PREVENTION OF PLANT INSTRUMENT AND UTILITY GAS SYSTEM CROSS CONTAMINATION

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As part of a programme of harmonisation of industry standards, the European Industrial Gases Associations has published EIGA Doc 238 *Prevention of Plant Instrument and Utility Gas System Cross-Contamination*, jointly produced by members of the International Harmonisation Council (IHC).

This publication is intended as an international harmonised standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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1 Introduction

Process gases in HYCO plants are flammable and can be toxic. Prior to maintenance, piping and equipment are purged with nitrogen to prevent exposure to flammable or toxic gases. After maintenance, similar purging is done to prevent the mixing of flammable gas with air that entered the piping or equipment during maintenance. In addition, HYCO plants utilize nitrogen during startup to carry heat through the process until the piping and equipment are hot enough for steam and feed addition. All operating plants utilize control valves to maintain control of the process. These control valves require an instrument gas to operate.

To facilitate purging and startup, utility nitrogen connections are present throughout the process. These interconnections provide the possibility for cross-contamination between the process and utility air or instrument gases (e.g., CO in N2, H2 in N2). Similar cross-contamination potential exists when air that is backed up by nitrogen is used for the instrument gas (e.g., N2 in air, air in N2). If there is a connection between the utility gas and the instrument nitrogen backup, further cross-contamination is possible. In any of these cases, cross-contamination can lead to hazardous conditions. Exclusive use of nitrogen as the instrument gas eliminates one of the cross-contamination concerns but increases the possibility of asphyxiation hazards.

2 Scope and purpose

This publication provides recommendations and minimum requirements for the design and safeguards of utility and instrument gas systems and their interconnections, both permanent and temporary. It includes startup systems as well as maintenance and continuous purge connections. It identifies the potential hazards resulting from the connections between purge gases, instrument gases, and the process. These requirements may also be considered for existing facilities.

This publication does not cover process or product cross-contamination issues, but some of the principles covered in this publication could apply.

This publication does not cover breathing air systems.

This publication was developed around and applies to HYCO plants, which are facilities that produce hydrogen and/or carbon monoxide. These plants are typically operated with feed stocks such as natural gas, refinery off gas, naphtha, and other light hydrocarbons. The principles and concepts identified in this publication are applicable to other segments of the gases industry (for example, specialty gas plants and air separation units), although some of the scenarios described might not apply and some design details can require modification. Other technologies could require either more or less stringent minimum requirements depending on the specific application, whether contamination is a safety concern or a quality or reliability concern, and the severity of any consequences.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Breathing air

Breathable air supplied by a gas distribution system or apparatus (e.g., self-contained breathing apparatus [SCBA]) for individuals working in a confined space or hazardous atmosphere.

3.2.2 Enclosure

Area that is sealed off with an artificial or natural barrier. This includes electrical switch gear, instrument/analyzer cabinets, and motor housings.

3.2.3 Hazardous work permit (HWP)

Formal document allowing specific hazardous work on a specific system at a given time of day, by a designated individual, where potential risks are identified and considered in the permission.

3.2.4 Instrument air

Dry compressed air (not backed up by an inert gas) used for operation of small equipment and instruments such as positioners or I/P converters, compressor unloaders, control valves, vortex coolers, barring devices, flame scanners, analyzers and flare pilot ignition panels, cabinet purges, and drive motors.

NOTE—Instrument air is not intended for human respiration. Instrument air and breathing air systems are distinct and mutually exclusive.

3.2.5 Instrument gas

Compressed gas (usually air backed up by an inert gas, typically nitrogen) used for operation of small equipment and instruments such as positioners or I/P converters, compressor unloaders, control valves, vortex coolers, barring devices, flame scanners, analyzers and flare pilot ignition panels, cabinet purges, and drive motors. Alternately, instrument gas can be just an inert gas.

3.2.6 Lockout/tagout (LOTO)

Formal procedure for the isolation and securing of energy and stored energy in a system so as to make it safe for work and not allowing reenergization to occur until work is complete and all locks and tags are removed. Generally issued in conjunction with hazardous work permit.

3.2.7 Management of change (MOC)

Formal process for the evaluation and approval/denial of a proposed change.

3.2.8 Risk assessment

Overall process of risk identification, risk analysis, and risk evaluation.

NOTE—Some of the tools and methodologies used in a risk assessment include HAZOP, LOPA, FMEA, What if, etc.

3.2.9 Utility air

Compressed air used in operating pneumatic equipment or other non-process uses.

NOTE—Sometimes referred to as plant air.

4 General safety

To facilitate startup, maintenance, and normal operation, facilities are designed with process and utility interconnections. Segregation of gas systems is crucial to prevent cross-contamination and the subsequent formation of hazardous conditions. Proper operating and maintenance procedures are also required to limit the potential for cross-contamination and formation of hazardous conditions.

Inadvertent or unexpected cross-contamination of gases can be hazardous, impact quality, and/or affect long term durability of equipment and components. Some of the most common concerns related to cross-contamination are:

- Fire, explosion, or the creation of a dangerous byproduct due to incompatible gases coming into contact with each other. Examples include air with carbon monoxide or air with hydrogen;
- Asphyxiation due to the presence of inert gases or products when air is expected. Examples include: inert/purge gases such as nitrogen, argon, or helium unintentionally entering into the air system or nitrogen intentionally being utilized as a backup to instrument air supply;
- Presence of toxic, corrosive, or flammable components in purge or instrument gases, potentially endangering personnel. Examples include process gases backflowing into an instrument air or nitrogen supply;
- Product quality issues due to the addition of a contaminant that is not completely removed or is not detected. Cross-contamination leads to the risk of contaminating a gas stream or process with gases that are not expected. If the contaminants cannot be removed by the process or detected by analysis, contaminated product could be produced and make its way to a customer. Examples include argon used for welding application, nitrogen used in a maintenance activity, or nitrogen used in place of helium for a specific application where nitrogen is a customer contaminant; and
- Contaminants or by-products that are incompatible with system materials, leading to reduced service life or durability. Examples include high strength carbon steel being exposed to carbon monoxide or moisture.

Fire, explosion, and asphyxiation risks are exacerbated when the equipment is located in a building or enclosure.

The probability of cross-contamination can be reduced by ensuring that:

- process gas supply systems, purge gas connections, utility connections, and instrument gas supply systems are properly designed, constructed, and operated;
- any temporary startup or maintenance connections of purge gas to a process gas system are properly designed, reviewed, and managed;
- management of change (MOC) documentation and review of any system changes such as back-up nitrogen addition to the instrument air system after the plant is operational (for example, to address reliability issues) considers and addresses all possible interconnections and scenarios; and
- good safety management practices and/or risk assessment tools are routinely employed and the resulting documents periodically reviewed for accuracy and effectiveness.

Although all interconnections have the potential for cross-contamination, infrequently used purge connections have the greatest risk potential, since making these types of connections is typically a nonroutine activity. Purge connections may be made with flexible lines/hoses, and pressure ratings might not be the same as the system design pressure. If this temporary connection is left in place after use, it can fail due to overpressure resulting in flammable or toxic gas release. Failure of a flexible hose/line can lead to ignition of low ignition energy flammable gases such as hydrogen.

Risk reduction techniques should be utilized when working with toxic, corrosive, and/or flammable materials. For example, reducing the number of line break operations by installing dedicated purge points rather than removing components and tying into existing connections is recommended.

When preparing to conduct a nonroutine activity such as purging a line or piece of equipment for maintenance, installing a temporary blowdown connection, or replacing a component, appropriate safety tools shall be utilized. Examples of such tools include hazardous work permit (HWP), lockout/tagout (LOTO), job safety analysis (JSA), MOC, and risk assessment (hazard and operability study [HAZOP], layer of protection analysis [LOPA], failure mode and effect analysis [FMEA], what if, etc.). Any temporary connection used during normal operation shall be reviewed and controlled via the MOC process. Temporary hose connections used for purging in preparation for or during maintenance shall be controlled by an administrative program (for example, work permit, checklist, and/or jumper log). If use of temporary hoses is required as part on an operating procedure, the procedure shall clearly document that the hoses shall be disconnected when no longer required. An inspection step should be included to verify disconnection.

