SAFE LOCATION OF OXYGEN AND INERT GAS VENTS

AIGA 067/17

Revision of AIGA 067/10

Asia Industrial Gases Association

52 Jurong Gateway Road,JEM, #15-02, Singapore 608550
Tel : +65 6276 0160 • Fax : +65 6274 9379
Internet : http://www.asiaiga.org

SAFE LOCATION OF OXYGEN AND INERT GAS VENTS

As part of a programme of harmonization of industry standards, the Asia Industrial Gases Association (AIGA) has issued publication, AIGA067, *Safe Location of Oxygen and Inert Gas Vents*, jointly produced by members of the International Harmonisation Council and originally published by the European Industrial Gases Association (EIGA) as IGC Doc 154, *Safe Location of Oxygen and Inert Gas Vents.*

.

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

ASIA INDUSTRIAL GASES ASSOCIATION
52 Jurong Gateway Road,JEM, #15-02, Singapore 608550
Tel: +65 62760160 Fax: +65 62749379
Internet: http://www.asiaiga.org

Table of Contents

Amendments from 067/10

Section	Change
	Editorial to align style with IHC associations
3.1	Addition of Publication terminology
6.6	Information added about low pressure vents and need for additional review
Appendices	Addition of “Casings and volutes”
3.4.1.6	Removal of tables covering low pressure vents.

Note: Technical changes from the previous edition are underlined

1 Introduction

This publication defines the criteria for the design of process vents to ensure the safe disposal of oxygen and inert gases.

Industrial gas producers are subject to more and more stringent demands from authorities to demonstrate that the operation of their plants is safe. A number of incidents have been reported where enriched or deficient atmospheres from venting operations have created operational safety issues [1, 2]. As air separation unit (ASU) capacity has increased, the risk of oxygen-enriched and oxygen-deficient atmospheres has become a significant safety concern.

2 Scope and purpose

2.1 Scope

This publication applies to air separation and cryogenic liquefaction plants in which the venting of oxygen, nitrogen, oxygen/nitrogen mixtures, argon, or air occurs.

Disposal of cryogenic liquid is not covered in this publication although the potential for vent releases to have some liquid present is included (see 5.5).

The recommendations contained in this publication for elevations and horizontal separation distances are not applicable to customer station tanks. Safety distances for such tanks are governed by the design criteria for plant layout or national regulations/codes of practice, whichever are more stringent [3].

2.2 Purpose

This publication is designed to give a basis on which to determine the safe location of oxygen or nitrogen and argon gas vents for normal operating, upset, and emergency conditions. This determination can be made by calculation against the criteria specified or by use of the tables provided in the appendices as a guide.

The publication contains calculated safe separation distances for a range of vent sizes and orientations based on commonly encountered but specific design conditions. If these design criteria are not met particularly with regard to vents intended to operate over a large range of flows (for example, product vents having turndown flows), the tables may not be appropriate and detailed calculations should be carried out.

This publication should be used for new designs but can be used on existing plants to determine whether existing vents are safely located or whether modifications/temporary structures will interfere with the original design intent.

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 Inert gases

Gases that do not readily react with other materials under normal temperatures and pressures.

NOTE—Examples include argon, nitrogen, and helium.

3.2.2 Pressure

Bar indicates gauge pressure unless otherwise noted: bar, abs for absolute pressure and bar, dif for differential pressure.

4 Hazards of oxygen-enriched or oxygen-deficient atmospheres

Oxygen, which is essential to life, is not flammable but supports and accelerates combustion.

Oxygen reacts with most materials. As the oxygen concentration in air increases, the potential fire risk increases. The more vigorously the combustion reaction or fire takes place, the lower the ignition temperature and the ignition energy to get the combustion reaction started, and the higher the flame temperature and destructive capacity of the flame.

If the oxygen concentration in air decreases or if the concentration of inert gases increases, there is a risk of asphyxia. Lack of oxygen can cause vertigo and speech difficulties but the victim does not recognise these symptoms as asphyxiation. The asphyxiating effect of inert gases takes place without any preliminary physiological sign that could alert the victim. This action is very rapid: it only takes a few seconds to occur at very low oxygen concentrations.

The hazards from oxygen enrichment are explained in AIGA document 005, *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres* [4]. The hazards of oxygen deficiency are explained in AIGA document 008, *Hazards of Inert Gases and Oxygen Depletion* [5]. Acceptable safe oxygen concentrations in air are as follows:

- The maximum safe concentration for entry into a confined space is 23.5% oxygen by volume;
- The minimum safe oxygen concentration for entry into a confined space is 19.5% oxygen by volume; and
- The space should be ventilated sufficiently to obtain a value approaching 21% oxygen by volume (indistinguishable from atmospheric air).

Vents are distinguished separately on the basis of the acceptability of minimal risk.

The choice of concentration limits acceptable for vent location design is discussed in Section 5.

5 Factors for consideration in the location of vents

5.1 General considerations

The safe location of any vent to atmosphere is dependent on the venting conditions, the hazards associated with the gas at the vent conditions, the vent use frequency, and environmental considerations resulting from the gas being released. From these conditions will come decisions on vent height and orientation relative to surrounding equipment, personnel access areas, and prevailing wind direction. Consideration also has to be given to the effects of any release outside the plant boundary where the risks are affected by the nature of the surrounding area (industrial, commercial, urban, or rural conditions) as well as the numbers of people that could be subject to any release.

The following hazards are associated with vented atmospheric gases from industrial gas operations:

- asphyxiation (nitrogen and argon);
- enhanced fire risk (oxygen);
- cold and low visibility (cryogenic gases and liquids); and
- hot gases (for example, compressor interstage relief/discharge gas vents).

NOTE Gases or mixtures containing flammable or toxic components such as hydrogen, carbon monoxide, or carbon dioxide can be discharged from operations involving atmospheric gas processing but venting of these is NOT covered by this publication.

Vent use frequency can be categorised in the following terms:

- continuous;
- intermittent in normal operation;
- commissioning/startup/shutdown;
- performance testing;
- emergency pressure relief; or

- emergency depressurisation.

In general, only those vents that are either within the total control of the plant operation such as vents operated manually on an intermittent basis (for example, start up, shutdown, tanker fill), or those vents expected to be open for a short duration protection (for example, pressure relief devices, automatic dumps) can be assessed as being on a non-continuous basis.

