applications. If a pressure switch is used, it is important to evaluate whether the isolation diaphragm seal is compatible with the process.

Differential Pressure Transmitter
For differential pressure (DP) measurement, consider the utilization of separate gauge or absolute pressure transmitters installed independently and calculate DP utilizing process control system devices. When this approach is not practical, remote seals with a capillary system or an all welded piping system for the process impulse legs have been used. An instrument connection system designed to eliminate or minimize screwed fittings, overall leak paths, and provide flushing capability has been used previously.

For additional information on transmitters, refer to *"Pressure Transmitters"* above.

6.5.6 Flow Management

Consider benefits associated with inline flow measurement devices for applications containing phosgene.

Coriolis Type Mass Flowmeter
An approach for installation of coriolis type mass flowmeters that has been used previously consists of material suitable for the process with 300# RF flanged end connections with secondary containment. Evaluate fitting the secondary containment with purge, monitoring, and/or decontamination fittings in the outer housing and housing rated to suit process conditions. Coriolis type mass flow-meters can be considered where highly precise and accurate measurements are indicated; however, the meters cannot be used in some applications because of flow constriction resulting in a high-pressure drop in the instrument. Coriolis type mass flow-meters provide their own internal compensation for temperature to account for thermal changes in the characteristics of the flow tube; otherwise, the meter directly measures mass flow rate.

Vortex Flow Transmitter
An approach for installation of vortex flow transmitters that has been used previously consists of using a 1" or larger 300# RF flanged model with appropriate wetted parts and all welded or cast construction. Other metallurgy may be required as the process dictates Users should evaluate the following:

(i) Sizing the flowmeter to meet the flow range and turndown required.

(ii) Using 300# RF flanged connections with material of construction suitable for the application.

(iii) Avoiding vortex meters with removable shedder bars in phosgene service due to potential for leakage through the sensor element.

Orifice Flow Transmitter
Orifice flow transmitters have been utilized on large pipeline flow measurement where other inline measurement technologies were not practical. A differential pressure (dp) cell may also be considered for low-pressure drop applications. Users might consider utilizing a DP transmitter and an all-welded instrument flush connection system as required to eliminate (minimize) screwed fittings and overall leak paths as well as provide flushing capability. For additional information regarding transmitter hardware and notes, refer to *"Pressure Transmitters" above.*

Orifice plates and flanges are specified to suit process conditions.

Turbine Flowmeters
A turbine meter may be considered in high-precision gas flow application with low-pressure drop.

Rotameters (Variable orifice)
This device is not used extensively in phosgene service. If required, an all-metal magnetically coupled indicator unit with line size flanging 300# RF, housing and trim suitable for the process has been used previously. Users may wish to back weld maintenance access to the housing at seal O-ring.

NOTE: Glass tube rotameters are rarely used in phosgene service due to the potential for breakage or seal leakage.

Scale and Loss of Weight Measurement
See Section 6.5.9, *Weight Measurement.*

6.5.7 Level Measurement

Continuous level measurement may be particularly useful for phosgene installations for monitoring and control, as high level switching is also possible from a continuous level. Live measurement and continuous monitoring have been used previously. Redundant level installations are often utilized in lieu of point measurement devices.

Non-intrusive level measurements such as nuclear, microwave (radar) and others have been used previously. Intrusive methods such as bubbler (head DP), displacer, float, sight glasses, etc., may create possibilities for leakage and are unable to isolate from the process for verification or maintenance. Level gauges using glass may need to be avoided. If direct indication is necessary, level gauges using magnetically coupled indication have been used.

NOTE: Intrusive level methods have been used in the past and in many cases continue to be employed. However, users may wish to consider the benefits associated with a **non-intrusive** method of measurement for new installations and retrofits.

Although continuous measurement has many benefits, point measurement devices are sometimes used for high level (overfill detection). Point contact devices such as nuclear, radio frequency (RF) admittance, capacitance, vibrating fork, or ultrasonic techniques are utilized. When used, this high level device may incorporate self-diagnostic fail-safe circuitry. This switch is intended to supplement the primary continuous measurement and must be independent of the continuous level measurement loop.