4.1 Basic design considerations for safety

Cross-contamination risks exist wherever process and purge gases interconnect. Well-designed systems consider the impact of cross-contamination and implement measures to reduce contamination risk that are consistent with the level of impact. When the impact of cross-contamination is significant enough, a quantitative risk analysis or layer of protection analysis is required in addition to the plant HAZOP. In some cases, an interconnection is prohibited. For example, instrument air systems shall not be used for breathing air; and breathing air systems shall not be interconnected with instrument air systems.

Instrument gas systems can be backed up by nitrogen for added reliability. When the instrument gas system is shut down and depressurized, the nitrogen backup cross-connection will activate and shall be considered when defining the isolation boundary for work permits.

If air is the primary source of instrument gas, proper design and sizing of the instrument air compressor system is necessary to limit the percent of time during normal operation that nitrogen enters the instrument gas system and/or to ensure proper operation of automatic valves, some of which may be used to limit cross-contamination. If instrument air demand exceeds compressor system capacity, the instrument air pressure will decrease; and control valves could cease to operate properly. Exceeding the capacity of the compressor system can cause moisture to break through, which could also impact control valve operation, in particular when the ambient temperature is below freezing. Whether the instrument air system is backed up by nitrogen or not, it is good practice to monitor the pressure of the instrument air and to alarm on low pressure. If analyzers are used to detect contamination, it should be noted that they can be in standby mode during maintenance outages.

Any instrument, instrumentation cabinet, or equipment enclosure purged with instrument gas should have an external warning label that advises that an oxygen deficient atmosphere can exist. Oxygen monitors may be carried or installed where appropriate.

If enclosures are purged for the purposes of area classification, drying, and/or cooling, purge gas can travel through electrical conduit to other areas. This can cause the inadvertent creation of a hazardous atmosphere where one might not be expected. Proper design of the conduit system is required to avoid this problem (see 6.1.2).

For processes containing toxic, corrosive, or flammable fluids, the plant design shall take into account the need to purge equipment and piping prior to and after maintenance. Enough purge connections should be installed as part of the original plant design to avoid the need to remove instruments or equipment (e.g., pressure safety valves [PSV]) to provide connections to facilitate purging. Use of instrument or equipment connections as purge points can increase the risk of leaks or equipment damage during and after reinstallation.

Regulators and regulator failures are a common factor in cross-contamination incidents, in part because of how regulators are designed and constructed. In regulators, the pressure specification break is halfway through the body of the valve: the pressure rating of the downstream half of the regulator can be less than the upstream half. This can apply either to the body of the valve or the regulator internals. In extreme cases, the downstream half of the valve body could fail if overpressured to the upstream pressure. Alternately, the internals could fail, increasing the likelihood of backflow across the regulator. Block valves installed upstream and downstream of the regulator to facilitate maintenance could create a scenario in which the downstream side of the regulator can be exposed to the upstream pressure. Over pressure protection shall be evaluated to protect the downstream half of the regulator.

Best practices when using regulators include:

correct installation and heat tracing to avoid formation of ice in the regulator spring, resulting in operational failure during winter;

addition of a vent pipe on the vent port and/or purge on a regulator to prevent moisture ingress;

routing the vent port pipe to a safe location based on leakage of upstream gas or backflowed gas (if identified as a hazardous scenario during system risk assessment); and

periodically reversing the set points of regulators that are installed in parallel, with slightly different set points such that one backs up the other, in order to verify that the regulators remain operable.

4.2 General design guidelines for avoiding cross-contamination

Although plant design details will vary depending on the specific process and the consequences of component failures and cross-contamination of process, utility, and instrument fluids, the following design guidelines apply to all systems:

Ensure that there is always sufficient driving force in the desired flow direction. If the pressure differential is small or if momentary equalization or pressure dips (reverse driving force) are possible, additional protective measures should be provided. Loss of source pressure is always a potential cause of the reverse flow/pressure drop case;

On both the process side and the purge gas side, ensure that materials of construction are compatible with all possible gases or contaminants that could be present at any time (temperature, pressure, and corrosion effects). Inadvertent misdirection of flow and side reactions should be considered;

Ensure that each component in the system used to prevent cross-contamination is included in the preventive maintenance program. Inspection and/or test frequency should be established based on cleanliness of the stream, compatibility of materials, and process conditions. Where check valves are used, if operating conditions favor only partial opening of a check valve, more frequent inspection and replacement will be necessary due to the rapid wear that occurs in partially opened check valves;

Ensure that the process streams are free from particulates (e.g., construction debris, corrosion products, and reaction products) to minimize damage to seating surfaces in valves (leak tightness);

Do not use regulators as the sole means of cross-contamination prevention. Regulators can and do fail, and they cannot provide sufficient isolation unless there is a positive pressure difference and gas is flowing through the regulator;

Do not depend on check valves as the sole cross-contamination prevention measure. Check valves, and the protection they provide, do fail. If a reverse driving force occurs repeatedly or for more than a few minutes (the time will depend on the specific application, including pressure differential), all check valves should be expected to leak; and

Check valve selection is a complex task. The following list contains key considerations in check valve selection:

Designer should consult the manufacturer or other industrial guidelines governing the selection of check valves

Specifying and selecting the correct sized check valve is essential to its operation and longevity:

Check valves that are partially open or chattering wear prematurely and have significantly more reverse flow leakage potential. Sufficient throat velocity is necessary to keep the check valve fully open during normal operation. The supplier may be consulted for assistance with sizing based on flow. A rule of thumb to consider for check valve sizing is that it should be one pipe size smaller than the pipe size on either side of the check valve. This raises the velocity in the throat of the check valve, which keeps the check fully open; however, any velocity safety limits for the gas shall be observed

Raising the cracking pressure of a check valve (e.g., with a spring) will improve the seating and minimize leakage in the reverse direction. However, the available pressure drop during operation should be high enough to allow for the valve to fully open

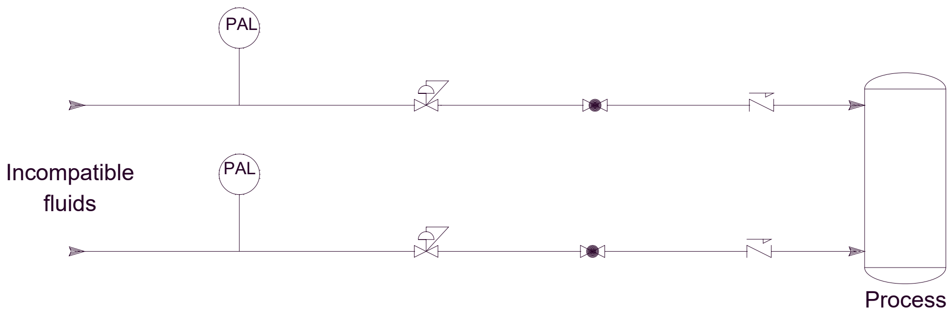
Check valve installation should be done in accordance with manufacturer’s instructions. In particular, orientation is a crucial characteristic that determines proper operation

Multiple check valves can be placed in series to increase the reliability of the backflow protection (see API 521, Pressure-relieving and Depressuring Systems for guidance on reverse flow through failed check valves) [1]. Using two different types of check valves from two different manufacturers is effective as diverse protection in reducing common mode failures (e.g., low flow effects on different valve types, manufacturing defects within a batch)

Check valves should be inspected internally or tested regularly if the criticality is sufficient. Check valves that require periodic testing could require installation of bleed valves on either side of each check valve to facilitate testing (see API 521 for check valve inspection and testing guidance) [1].