In addition, the influence of exit velocity is important where gases being vented at the warm end of an ASU can be vented at any flow rate between the nominal design capacity and zero. Such reduced venting flow rates are typically met during the adaptation period of the ASU after a sudden change of the client demand or when the nitrogen/oxygen ratio of the client demand does not match with the ASU production ratio. Therefore, the correct design of the vent stack of the separated gas streams exiting the warm end of an ASU shall take into account the potential reduced flow rates in normal operation when determining the vertical height of the vent. See 6.6 and Appendix H for further information.

Environmental protection considerations include:

- acceptable noise levels;
- visibility of emission; and
- local and national authority requirements.

In determining the disposal of vented gases, consideration should be given to whether the plant is unmanned because remedial action in the event of a gas release could be delayed. In general, the risks from venting from an unmanned plant should be no different from a fully attended facility because the periodic presence of people cannot be ignored.

The risk of damage to adjacent equipment or injury to people shall be determined taking the previous considerations into account.

The following subsections give more detailed consideration to the factors involved in safely locating atmospheric vents.

5.2 Selection of concentration criteria for specific circumstances

Vent locations shall be determined in relation to the hazards of oxygen or inert gas releases given in Section 4. On the basis of the risks from various gas concentrations summarised in Section 4, organisations may set their own concentration limits for the various vent types taking account the general considerations given in 5.1, and based on their own safety philosophy.

In principle, the general public should not be subject to any potential risk greater than that resulting from their normal activities, and so consideration shall be given to ensuring that all identifiable vent release cases do not result in oxygen concentrations outside the range of 19.5% to 23.5% oxygen by volume at ground level outside the plant boundary or at the height of buildings adjacent to the property line. These limits can also apply to adjacent industrial sites; however, for customer premises where the air separation plant products are being piped, it may be appropriate to treat the risks from gas vents as being the same as within the air separation plant boundary.

Within the plant boundary, a higher oxygen concentration from any vent may be acceptable at all normally accessible points within the facility provided that management controls of items such as unshielded flames, grinding or welding, and smoking are in force. The recommended value is a maximum expected concentration of 25% oxygen by volume for all identified vent cases.

Similarly, the risk from exposure to low oxygen concentrations (inert gas releases) can be controlled within a plant. For vent locations with known release conditions, it is recommended that a minimum expected oxygen concentration of 17% oxygen by volume be used as the design basis for all vents. Consideration may be given to increasing this limit to a higher value in order to provide safety margins for the effect of unknowns in the release cases or atmospheric conditions in making such an evaluation. The calculations described in Section 6 give inert gas dispersion limits to 18% oxygen by volume as a guide as well as 19.5% oxygen by volume and 17% oxygen by volume.

National or local regulations can specify different concentration limits for exposure, in which case these would supersede any previously recommended criteria.

The effects of variations in the release conditions are discussed in the following subsections.

5.3 Vent locations

In general, vents shall be orientated such that the discharge gases, warm or cold, cannot impinge directly on personnel, structures, working areas, or equipment.

The following is a summary of experience during engineering and operation of air separation plants:

- Ingress of vented gas into process air intakes, buildings, and air conditioning/ventilation systems shall be avoided;

- Vents from equipment situated inside totally enclosed rooms or buildings shall be piped to outside locations unless preventative measures against the hazards of oxygen-enriched or oxygen-deficient atmospheres are adopted;

- Vents shall be located so personnel on access platforms or walkways are not exposed to the hazards of oxygen-enriched or oxygen-deficient atmospheres unless controls are in place to manage the risk;

- Separation distances between oxygen vents and flammable gas vents shall be considered to avoid the risk from the effects of enhanced combustion;

- Separation distances between oxygen vents and flare systems of adjacent plants shall be defined to ensure the safety of the installation;

- Cold gas vents should be designed and located to manage fogging, ice formation, blockage due to precipitation, and cold embrittlement of structures and equipment;

- Even though the vertical release of a vent gives the best location in relation to height, it is often useful to install the vent outlet with an angle to give the gas stream a specific release direction, for example, away from a supporting structure such as a coldbox;

- If the vent outlets are located adjacent to or between taller structures such as buildings that are relatively close, the vent heights should be selected to mitigate the hazards of oxygen enrichment or deficiency. The influence of obstacles to unrestricted venting shall require a specific risk assessment;

- High pressure non-continuous vents (for example, safety valves outlets) shall not be directed at platforms, ladders or other access points, and shall not blow directly onto equipment. This is to prevent injury to persons and damage to equipment from high velocities even if a hazard from an oxygen-enriched or oxygen-deficient atmosphere is not anticipated;

- Even if safely located with regards to dispersion, vent outlets (particularly at high pressure) can be a noise hazard. Vent position and orientation should account for both the environmental and occupational health effects of noisy releases; and

- Vents released at higher elevations can be exposed to a higher local wind speed than those released at lower elevations. Greater turbulence due to higher wind velocity at higher release elevation tends to cause releases at higher elevations to disperse more readily. Reduced separation distances may be justified for elevated platforms if the vent location is relatively high off the ground but it should be determined through a risk assessment.

NOTE Dispersion calculations usually do not take into account vents that are located on or at the side of buildings in the area where flow patterns across roofs can give rise to downdrafts of air flow. The likelihood of downdraft flow patterns should be considered during the design phase and the location of vents should be selected to minimize or eliminate any adverse effects on the gas dispersion plume.

Care shall be taken in case of plant modifications, including erection of temporary structures to gain access to maintenance or modification work to ensure that changes in the plant do not make the locations of existing vents unsafe with regards to orientation. Existing vent locations need to be fully reassessed if the vent cases are likely to change as a result of modifications.

In any case where an oxygen-enriched or -deficient atmosphere is possible, a warning sign should be posted at the base of ladders and access points concerning possible oxygen-enriched or oxygen-deficient atmosphere. The location and arrangement of such vents and the disposition of warning signs should be the subject of a safety review. Portable air monitoring instruments should be worn during access to such areas.