6.5.8 Temperature Measurement

The insertion of temperature elements directly into the process increases the likelihood of phosgene leakage due to material compatibility issues with standard temperature elements, and weaknesses in the sealing arrangement needed for direct insertion of the temperature elements. Thermocouples and resistance temperature devices (RTD) can be used for remote reading of temperature. Bimetallic-indicating thermometers are also used for local temperature indication. Sheathed type Thermocouples, RTDs, and bimetallic thermometers may be considered for insertion into thermowells.

Consider the use of thermowells mentioned below. Consider installing thermowells on tanks in phosgene service from top, whenever practical.

Consider checking the welds on thermowells with dye-penetrant checked on the root and final pass, and on all full-penetration welds consider a volumetric inspection (e.g., ultrasonics and radiography) for mechanical integrity.

Thermowell: One approach consists of 1 ½" 300# RF flanged unit, 304L/316L material or better to suit process requirements and piping specifications. Utilize good engineering judgment in pipeline crossflow applications. Consider potential use of tapered design and whether the tip has been extended into the pipe farther than necessary. Sheaths for thermowells, of a more exotic material, or higher alloys, are often used to protect the thermowell from corrosion (material of construction to suit process requirements).

NOTE: Thermowells welded into the piping or vessels are being used in phosgene applications, especially double walled installations. Consider replacement and/or inspection of the thermowell in applications.

NOTE: The use of ceramic and graphite thermowells in phosgene service has raised concerns related to potential for breakage.

One approach that has been used in a number of installations is a temperature measurement that consists of temperature element, a spring-loaded thermocouple (T/C) or resistance temperature detector (RTD) assembly with ¼" outer diameter (OD) stainless steel sheath and flexible extension, and a transmitter, in many cases a smart programmable device with local indication. In some instances the temperature transmitter is not used. A thermocouple or RTD element is directly connected to monitoring and control equipment such as programmable logic controller (PLC) or distributor control system (DCS) input circuit/card.

NOTE: The direct mounting of a temperature transmitter to a thermowell has been utilized, if it is accessible for testing/calibration and when properly specified and maintained, there is reduced concern of process passing to the transmitter electronics and conduit system due to a thermowell failure.

6.5.9 Weight Measurement

Load cells, strain gauge scales and other weight measurements are non-intrusive methods used to infer other measurement types such as flow or level. This weight data can be used to infer flow when rate of change over time is calculated or level at a point in time, if vessel dimensioning and material properties are known.

6.5.10 Control Valves

Control valve(s) used for phosgene service include globe type valves with bellows seal stem design and a backup live loaded stem packing system.
Globe valve design with double set packing arrangement (live loaded), without bellows, has also been utilized. A leak detection port for monitoring may be considered.

Rotary valves are also used for phosgene service. These valves are often flanged, double packed with live loaded packing systems. It may be necessary that the ball valve cavity, when used in liquid phosgene, is vented.

Consideration of the following additional items may be useful:

- Tapped lug type butterfly valves installed between class 300# RF flanges have been used.

- It may be desirable to avoid the use of other flangeless (wafer style) valves, split body valve designs, and pop-out devices for the leak detection port.

- A switch, gauge or transmitter has been used when the monitoring of bellows or live load packing area was desired.

- Valves may need to be degreased/cleaned for phosgene service through the use of chlorine-cleaning practices. Consider whether packing materials and lubricants are suitable for process fluid and conditions.

- Evaluate whether the material of construction for a valve is suitable for the process fluid and conditions.

- Consider backwelding or otherwise eliminating threaded plugs or set screws (typically used to facilitate assembly/disassembly) which penetrate the valve body and are exposed to the process.

6.5.11 Actuated On-Off Plug Type Valves

A number of installations have utilized toxic service plug valves. One approach used previously, for reference, is: severe service design, live load packing, actuated by quarter turn rack and pinion actuator with 316SS coupling, mounting brackets and bolting, utilizing a limit switch package including SS solenoid valve, tubing and rebreather option.