Figures 1 through 3 illustrate the application of these general principles and do not include all of the instrumentation and valves required. In all of these figures, over pressure protection needs to be considered in a misdirected flow scenario. A single check valve and / or regulator cannot be used to mitigate over pressure.

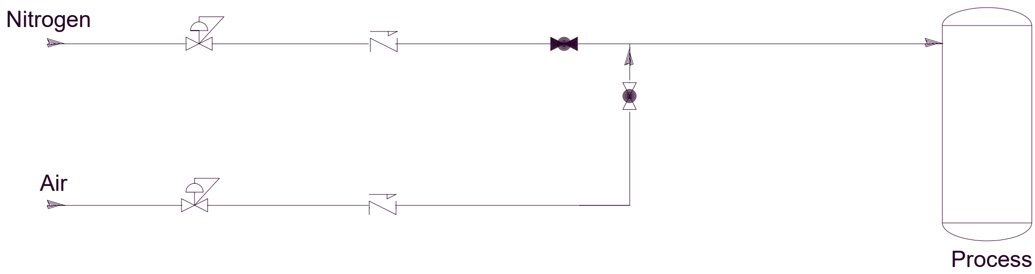
In Figure 1, two incompatible fluids (for example, two fluid streams that would react with each other) are both feeding a process. In this system, check valves and manual valves alone are not adequate backflow prevention if the process pressure can exceed the pressure of either or both feed streams. Using regulators and low-pressure alarms to manage pressure drop with less reliance on operator interaction provides an additional layer of backflow and contamination protection.



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 1—Indirect interconnection of incompatible fluids

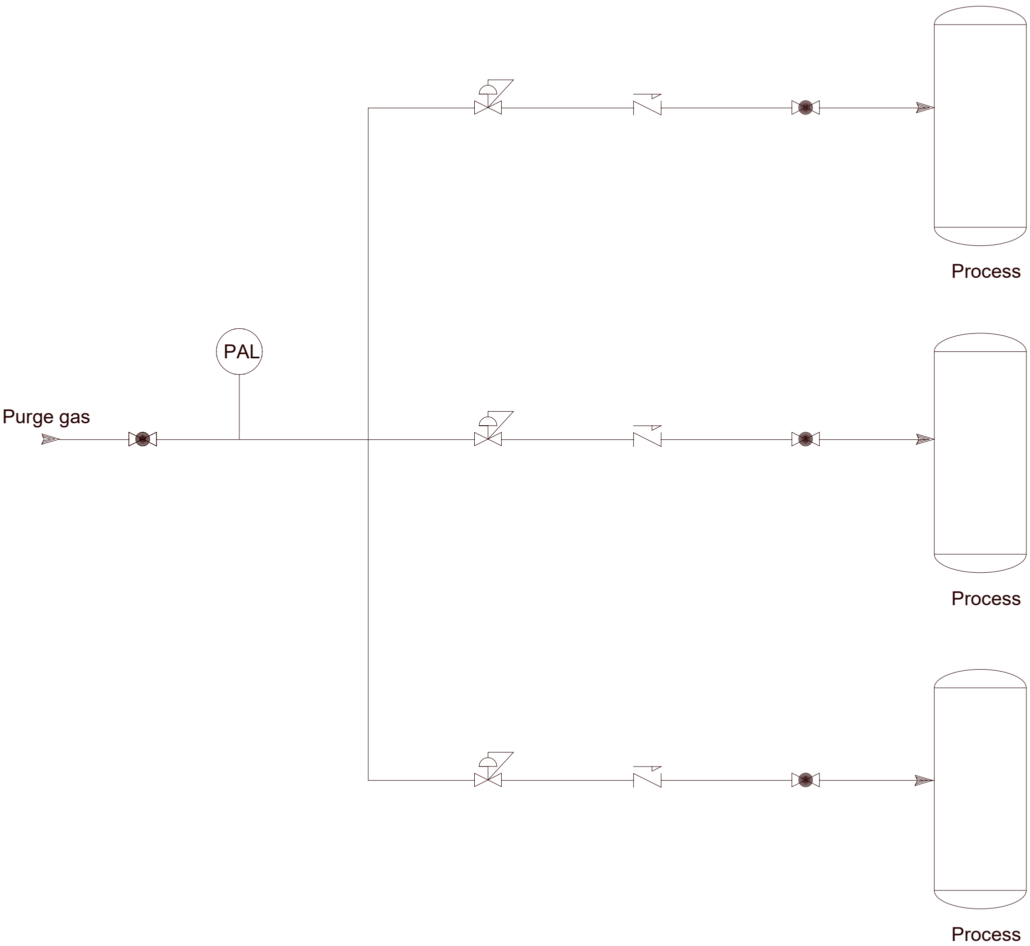
In Figure 2, two compatible fluids connect directly with each other, and the intent is to have only one of the lines in service at any one time. Check valves are required in the individual lines and provide a measure of protection against misoperation. The regulators provide another layer of protection, and pressure alarms may also be added to make the system more robust. The two individual check valves shall not be replaced by a single check valve in the common line feeding the process. A single check valve in the common line does not provide the same functionality as the two check valves.



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 2—Direct interconnection of compatible fluids

In Figure 3, a single purge stream is connected to multiple process purge connections that are attached to systems containing incompatible fluids (for example, multiple process streams that would react with each other). Individual regulators and check valves are required on each individual purge line. If a single regulator was installed in the common purge line, a single check valve would be the only backflow prevention measure on loss of purge gas pressure. The low-pressure alarm on the purge/feed stream further decreases the likelihood of reverse flow.



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 3—Single purge stream to multiple process lines with incompatible fluids

5 Types of systems

This section describes some of the types of systems that can be connected to the process as well as general configuration information of those systems.

Operating plants generally have a combination of process and support systems. Process fluids are utilized in the generation of products for customers or internal uses. Support systems terminate in convenient locations, often called utility stations, and typically provide or make accessible compressed air, water, nitrogen, carbon dioxide, helium, and/or steam. Utility purposes are those nonprocess-related general uses such as instrument gas, purging, pressure testing, cleaning, tool operation, etc. Instrument gases are utilized in the operation of instruments or equipment. Instrument air can be backed up by nitrogen or other dry gas for reliability purposes. Nitrogen is used for continuous or temporary purging. Where oil-free or high purity is required, users should verify the source of gas is appropriate.

Figure 4 gives an overview of the types of systems that can exist in a HYCO facility and how they can be cross-connected. Typical connections are:

- startup nitrogen for carrying heat through the process;
- temporary or permanent connections for purging of piping and equipment for maintenance;
- permanent connections for continuous equipment purging (e.g., compressor distance piece);
- permanent connections for continuous purging to maintain area classification;
- permanent connections for use of nitrogen to back up an instrument gas system;
- permanent connections for use of nitrogen to sweep flare headers; and
- permanent connections for use of a purge gas to automatically sweep out reactive gases or to sweep reactants out of a catalyst bed.

Figure 4 also illustrates that there can be multiple sources of nitrogen and instrument gas supply. These gases could have destinations beyond the plant boundary (such as to a customer), which results in additional cross-contamination concerns. These concerns are not explicitly addressed in this publication, although the general principles apply.