By design, continuous, large capacity process vents such as oxygen, waste, and low pressure nitrogen can be grouped in one general area to make use of a common support structure. Normal vent location selection criteria would not generally account for several or all of these vents operating at the same time. Special consideration may be required for such arrangements.

5.4 Effect of weather and release conditions

The following weather factors can have a detrimental effect upon the dilution of the vented gas:

- high ambient temperatures in relation to the vented gas;
- moderately stable atmospheric conditions; and
- low wind speed.

Calculations are usually carried out over the normal reported range of weather conditions to determine the worst case effect but extremes in the previous factors can have significant impact on estimated plume distances especially if the vent release conditions are a plume (low velocity) rather than a gas jet (high velocity).

In order to minimise the weather effects and achieve the best possible dilution, it is recommended that the outlet design velocity of a vent be set as high as possible within the realms of process possibility (for example, pressure loss, noise, etc.).

The prevailing wind at a plant site should be taken into account, but it has to be considered that the wind can come from any direction. For higher release velocities, horizontal or angled releases will negate much or all of any wind direction effect, although most computer modelling cannot take appropriate account of any crosswind condition except for truly vertical releases.

5.5 Venting of cryogenic liquid

To minimize exposure of, and injury to personnel and damage to equipment, intentional venting of cryogenic liquids directly to atmosphere should be prohibited. Cryogenic liquids that are released in quantity, either during routine operations or predicted upset conditions, should be directed to a disposal system designed for this purpose. However, care shall be taken in the design of common headered liquid and vapour disposal systems to avoid the possibility of liquid backflow into gas vent headers, and to avoid risk of plugging of cryogenic relief valve discharges with ice from water accumulating in the header.

Some small liquid venting systems may be directed to a safe location without the need to pass through a disposal system:

- Vents from cryogenic thermal relief valves that could discharge cryogenic liquid in upset conditions may be vented at grade because of the small orifice size and short duration of any liquid release. However, there should be consideration of any consequence of releasing a significant inventory of liquid in the event that the discharging relief valve fails to completely reseat after venting off the excess pressure; and

- Small vents, drains, and trycocks from liquid fill lines, pump cooldown lines, or similar systems can be directed to catch trays or local spillage areas having adequate natural ventilation.

6 Calculations for the determination of safe vent locations

6.1 Introduction

Factors to be considered as the basis for specifying safe locations for oxygen or asphyxiant atmospheric gas vents are given in Section 5, which also gives accepted concentration criteria that can be used for detailed dispersion calculations. Following generally available textbook methods such as Chapter 2 in *Guidelines for Consequence Analysis of Chemical Releases* or using equivalent computer programs, it is possible to model predicted safe separation distances for vent designs when all the appropriate release data are available [6]. The calculations are case specific but can result in separation distances optimised to minimise risk without requiring excessive safety margins. However, for a large majority of atmospheric gas vents in an air separation plant, detailed calculations are either not practical because of insufficient information or because of the number of possible vents involved. In these circumstances the use of previous designs or look-up tables or graphs may be sufficient providing the assumptions made for the previous designs or tables or graphs are met by the specific vent designs under review.

Expert opinion has been gathered and calculations carried out to prepare look-up tables that cover a variety of common vent designs cases so detailed calculations are not required. It should always be noted that the preparation of look-up tables will always involve compromises on the presentation of results, and as a consequence the separation distances presented in this publication may be conservative. In the event that use of these or other look-up tables indicates that an identified vent location is too close to people or other equipment, the option to revert to carrying out detailed calculations for that specific case is always available.

The following paragraphs provide the basis on which the vent elevations and separation distances in this publication have been determined. It is important to recognise when unusual conditions exist that could vary significantly from those assumed for the calculations. In this event, the user shall review the available data and judge whether a separate assessment is necessary.

When a gas is released, the resulting vapour cloud will be diluted by air entrainment. The rate of dilution is controlled by several factors that include gas properties, the release flow and velocity, meteorological conditions, and terrain. There are also the various release scenarios to be considered, such as continuous releases, high momentum releases from the opening of a relief valve, or low momentum releases from conservation vents (pressure or flow control). For these reasons, there is generally no universal dispersion model that can handle all types of releases. The appropriate model shall be chosen for the particular release. Some computer programs can combine various models to allow automatic selection for the vent case under consideration.

6.2 Choice of software

Appendices A, B, C, D, E and F provide the results of calculations for high pressure vents using PHAST™ program version 6.4.2, using the assumptions listed in 6.3 through 6.8.[7] Calculations for low pressure vents are not provided because the PHAST program may underestimate the separation distances. Alternative methods to model the dispersion such as computational fluid dynamics (CFD) should be considered for low pressure vents. The calculations are for continuous releases under the conditions noted in 6.3 through 6.8. The results will also be valid for intermittent or instantaneous release cases at the same flow rates. Thus, as discussed previously it is anticipated that the information presented for the location of vents that meet the design criteria can apply in the majority of cases where a conservative result is acceptable.

Different versions of the PHAST program can give different results compared to the CFD or the PHAST program version 6.42 mentioned previously.]

6.3 Weather conditions

The range of weather stability and wind speeds used in the calculations were selected as follows in accordance with best practice for capturing the worst case results from atmospheric dispersion calculations using PHAST.

Stability	Wind speed
D	1.5 m/s
D	5 m/s
D	9 m/s
F	1.5 m/s

The stability is represented according to the Pasquill Stability Class (D: neutral conditions and F: moderately stable conditions).

Depending on the release rate, direction, and physical conditions of the gas release being considered, the worst case vent elevations and separation distances can result from any of these weather conditions.

The largest safety separation distances for vents discharging horizontally are determined on the basis that the wind direction is the same as that of the gas discharge at the vent tip.

6.4 Release temperature

Gas vents from industrial gas plants can vary in temperature from significantly greater than ambient (for example, compressed gas discharges) to dew point cryogenic gas temperatures (for example, vents from cryogenic columns).

Since the calculation results are given in terms of the vent size for a design minimum velocity of release (see 6.6), conservative separation distance results are obtained from selecting minimum values for warm or cold releases (highest density = highest mass flow for a given vent size and release velocity). The following release temperatures were the basis of calculation.