ISO and NAMUR standards for accessories and mounting exist for valve and actuators. All stainless steel tubing and fittings have been used. Consider whether the actuator is sized for valve actuation and closure under all process conditions. Often these valves are the process isolation valves, as listed in piping notations *(Refer to Piping Items and Valves Section 6.3),* with actuator packages installed for remote operation.

6.5.12 Actuated On-Off Ball Type Valves

Installations have utilized "severe service" ball valves. One approach used previously, for reference, is: severe service ball valves, live load double packing (may be bellows sealed), actuated by quarter turn rack and pinion actuator with 316SS coupling, mounting brackets and bolting, utilizing a limit switch package including SS solenoid valve, tubing and rebreather option. ISO and NAMUR standards for accessories and mounting exist for valves, actuators and accessories. All stainless steel tubing and fittings have been utilized. Consider whether the actuator is sized for valve actuation and closure under all process conditions. Consider if this valve meets or exceeds the requirements of applicable piping specifications and process requirements. *(*Refer to *Piping Items and Valves Section 6.3).*

Chlorine-service valves have been used in pure, dry phosgene applications. *(*Refer to *Piping Items and Valves Section 6.3)*

6.5.13 Process Analysis

Process analyzers are used to provide continuous indication/control of operating parameters within the phosgene process. These systems are used to reduce and/or minimize the need for process sampling with its inherent dangers in sampling, containment, transport, lab analysis and disposal. It may be beneficial that a phosgene process analyzer system design employs inline equipment whenever possible and that the number of analyzer locations, the length of run and the number of tubing fittings used in the sample run are minimized.

NOTE: This section does not apply to laboratory analyzers.

Some examples of different measurements and analysis methods are listed below:

<u>CO Excess in Phosgene</u>
The infrared (IR) absorption method is frequently utilized. Gas Chromatographs (GC) have also been used, but can create drawbacks due to the multitude of additional leak paths and valves involved in GC design.

Cl2 in Phosgene
The UV absorption method has been used. GCs have also been used, but can create drawbacks due to multitude of additional leak paths and valves involved in GC design.

Phosgene in Offgas /Vent Gas
The IR absorption method is frequently used. GCs have also been used, but again may be subject to identified drawbacks.

Carbon Tetrachloride in Phosgene
Flame ionization or GC is frequently used.

Phosgene Concentration
The measurement method is based somewhat on the solvent used in the process. Nuclear, refractometers, and near infrared (NIR) absorption methods have been employed. A fiber optic based NIR system has been useful for this measurement.

6.5.14 Analyzer Sampling System Tips

- Consider minimizing fittings, and using pre-insulated/heat traced tubing bundles when practical.
- Consider physically protecting and marking sample tubing and bundles for phosgene service.
- Samples from the analyzers containing phosgene can be sent to the decomposition system or returned to the process.
- Analyzer systems have been installed locally in analyzer rooms/buildings to minimize length of sample runs.
- Analyzer building/rooms are not normally inhabited and access is monitored and controlled. Providing remote alarming for phosgene leak inside the building enhances personnel protection efforts.
- Near IR Fiber Optic, in situ, or other analyzer systems without sample systems have been used in a number of applications.
- Sample lines have been hard piped, per specification, as close as possible to the analyzer's sample conditioning system to minimize leak paths.
- Precautions used with calibration gas bottles are also relevant to activities involving the associated analyzers.

6.5.15 Process Sampling for Lab Analysis

Consider process sampling with a system designed for the safe sampling of fluids under pressure. The system can be designed so that the sample can be collected without any exposure to the operator. It is beneficial that the sample taken is the minimum size required for the analysis. Route venting or purging of the sample line or container to a safe and environmentally sound location. Consider whether the operators collecting the sample and the laboratory personnel performing the analysis have proper personal protective equipment (PPE).

References

[1]American Institute of Chemical Engineers (AIChE)
http://www.aiche.org/

[2]NAMUR – User Association of Automation Technology in Process Industries
https://www.namur.net