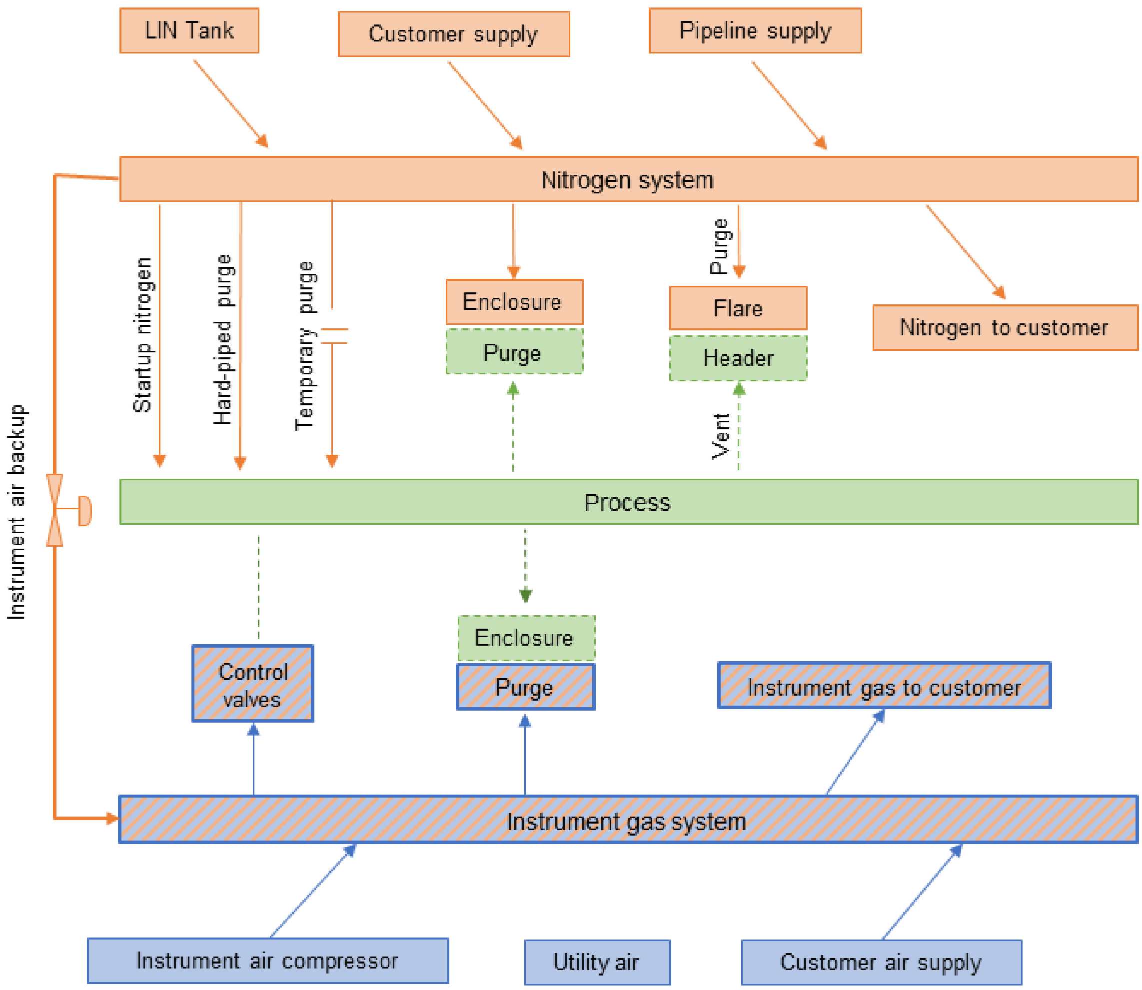


Figure 4—Overview of possible systems and interconnections in a HYCO plant

5.1 Utility air

Utility air can be used for driving pneumatic tools, pressure testing, or other nonprocess purposes. Because utility air is used for noncritical applications, it generally is not required to be dry. Typically, utility air has a dedicated pipe header running throughout the facility with drops in critical locations of the plant. These drop locations are primarily in areas with high maintenance activities.

Utility air should be supplied to the header via a standalone air compressor. It is possible to supply the utility air header from the instrument air compressor/header, but this comes with risks. These include overdrawing the instrument air header, leading to a potential facility reliability risk or cross-contamination potential.

Utility air headers should not be cross-tied with nitrogen headers or with instrument gas headers. If the utility air system is supplied from the instrument gas system, there shall be a method to positively isolate the utility air system from the instrument gas system. Nitrogen or the potential to have nitrogen used in a pneumatic tool can be a serious safety hazard, especially within a confined space.

5.2 Instrument air

Instrument air is a critical part of a running facility. Primary uses are to drive instrumentation and to purge or cool small equipment or cabinets. Typically, a pipe header is run throughout the facility with take-offs to each instrument air consumer. Main consumers of instrument air are control valves, vortex coolers, and small panel purges.

Air used for the purposes of instrument air should meet the requirements of ISO 8573-1 [2].

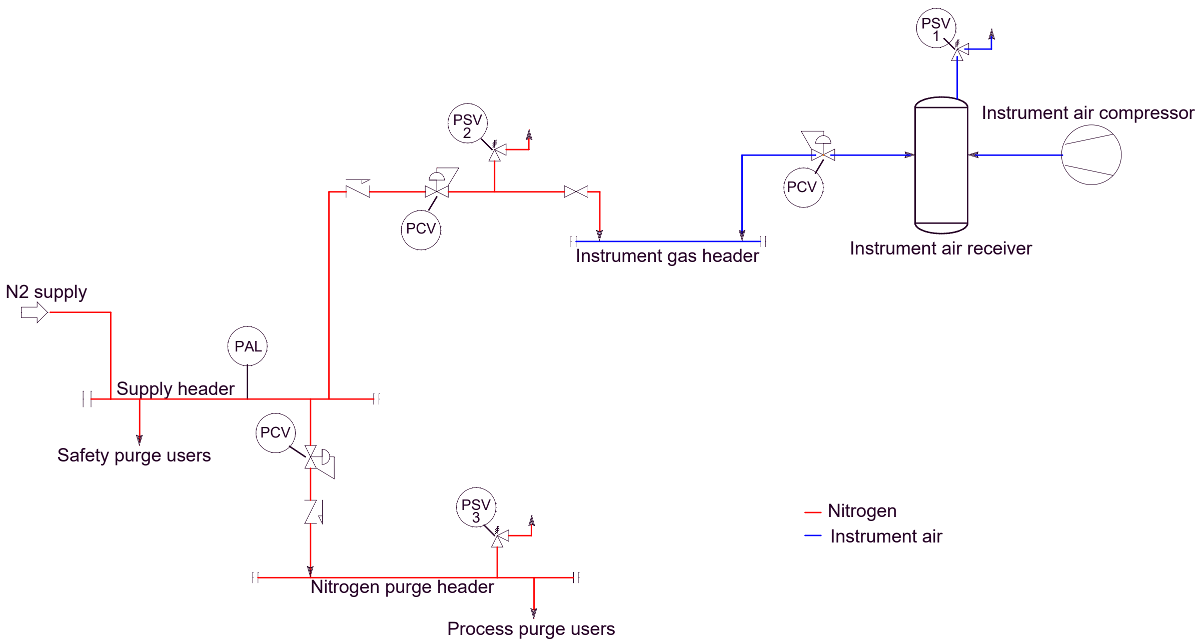
5.3 Instrument gas

For high reliability applications, nitrogen can be used to back up an instrument air system. When instrument air is backed up by nitrogen or other gas, the system is renamed instrument gas. In case of a loss of air supply to the instrument gas system, nitrogen will back it up until the air supply is restored. Alternately, another gas such as nitrogen, carbon dioxide, or helium can be used as the only source of instrument gas in a facility.

The cross-tie between the air and nitrogen systems leads to a chance of cross-contamination with oxygen in the nitrogen header and is designed to prevent backflow. The following are examples of the risks of backflow:

- If backflow of air from the instrument gas system into the nitrogen system were to occur, the contaminated nitrogen could introduce oxygen (from air) into a purged flammable fluid circuit. Because of this, an effective backflow prevention mechanism between the nitrogen system and the instrument gas system shall be designed into the system;
- When nitrogen is used to back up the instrument gas system, nitrogen that vents or leaks from instrument gas users could create an asphyxiating hazard for personnel. Consideration shall be given to the safety implications; and
- When nitrogen is used to back up the instrument gas system, equipment (for example, analyzers) that rely on the presence of oxygen to perform their intended function will cease to operate when on nitrogen backup. Consideration shall be given to the impact of loss of oxygen (in air) normally delivered to this equipment.