Material	Temperature
oxygen (warm)	10.0 °C
oxygen (cold)	–183.0 °C
nitrogen (warm)	10.0 °C
nitrogen (cold)	–195.6 °C
argon (warm)	10.0 °C
argon (cold)	–185.9 °C

The 10 °C warm temperature condition is representative of the temperatures achieved in separated gas streams exiting the warm end of an ASU.

Should warmer release temperatures need to be considered, the calculation results could be conservative for a given line size and release velocity as the released gases will be more buoyant and have less mass flow rate (resulting in shorter distances to dispersion).

6.5 Release angle

For all warm and cold vents, the orientation can be anywhere between the horizontal and the vertical. Calculations have been completed for horizontal, vertical, and 45 degree angle vent releases.

6.6 Release velocities

The venting systems have been divided into low pressure and high pressure sources for both warm and cold gases. Low pressure systems are generally applicable to continuous or intermittent process vents for which silencers are usually installed. High pressure systems apply primarily to vents from PRDs or high pressure vents where no silencer is required on the outlet and release velocity restrictions do not exist. Release velocities for low pressure and high pressure systems were selected accordingly as follows.

Source	Velocity
Low pressure gas (oxygen, nitrogen, or argon)	20 m/s [1)]
Low pressure gas (oxygen, nitrogen, or argon)	10 m/s
High pressure oxygen (warm)	160 m/s [2)]
High pressure nitrogen (warm)	171 m/s
High pressure argon (warm)	160 m/s
High pressure oxygen (cold)	90 m/s
High pressure nitrogen (cold)	89 m/s
High pressure argon (cold)	85 m/s

[1)] 20 m/s is considered as representative design velocity for gas discharging from a vent silencer whereas a lower release velocity may be required by design in extreme noise suppression cases, or where a very low pressure direct gas release to atmosphere is required (for example, waste venting from a water chiller tower).

[2)] Vent discharge velocities of 0.5 Mach are taken as representative of the design cases for items such as pressure safety valves. The velocity has been calculated for the properties of the gas in air at the release temperatures selected.

For design cases where release velocities are lower than <u>30</u> m/s, a specific assessment of the cases shall be required.

As stated in 5.1, the influence of release velocity is important in determining minimum stack height when gas can be vented at any flow rate between the nominal design capacity and zero. This is particularly important if the design full flow release conditions already require a low velocity with a dense gas relative to ambient air. For process vents with a large range of potential flow rates, detailed vent calculations are recommended for the cases in question.

PHAST has limitations in the dispersion modelling, which reduce the accuracy of calculation at low gas release speeds below 1 m/s. If release conditions need to be considered at this low velocity, the use of PHAST is not recommended and more complex methodologies such as three-dimensional CFD simulations may be required.

<u>The use of PHAST should be limited to high pressure vents. PHAST has been shown to overestimate the amount of air entrainment for low release velocities. As a result, separation distances calculated by PHAST for low pressure vents may not be sufficient. Alternative methods such as applying a safety factor to the PHAST results or the use of CFD should be considered.</u>

6.7 Concentration limits

The jet dispersion model calculation within PHAST does not account for the components of air that are present in the released gas prior to the dispersion of the jet. The levels of concern that are published for oxygen-enriched or oxygen-deficient atmospheres include the background concentration in the air. For example, 23.5% oxygen <u>by volume</u> is a level of concern for possible ignition. However, if this concentration was entered into the dispersion program as the level of concern, the program would calculate a 23.5% oxygen by volume concentration assuming that the original concentration in air was zero. Therefore, a mathematical adjustment has to be made to determine the oxygen or inert gas concentrations of concern to be used as final values in the dispersion calculation. The ranges of hazard criteria used for oxygen-enriched and oxygen-deficient atmospheres are:

- oxygen-enriched atmospheres—23.5% oxygen by volume; and
- oxygen-deficient atmospheres—19.5% oxygen by volume.

The dispersion calculations were performed on the basis of pure gaseous oxygen, nitrogen, or argon releases. The mathematical method for the concentration adjustment is given in Appendix I.

Corresponding concentration limits for the dispersion calculations are as follows:

Hazard criteria	Calculated range of concern
25% oxygen	0.05123 mol fraction oxygen
23.5% oxygen	0.03226 mol fraction oxygen
19.5% oxygen	0.07140 mol fraction nitrogen/argon
18% oxygen	0.14286 mol fraction nitrogen/argon
17% oxygen	0.19048 mol fraction nitrogen/argon

6.8 Ambient conditions

Temperature difference between the gas as vented and the ambient temperature can have an effect on the dispersion. In order to examine this effect, base calculations were carried out for ambient air temperature of 10 °C, 20 °C, and 30 °C for a constant gas release temperature.

In many cases, the calculations showed that the ambient temperature effect was negligible in determining safe separation distances, and in all cases the variation never exceeded 10% of the worst case separation value calculated.

Thus, the tables presented in the appendices correspond to the highest value of separation distances (horizontally, above the vent and below the vent) found by calculation for any of the ambient air temperatures selected.

An average relative humidity of 70% was selected for the calculations.

All calculations were carried out for an atmospheric pressure of 1.013 bar, abs (i.e., sea level conditions).

6.9 Interpretation of the tables

The individual PHAST dispersion calculations give concentration versus distance results in three dimensions for each scenario and each weather condition selected. For interpretation of gas cloud dimensions at any concentration limit, the program can produce graphical outputs that overlay the results for the same release scenario under various weather conditions onto a single diagram.

Examples of such output are shown in Figures 1 and 2. The cases are for warm oxygen released either vertically or horizontally giving side view dimensions of the dispersed cloud downwind at 23.5% oxygen by volume for each of the four weather conditions selected for review for each release direction. The ppm concentration indicated in the figures is calculated according to Appendix I.

The vent heights specified in the tables in the appendices have been set to achieve a minimum safe elevation below any plume of 3 m above working areas. This gives approximately 1 m margin above body height to allow for slumping and also slight variations between cases in the modelling output.

Other graphical views are possible including those showing concentration changes with distance for any single release case under a stated weather condition. However, the form of graph shown illustrates best how to interpret the worst case separation distances given in the tables in the appendices.

