



CGA P-89—2021

PREVENTION OF PLANT INSTRUMENT AND UTILITY GAS SYSTEM CROSS CONTAMINATION

FIRST EDITION

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PREFACE

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has published CGA P-89, *Prevention of Plant Instrument and Utility Gas System Cross-Contamination*, jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized 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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NOTE—Appendix A (Informative) is for information only.

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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

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 of 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