Figure 5 illustrates one method for providing nitrogen backup to the instrument gas header. There are multiple levels of nitrogen supply, which use cascading pressure levels as a primary safeguard against cross-contamination. The higher nitrogen pressure header (supply header) is protected from contamination by the lower pressure header (purge header). The lower pressure header can have hard piped connections to the process (see 6.2.2), where some contamination could occur if the connections are operated improperly. This is acceptable as the lower pressure nitrogen purge header is used for process purging, where contamination of the nitrogen with process gas does not create a hazard (the contaminants in the nitrogen are the same components as in the process line/equipment). Contamination of the higher pressure nitrogen supply header is less likely because of the pressure differential between it and the potentially contaminated lower pressure nitrogen purge header. The higher pressure nitrogen supply header is used for applications where the presence of process gas is a safety hazard (e.g., enclosure purges, where the purge gas comes in contact with air/oxygen).



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 5—Segregation of instrument gas and nitrogen headers using cascading pressures

In the system described in Figure 5, the following criteria apply:

- Instrument gas pressure typically ranges from 415 kPa to 760 kPa)[1] (60 psi to 110 psi)
- Nitrogen supply header pressure typically ranges from 1030 kPa to 4825 kPa (150 psi to 700 psi);
- Instrument gas header is backed up from the nitrogen supply header;
- PSV 1 is sized and set to protect the vessels and piping of the instrument air supply system;
- PSV 2 is set at a pressure less than that of the nitrogen supply header operating pressure and sized to avoid backflow of air into the nitrogen supply header;
- Low pressure alarm on the nitrogen supply header provides warning if the pressure differential drops to a point that might allow backflow of air into the nitrogen system. A double block and bleed is used for positive isolation to prevent backflow during this low pressure differential condition;
- Check valves are only dependable for momentary backflow interruption and cannot be used for prevention of cross-contamination;
- Nitrogen purge header operating pressure is set to less than that of the nitrogen supply header;
- PSV 3 is set at a pressure less than that of the nitrogen supply operating pressure and sized to avoid backflow of potentially contaminated nitrogen into the nitrogen supply header; and
- Multiple purge headers could be required depending on the level of compatibility of different process streams (for example, oxygen and natural gas).

Figures 5 and 6 illustrate, in more detail than Figures 1 through 3, the possible different approaches to system segregation.

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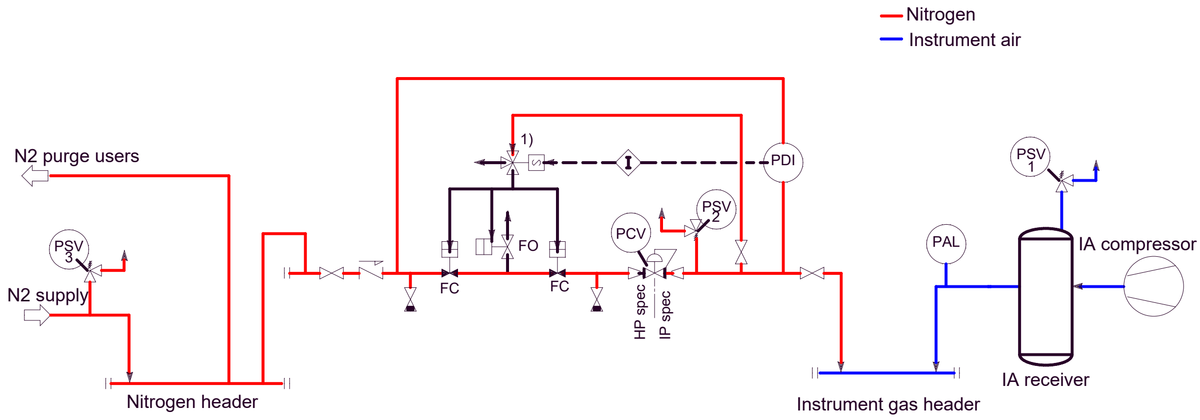
[1] kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off. (The CGA publication CGA P-89 refers to CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [3], which is not used in Europe).

Figure 6 illustrates another method for providing nitrogen backup to instrument gas using multiple valve types (check valve, regulator, automatic double block and bleed) to provide layers of protection against cross-contamination. This configuration should be used if the conditions for Figure 5 cannot be met. In Figure 6, the nitrogen header is being protected from air contamination. In this configuration, there is only one nitrogen header, which is used for all purge supplies.



NOTE—See Appendix A for the key to the symbols in the figure.

1) For simplicity, figure is shown with a single solenoid. For appropriate reliability and safety function, there should be redundant solenoids going to the three valves (configured such that either solenoid will cause the valves to operate), or each valve should have its own solenoid.

Figure 6—Nitrogen backup of instrument air with automatic double block and bleed

The basic guidelines for this type of connection are:

- Instrument air pressure typically ranges from 415 kPa to 760 kPa (60 psi to 110 psi);
- Nitrogen supply header pressure typically ranges from 1030 kPa to 4825 kPa (150 psi to 700 psi);
- Instrument gas header is backed up from the nitrogen supply header;
- Double block and bleed is used for positive isolation when nitrogen backup is not in use;
- PDI with interlock closes the double block and bleed if conditions are detected that could lead to reverse flow (air into nitrogen);
- PSV 1 and PSV 3 are sized and set to protect the vessels and piping of the instrument air (PSV 1) and nitrogen supply systems (PSV 3);
- Design pressure specification changes at the midpoint of the regulator body. Therefore, PSV 2 is sized and set to protect the downstream half of the regulator body up to the downstream isolation valve;
- Check valve is only dependable for momentary backflow interruption and cannot be used for prevention of cross-contamination; and
- Instrument gas pressure indicator has a low differential pressure alarm/interlock which is used to trigger open the double block and bleed if the N2 pressure exceeds the instrument gas system pressure, allowing back-up nitrogen to flow to the instrument gas system.

5.4 Nitrogen

Plants typically have a nitrogen header system that supplies gas to process equipment for purging, generally to remove flammable or toxic fluid or air/oxygen. The nitrogen header can also be used to sweep a vent or flare system to maintain an oxygen-free environment in the vent or flare system or to purge instrument cabinets or enclosures. The nitrogen header system is designed to minimize the likelihood of contamination due to backflow from the process. Depending on the level of incompatibility of the process fluids, the plant could be designed with multiple nitrogen headers with staggered operating pressures, with interconnections between the headers as illustrated in Figure 5 and described in 5.3. This configuration could provide an additional layer of protection in the event of contamination of one of the nitrogen headers by process fluid.

In addition to purging, the nitrogen system can also be used to:

- provide startup/circulation gas to the process circuit;
- provide pressurization gas to conduct a leak/pressurization/seal test of a reformer fuel system prior to lighting burners;
- maintain an oxygen-free blanket on catalyst beds or other equipment;
- maintain an oxygen-free blanket on liquid hydrocarbon and liquid ammonia storage vessels;
- provide nitrogen gas to utility stations;
- regenerate adsorbers;
- dry out piping or equipment; and
- derime cold boxes with heated nitrogen.

Nitrogen stations typically are installed at several locations throughout a facility.

6 Types of systems

Described below are typical connections from an inert gas purge source (typically nitrogen) to inert gas purge users (e.g., compressors, process piping, instrumentation, or electrical enclosures). Depending on the connection, one or more safeguards are required to prevent gas from the purged location flowing backwards and contaminating the purge gas source. The type and number of safeguards depends on the type of purge source and the risk assessment for each connection.