For each of the release scenarios listed in the appendices, the corresponding table gives the following (derived from the appropriate graph):

- Maximum horizontal distance reached by the cloud dispersing to a given concentration for each nozzle size at any weather condition;
- Minimum necessary height of the vent release point for safety at any point below the dispersing cloud (accounting for negative buoyancy where observed from the results);and
- Maximum vertical height above the release point reached by the cloud for any weather, if appropriate. Horizontal releases of atmospheric gases generally do not result in any significant cloud height above the release point. A standard maximum can be established for these cases as a simplification (see Figures 3, 4, and 5).

Examining the vertical release graphical example illustrated in Figure 1, the maximum horizontal distance reached under any weather condition for 23.5% oxygen by volume is indicated at 6.7 m, the maximum vertical elevation above the release point is 5.5 m, and the dispersed cloud never extends below the release point. Since the cloud never extends below the release point, the 3 m release elevation noted for the example is acceptable. Other factors, as noted previously, could affect the location. Note that the extreme horizontal and vertical dimensions are not obtained by a single weather case (this is the case for all releases and there is no general rule about which scenario results in which extreme dimension).

The horizontal release case result behaves similarly except that the model cloud dimensions are never significantly above the release height whereas the worst case cloud has negative buoyancy justifying an increase in recommended minimum vent elevation from 3 m to 5 m.

The graphs provided for the release scenarios are idealised mathematical model shapes from the data and only approximate to the cloud shapes actually resulting from venting under the same conditions. The distances shown in the tables for the release scenarios have been rounded up to whole meter values.

Figures 3, 4, and 5 illustrate how the separation data provided in the appendices should be interpreted for horizontal, vertical, or 45 degree angled vents respectively.

6.10 Limitations on the calculation methodology

The main limitations on performed calculations include the following:

- All dispersion calculations are based on a continuous release rate;
- Obstacles (buildings, structures, etc.) are not taken into account in simulations;
- Modelling assumes that any release, if not vertical, is being vented in the same direction as the wind prevailing at the time of release; and
- Visual impact generated by the dispersion of cryogenic gas (fog) is not taken into account.

7 Recommendations

The recommended basis for determining the safe location of oxygen and inert atmospheric gas vents is given in Section 5.

From the calculation factors detailed in Section 6, the venting of oxygen and inert atmospheric gases can be safely accomplished by adhering to the separation distances given in Appendices A, B, C, D, E, and F for the selected vent sizes and vent orientation. This requires that a prior determination of the hazard concentration of concern is carried out in accordance with 5.2.