Connections between the process and a purge gas source are a contributing cause of a cross-contamination incidents. Many cross-contamination incidents occur because the process side pressure was greater than the purge gas source pressure. In these scenarios, the reverse flow rate will be dependent on the devices limiting backflow and their condition. The typical types of connections described below consist of at least two layers of protection. First, forward flow (source pressure greater than process pressure) and, secondly, a check valve. In a reverse pressure incident, only the check valve remains, and it is insufficient to prevent backflow if the reverse pressure condition lasts more than a few minutes (the time will depend on the specific application, including pressure differential).

Risk assessment methods applied to these types of connections shall consider the element of reverse flow. The following list contains some examples of cross-contamination incidents resulting from purge connections:

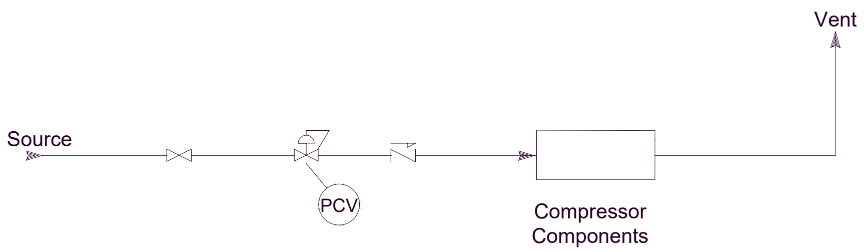
- Process leak into a continuously purged space exceeded the vent path flow capacity, which caused the space pressure to exceed the purge gas source pressure. The leaking gas contaminated part of the purge gas system;
- Inadvertent operations on the process caused process gas to be introduced prior to the temporary purge connections being removed. The process pressure exceeded the pressure of the purge gas source, and the purge gas system was contaminated with process gas;
- Flare subheader was left isolated from the main flare system with a nitrogen purge lined up. The process associated with this flare subheader was started, causing the flare subheader to go up in pressure. Process gas flowed in the reverse direction and contaminated the nitrogen system; and
- Using typical utility nitrogen through a temporary connection to derime a cryogenic tank (semi-trailer). Unknown to the operator, the tank contained some residual liquid; and the liquid vaporization caused the tank pressure to exceed the purge gas source pressure. The purge gas system was contaminated by the boil off gas.

In a plant designed with multiple nitrogen headers operating at staggered pressures, the implications of reverse flow of the process gas could be less than in a system where all inert gas users are supplied from the same header.

6.1 Continuous purges

6.1.1 Compressor components

Continuous purges on compressors are used for maintaining separation between a flammable material and an oxygen source such as air. On reciprocating compressors, the distance piece (between the crankcase and the cylinder) and piston rod packing are purged. On centrifugal compressors there are typically multiple layers of mechanical or labyrinth seals with an inert gas purge being used to separate the process gas seal from the air seal, see Figure 7. The crankcase is another commonly purged location. These are continuous purges and require sufficient safeguards between the process gas and the purge gas source to prevent process gas from flowing in the reverse direction and contaminating the purge gas source. Typical safeguards are a sufficiently large vent path such that the purged space cannot be pressurized, pressure drop (for example, due to a regulator or orifice) between the purge source and a compressor component, and a check valve to limit reverse flow.



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 7—Typical reverse flow protection for continuous compressor purges

6.1.2 Electrical and instrumentation enclosure purges

Purging of electrical and instrumentation enclosures can be done to meet area classification requirements. There are many suppliers that provide premanufactured area classification purge controllers that meet the requirements of IEC 60079-2 [4]. These controllers are simply installed on the enclosure and provide flow/pressure control, flow/pressure indication, overpressure protection, and alarm functions. Specific enclosure configurations vary by supplier and are not provided in this publication.

Purges may also be used for other purposes such as moisture control in large motor casings or terminal enclosures.

When purging for area classification or other purposes, the purge process puts pressure on conduit sealing fittings. The sealant material is not designed to stop gas passage when there is a pressure gradient across the conduit sealing fitting. This can allow purge gas to flow through the conduit leaving the enclosure. If an inert purge gas is used, this can cause a breathing hazard as the gas can be transported to unexpected locations. A break in the conduit run or additional conduit sealing fittings and venting can be required to provide a flow barrier.

When purging electrical panels or instruments with N2 or Air, the failure of the regulator controlling the purge shall be considered as a scenario that can lead to over pressure of the panel or instrument and which can result in injury to personnel. Over pressure protection shall be considered and evaluated.

6.1.3 Flare or vent sweep

Flare/vent headers and major branch lines are typically purged. The purge gas may be either inert or flammable. Purging of a flare or vent header ensures that deflagration or detonation does not occur within the header when flaring or venting flammable gas. These are continuous purges that require sufficient safeguards between the process gas and the purge gas source to prevent process gas from flowing in the reverse direction and contaminating the purge source, see Figure 8. Typical safeguards are:

- sufficiently large vent path such that the purged headers and branch lines cannot be pressurized;
- pressure drop (for example, due to a regulator, orifice, or rotameter) between the purge source and the headers and branch lines;
- flow control/indication (could be the source of pressure drop);
- check valve to limit reverse flow; and
- optionally, a low flow or pressure alarm.

NOTE—See Appendix A for the key to the symbols in the figure.

Figure 8—Typical reverse flow protection for flare or vent purge

6.2 Connections for maintenance

6.2.1 Temporary connection

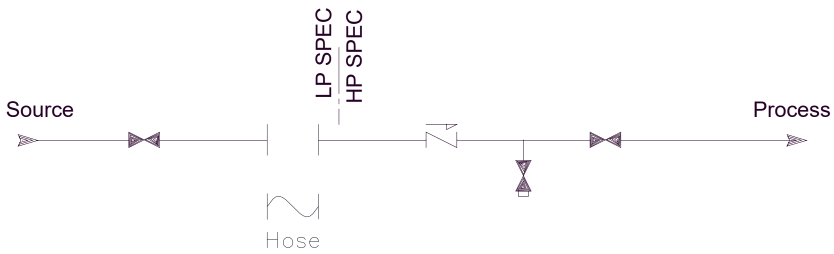
Utility stations provide sources of fluids that can be used to purge process equipment for routine maintenance. These stations typically use relatively low pressure rated hoses and should only be used on depressurized equipment, depressurized process piping, or activities external to the process.

Figures 9 through 11 illustrate the minimum requirements for a hose connection. Figures 9 and 10 show temporary connections in their isolated or safe condition. Figure 11 shows the valve lineup when the temporary connection is in use:

- Isolation valves shall be provided on both the source side and the process side. Valve selection will be dictated by the degree of leak tightness and the required flow;
- Throttling valve may be added on the source side;
- Bleed valve shall be provided to depressurize the hose prior to disassembly. The order of the bleed valve, check valve, and block valve may be varied depending on the specific requirements of the application;
- Check valve shall be provided on either the source side or the process side to reduce the risk of process gas contaminating the source. A check valve on the process side also prevents backflow in the event of misoperation and limits any release in the event of a hose failure. In some applications, there will be check valves on both sides;
- Design pressures of the source side and process side shall be considered in the selection and orientation of the components, including the pressure rating of the hose. If there is sufficient risk (e.g., highly toxic fluid), hoses that are inherently safe from overpressurization due to their pressure rating should be chosen. Figure 9 shows the pressure specification break location for the case where the process design pressure is greater than the source design pressure. Figure 10 shows the pressure break location for the case where the process design pressure is lower than the source design pressure; and
- Specific characteristics (e.g., pressure, temperature, toxicity, corrosivity, flammability) of the process gas can dictate valve selection and preferred placement of the check valve due to safety and environmental concerns.