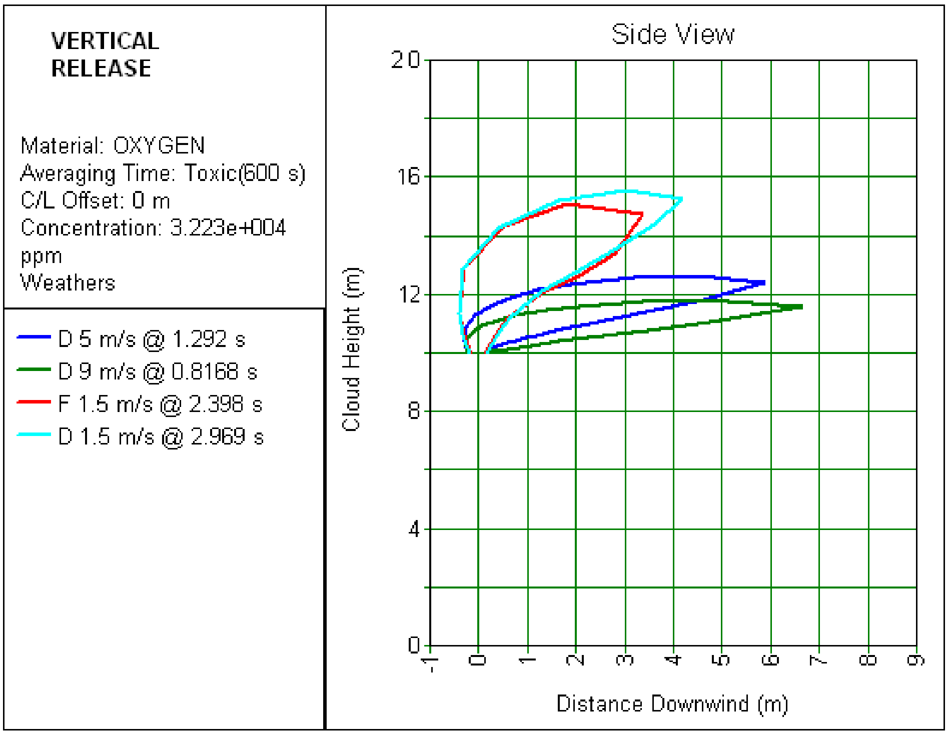


Figure 1 Example of warm oxygen vertical release with 23.5% oxygen concentration

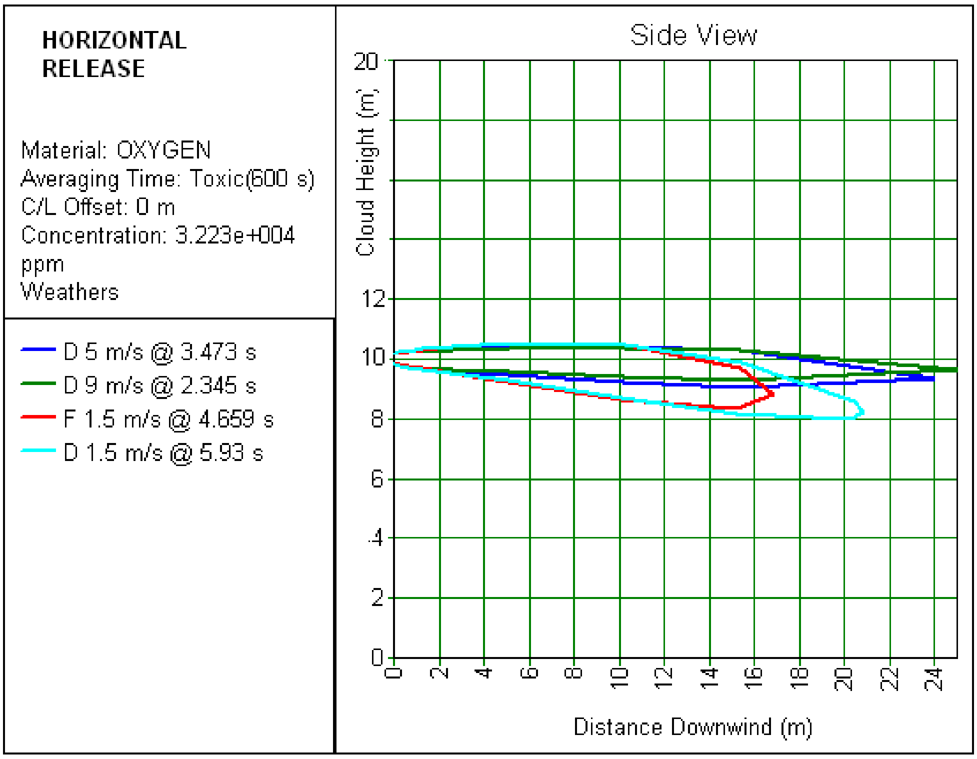


Figure 2 Example of warm oxygen horizontal release with 23.5%oxygen concentration

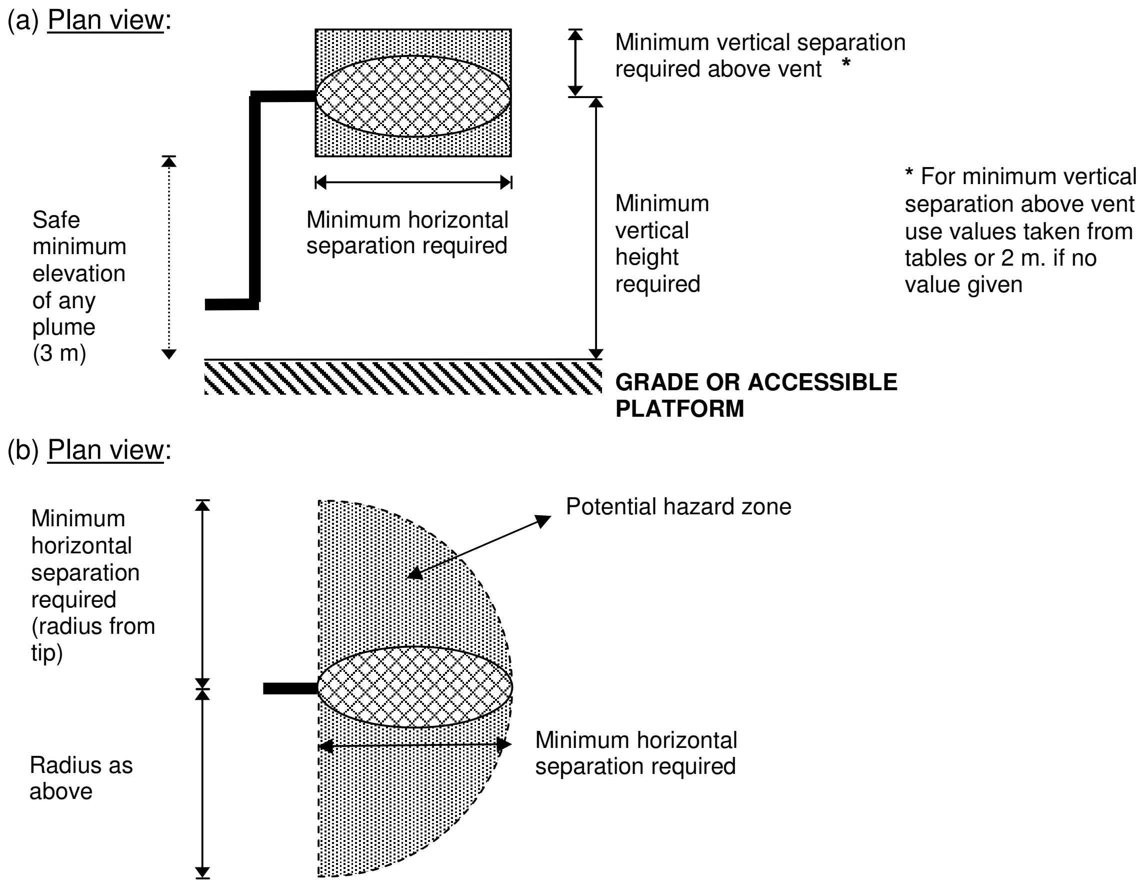


Figure 3 Horizontal vent separations

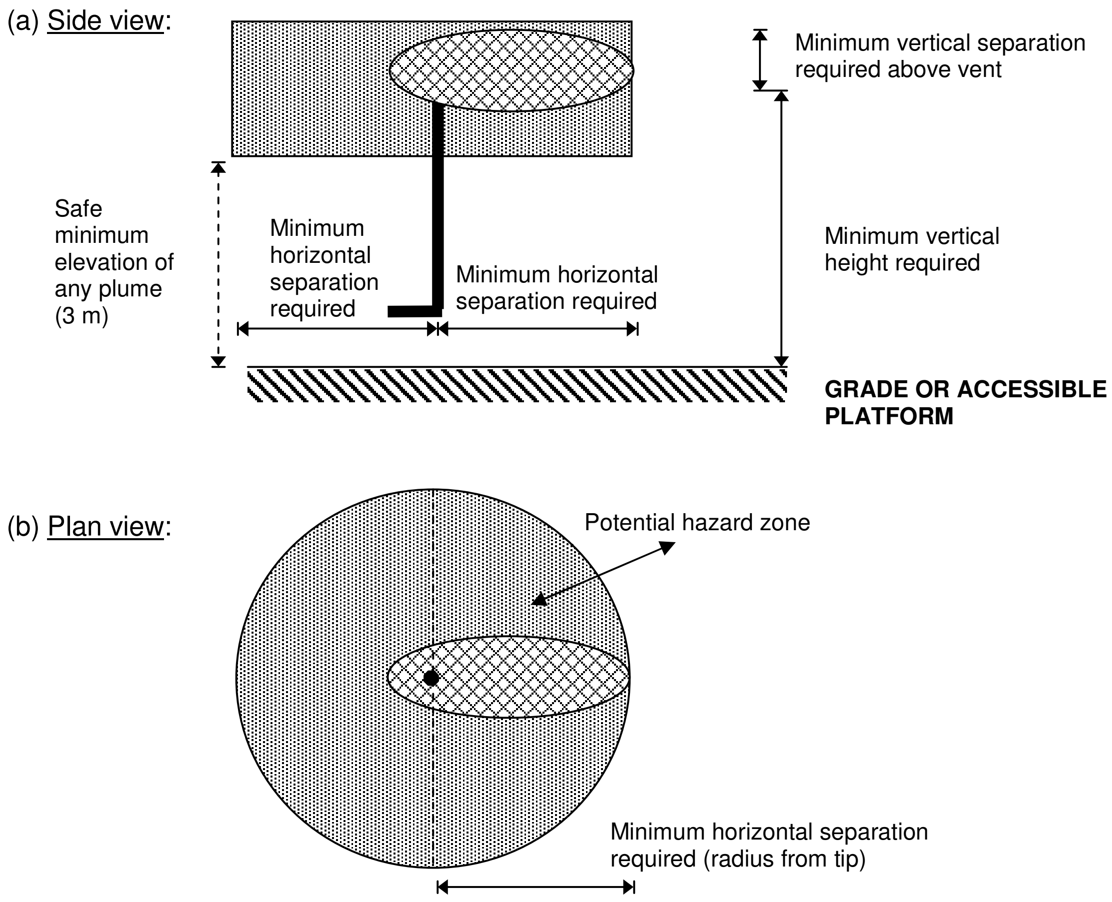


Figure 4 Vertical vent separations

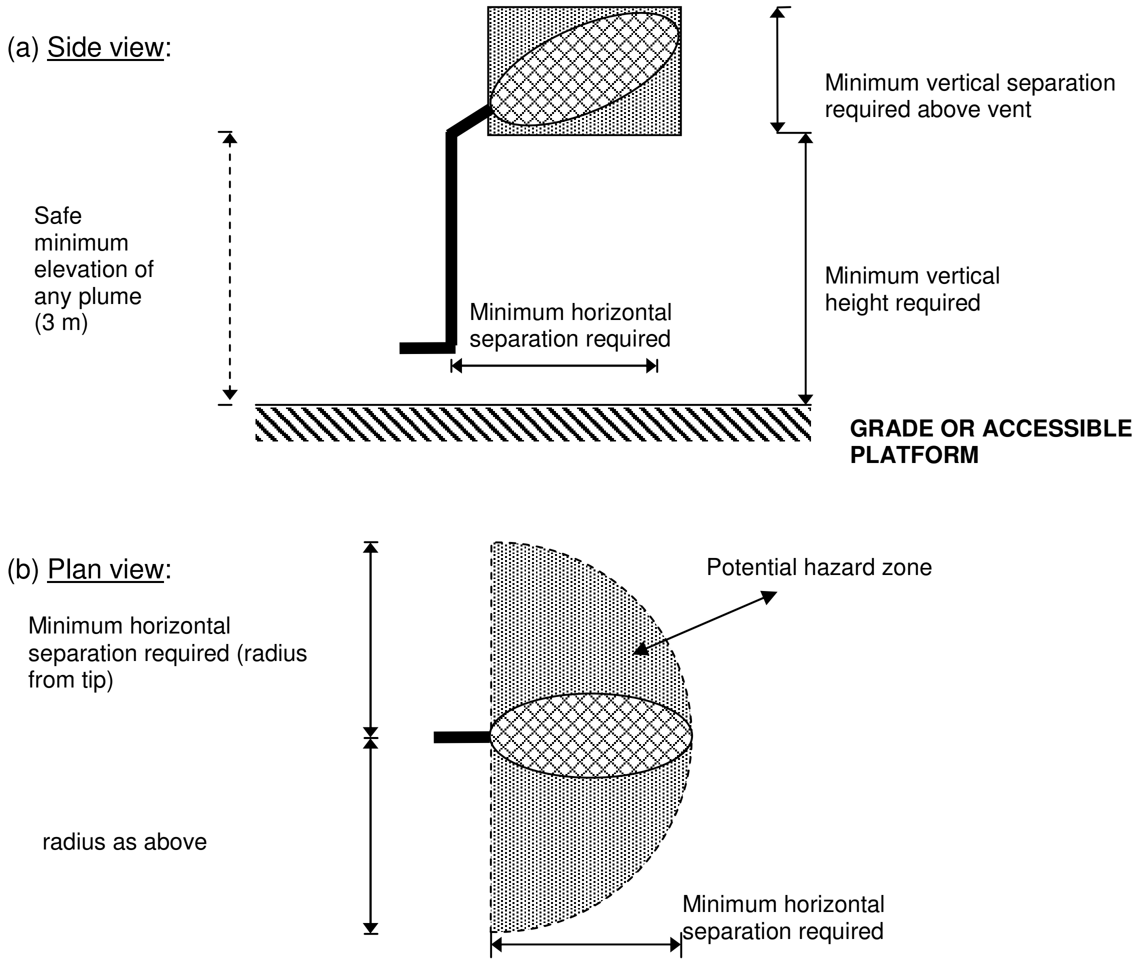


Figure 5 Angled vent separations

8 References

[1] EIGA Safety Advisory Group Newsletter 79, *Hazards of oxygen enriched atmospheres*, European Industrial Gases Association, Avenue des Arts 3-5, B-1210 Brussels, Belgium. www.eiga.eu

[2] EIGA Safety Advisory Group Newsletter 78, Asphyxiation fatalities on a construction site"

[3] AIGA 030, *Storage of cryogenic air gases at users' premises,* Asia Industrial Gases Association. www.asiaiga.org

[4] AIGA 005 , *Fire hazards of oxygen and oxygen enriched atmospheres*, Asia Industrial Gases Association www.asiaiga.org

[5] AIGA 008, *Hazards of inert gases and oxygen depletion*, Asia Industrial Gases Association. www.asiaiga.org

[6] *Guidelines for Consequence Analysis of Chemical Releases*, 1999 Center for Chemical Process Safety (CCPS), 120 Wall Street, Floor 23, New York, NY 10005. www.wiley.com

[7] PHAST™, Det Norske Veritas (DNV), software. www.dnv.com

Appendix A—Warm high pressure oxygen[1,2]