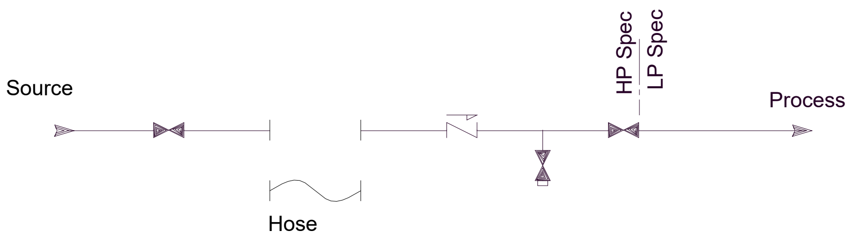
During normal operation, the hose shall not be connected to the process side. The disconnected hose provides an air gap, which is a positive (visible) isolation that prevents cross-contamination. In the event that the hose is left attached to the source side, its outlet should be capped, plugged, and/or blinded in order to prevent hose whip or release of an asphyxiant. The hose connection on the process side should also be capped, plugged, and/or blinded. The cap/plug/blind shall have a pressure rating and material of construction consistent with the process.

Good industrial practice requires the use of hose whip restraints at all connection points. Armored hoses or hoses with internal whip restraint cables protect against hose whip resulting from failure anywhere along the length of the hose.



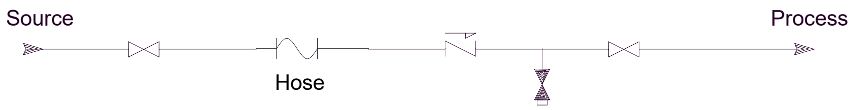
NOTE—See Appendix A for the key to the symbols in the figure.

Figure 9—Hose connection in isolated safe condition, low pressure source



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 10—Hose connection in isolated safe condition, high pressure source



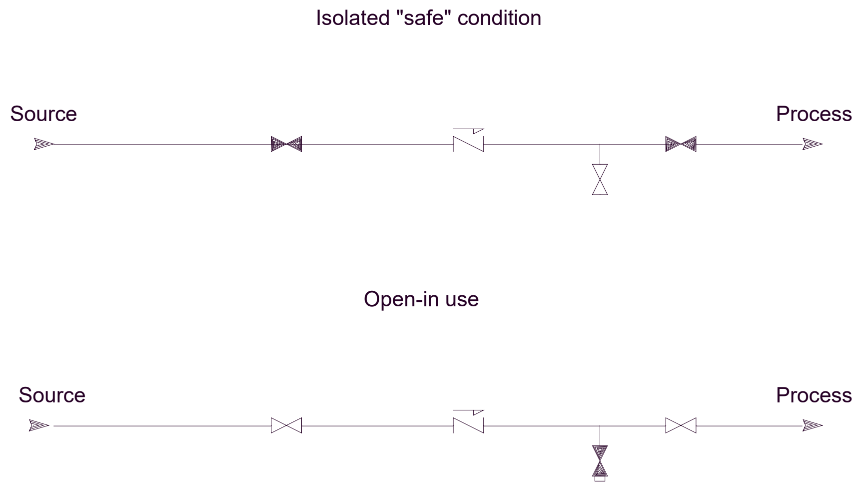
NOTE—See Appendix A for the key to the symbols in the figure.

Figure 11—Hose connection in use

6.2.2 Hard piped purge connections

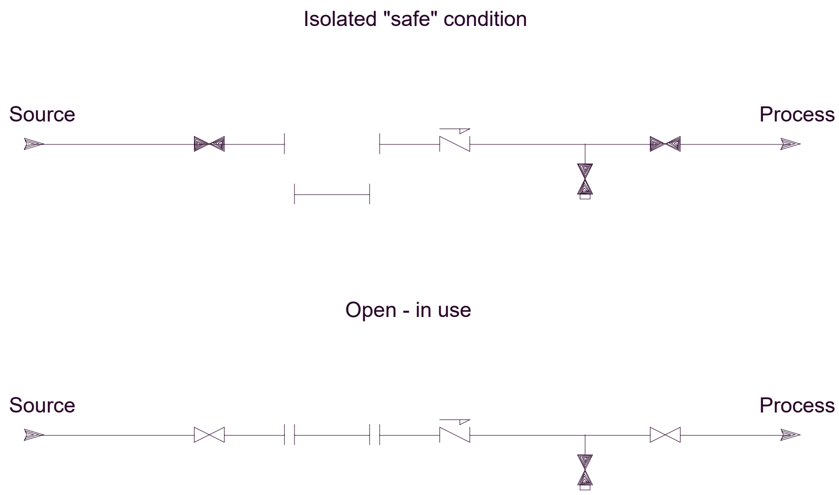
Some purge connections that are only used for maintenance (i.e., not normally flowing) are hard piped. Using a double block and bleed connection, with the block valves closed and the bleed valve open when the connection is not in use, is one option. If the bleed valve cannot be left open, a removable spool piece that has blind flanges installed when the connection is not in use, or a spectacle blind are possible alternatives. When a spectacle blind or blind flanges is/are utilized, consideration needs to be given as to whether additional valves are required to enable the blind(s) to be installed, removed, or swung.

Figures 12 and 13 show the minimum requirements for the 2 configurations. Figure 12 as shown is applicable primarily when the purge header can tolerate some amount of contamination (i.e., multiple purge headers at cascaded pressures exist – see Figure 5). If the purge header cannot tolerate any contamination, the need for additional layers of protection (e.g., multiple block valves on the process side) should be considered. The process fluid and operating conditions can dictate additional layers of protection requirements whether the Figure 12 or Figure 13 configuration is followed. Additional layers of protection could also be required if the isolation valves could have a tendency to leak due to either size or type. The pressure specification break and over pressure protection requirements can vary depending on the relative design pressures of the source and process.



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 12—Hard-piped purge connection with double block and bleed reverse flow protection

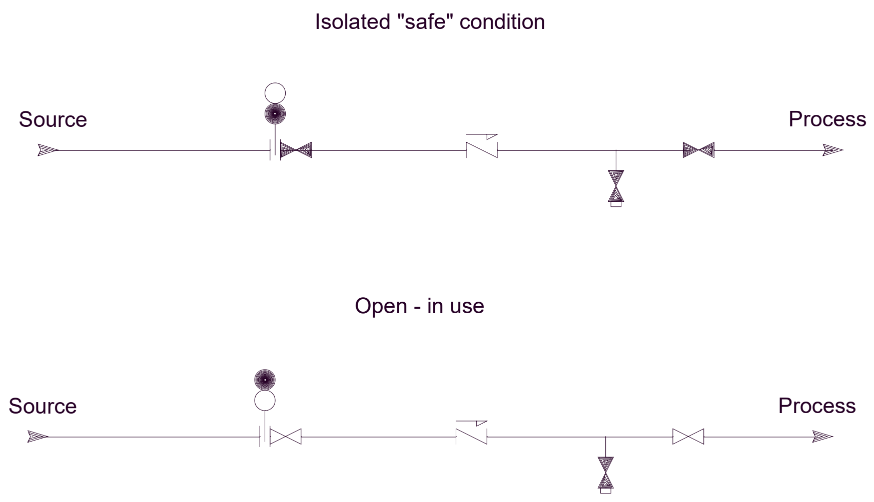


NOTE—See Appendix A for the key to the symbols in the figure.

Figure 13—Hard-piped purge connection with removable spool piece for reverse flow protection

6.3 Process connections for startup

Heat transfer gas such as nitrogen is used for startup. This may be supplied through a once-through connection or a recirculation loop. Startup recirculation loops do not contribute any additional risk of cross-contamination of the instrument air, instrument gas, or nitrogen supply systems. However, the recirculation loop attachment points are isolated from the main process gas line during operation. These connections are large and may be configured as shown in Figure 14 where a spectacle blind is used to provide positive isolation. In this configuration, the bleed valve is plugged during normal operation and closed when the line is in use and flowing. Note that additional provisions could be required to enable rotating the position of the blind. Alternately, a hard-piped connection like that shown in Figure 12 may be utilized, although modifications to reduce contamination potential could be required depending on the source and destination of the recirculation gas (for example, from upstream/downstream of PSA, to product/feed/standalone compressor). In this configuration, there is no blind to provide positive isolation, so the bleed valve is required to be open to atmosphere when the line is in its isolated condition (with plug removed).



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 14—Nitrogen startup connection using blind for reverse flow protection

6.4 Pneumatic force to drive valve actuators and pneumatic motors

Instrument air, instrument gas, or nitrogen can be used for the purpose of driving valve actuators or pneumatic motors. Use of a gas for this purpose does not usually present a risk of cross-contamination, unless the valve actuator is direct-connected to the valve body such that an actuator diaphragm leak can backflow into the pneumatic gas depending on pressure differential. However, the use of nitrogen or instrument gas to drive an actuator or a pneumatic motor that is enclosed in an insufficiently ventilated space can present an asphyxiation risk. This risk is particularly acute if instrument gas is used, as it can suddenly switch to nitrogen and convert a breathable atmosphere to an asphyxiating atmosphere. General information on the prevention of the hazards associated with inert atmospheres can be found in EIGA Doc 44, *Hazards of Oxygen-Deficient Atmospheres* [5].

6.5 Back-up connections

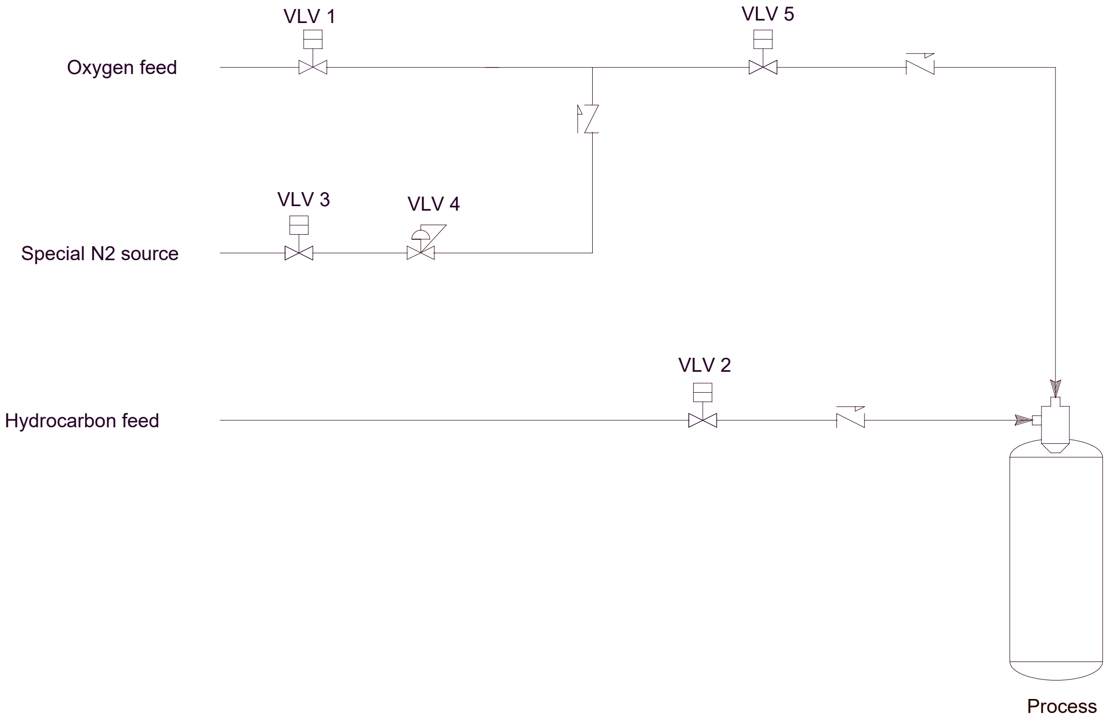
See Section 5 for more information on purge gas source systems and for methods to back up an instrument gas system.

6.6 Automatic sweep of reactive gases

In systems where two incompatible fluids are indirectly connected to the same process (see 4.2), an inert purge may be used to provide a buffer between the fluids in the event of a shutdown or loss of flow. This is illustrated in Figure 15 for a gasification process. The hydrocarbon feed gas and oxygen are fed into the reactor, which is above the autoignition temperature. The reactant gases meet indirectly at the end of the feed injector. The nitrogen purge system, through sequential valve operation, provides a safe buffer in the event of a shutdown and flushes the remaining reactant into the process (valves 1 and 2 shut off the reactant flow; valves 3, 4, and 5 operate in a sequence to provide the safe buffer).

NOTE—VLV 1, VLV 2, and VLV 3 may be double block valves.

A similar configuration to that shown in Figure 15 may be used to sweep process fluids out of a catalyst bed or other piece of equipment.



NOTE—See Appendix A for the key to the symbols in the figure.

Figure 15—Automatic sweep of reactive feed gases

7 Operational and retrofit considerations

Previous sections have focused on design concepts and minimum requirements for the hardware associated with instrument air, instrument gas, utilities, and nitrogen supply systems. These concepts have been developed over time to minimize cross-contamination and other hazards associated with the use of these gases. Procedures that are consistent with the system design are necessary to operate in a safe manner.

When a system within the scope of this publication is found with either inadequate design or inadequate/inconsistent procedures (such as after an acquisition), a plan for improvement is required. A risk assessment should be performed, and the procedures or equipment shall be adjusted to address the identified hazards. If equipment changes are required and cannot be done immediately, additional administrative controls shall be put in place per the results of the risk assessment.

Because design concepts and operating procedures evolve over time, changes will continue to be made throughout the life of the plant. In addition, there will be continuous improvement initiatives, plant reliability improvements, plant optimizations, debottlenecking, and replacement of obsolete equipment. Every change within the scope of this publication, regardless of scale or complexity, has the potential to increase the risk of contamination and to negatively affect safety. Each proposed change shall be fully evaluated to ensure that the change does not unduly affect the safety of the plant. All hazards shall be documented, actions identified, and closures tracked.

One example that has the potential for significant implications is when an existing facility has a separate instrument air and nitrogen system, and the decision is made to improve the reliability of the instrument air system by cross-tying it with the nitrogen system. In addition to overpressurization hazards, switching over to nitrogen can cause items such as analyzers to stop working, or can cause cross-contamination risks or unexpected asphyxiation hazards.

Any change shall follow, at a minimum, the site's MOC process, including full documentation of the change, completed engineering drawings, procedure modifications, hazard review, and training. Additional tools such as process hazard analysis, quantitative risk assessment, and layer of protection analysis might be required.

8 References

Unless otherwise specified, the latest edition shall apply.

[1] API 521 *Pressure-Relieving and Depressuring Systems*, American Petroleum Institute. www.api.org

[2] ISO 8573-1 *Compressed air – Part 1: Contaminants and purity classes*. www.iso.org

[3] This reference is not used in Europe, only given to be aligned with IHC: CGA P-11 *Guideline for Metric Practice in the Compressed Gas Industry,* Compressed Gas Association, Inc. www.cganet.com

[4] IEC 60079-2:2014 *Explosive atmospheres - Part 2: Equipment protection by pressurized enclosure "p"*, www.iec.ch

[5] EIGA Doc 44 *Hazards of Oxygen-Deficient Atmospheres,* www.eiga.eu

Appendix A—Legend for figures (Informative)

 Bleed valve closed with plug

 Check valve

 Gate valve open

 Gate valve closed

 Globe valve open

 Globe valve closed

 Flexible hose

 Pressure regulator

 Removeable spool piece

 Automatic open/close valve