Table A-1—Warm high pressure oxygen venting horizontally at high velocity

Vent size (mm)	Horizontal separation required (m)		Minimum vertical height required (m)	
	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen
25	5	3	3	3
50	10	6	3	3
80	13	9	4	3
100	18	12	4	4
150	25	17	4	4
200	36	22	4	4
250	43	25	5	4
300	49	32	5	5
400	67	43	6	5

Table A-2—Warm high pressure oxygen venting vertically at high velocity

Vent size (mm)	Horizontal separation required (m)		Minimum vertical height required (m)		Minimum vertical separation required above vent (m)	
	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen
25	1	1	3	3	2	2
50	1	1	3	3	5	3
80	1	1	3	3	7	5
100	2	1	3	3	8	7
150	3	2	3	3	13	11
200	4	2	3	3	17	13
250	5	3	3	3	23	17
300	6	3	3	3	25	21
400	7	4	3	3	35	25

[1] Oxygen percentages listed are oxygen by volume.

[2] The values in these tables shall not be used if the gas venting velocity in any of the operating modes is above or below the velocity specified in the tables. When actual venting velocity is outside of the velocity range of the tables, then the distances shall be calculated using the PHAST program or an equivalent method.

Table A-3—Warm high pressure oxygen venting angled at high velocity

Vent size (mm)	Horizontal separation required (m)		Minimum vertical height required (m)		Minimum vertical separation required above vent (m)	
	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen
25	2	1	3	3	2	2
50	4	3	3	3	4	3
80	6	5	3	3	5	4
100	9	6	3	3	7	5
150	12	9	3	3	10	8
200	17	11	3	3	15	10
250	19	15	3	3	16	13
300	24	17	3	3	20	15
400	34	22	3	3	28	19

Appendix B—Cold high pressure oxygen[3,4]

Table B-1—Cold high pressure oxygen venting horizontally at high velocity

Vent size (mm)	Horizontal separation required (m)		Minimum vertical height required (m)	
	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen
25	9	6	3	3
50	16	11	4	3
80	23	16	5	4
100	29	20	6	4
150	39	29	8	6
200	50	38	11	7
250	62	46	15	9
300	70	55	18	10
400	88	70	24	16

Table B-2—Cold high pressure oxygen venting vertically at high velocity

Vent size (mm)	Horizontal separation required (m)		Minimum vertical height required (m)		Minimum vertical separation required above vent (m)	
	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen
25	1	1	3	3	2	2
50	2	1	3	3	5	3
80	3	2	3	3	7	5
100	4	2	3	3	8	7
150	6	4	3	3	13	11
200	8	5	3	3	17	13
250	10	6	3	3	23	17
300	12	7	3	3	25	21
400	18	9	3	3	35	25

[3] Oxygen percentages listed are oxygen by volume.

[4] The values in these tables shall not be used if the gas venting velocity in any of the operating modes is above or below the velocity specified in the table. When actual venting velocity is outside of the velocity range of the tables, then the distances shall be calculated using the PHAST program or an equivalent method.

Table B-3 Cold high pressure oxygen venting angled at high velocity

Vent size (mm)	Horizontal separation required (m)		Minimum vertical height required (m)		Minimum vertical separation required above vent (m)	
	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen	23.5% oxygen	25% oxygen
25	4	3	3	3	3	2
50	8	6	3	3	6	5
80	12	8	3	3	9	7
100	16	11	3	3	11	9
150	25	17	3	3	16	13
200	37	24	3	3	21	17
250	49	30	3	3	25	21
300	58	37	3	3	28	24
400	76	53	3	3	34	31

Appendix C—Warm high pressure nitrogen[5,6]

Table C-1—Warm high pressure nitrogen venting horizontally at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	3	1	1	4	4	4
50	5	2	2	4	4	4
80	6	3	3	4	4	4
100	9	4	3	4	4	4
150	12	6	5	4	4	4
200	17	8	6	4	4	4
250	21	10	7	4	4	4
300	24	11	8	4	4	4
400	33	15	11	5	4	4

Table C.2—Warm high pressure nitrogen venting vertically at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18 % oxygen	17% oxygen
25	1	1	1	3	3	3	2	1	1
50	1	1	1	3	3	3	3	2	1
80	1	1	1	3	3	3	4	3	2
100	1	1	1	3	3	3	6	3	3
150	1	1	1	3	3	3	8	5	3
200	1	1	1	3	3	3	11	6	5
250	2	1	1	3	3	3	12	7	6
300	2	1	1	3	3	3	16	9	6
400	3	1	1	3	3	3	22	11	9

[5] Oxygen percentages listed are oxygen by volume.

[6] The values in these tables shall not be used if the gas venting velocity in any of the operating modes is above or below the velocity specified in the table. When actual venting velocity is outside of the velocity range of the tables, then the distances shall be calculated using the PHAST program or an equivalent method.

Table C-3—Warm high pressure nitrogen venting angled at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18 % oxygen	17% oxygen	19.5 % oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	1	1	1	3	3	3	1	1	1
50	2	1	1	3	3	3	2	1	1
80	4	2	1	3	3	3	3	2	1
100	5	2	2	3	3	3	4	2	2
150	7	4	2	3	3	3	7	4	2
200	9	4	3	3	3	3	8	4	3
250	11	6	4	3	3	3	10	6	4
300	14	7	5	3	3	3	13	7	5
400	18	9	7	3	3	3	16	8	7

Appendix D—Cold high pressure nitrogen[7,8]

Table D-1—Cold high pressure nitrogen venting horizontally at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	5	3	2	4	4	4
50	10	5	4	4	4	4
80	14	8	6	4	4	4
100	18	10	8	4	4	4
150	26	15	12	4	4	4
200	33	19	16	6	4	4
250	40	24	20	7	4	4
300	47	29	22	7	5	4
400	60	38	30	10	5	5

Table D-2—Cold high pressure nitrogen venting vertically at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	1	1	1	3	3	3	3	2	2
50	1	1	1	3	3	3	6	4	3
80	2	1	1	3	3	3	8	5	4
100	2	1	1	3	3	3	10	7	6
150	3	1	1	3	3	3	16	10	9
200	3	2	1	3	3	3	20	15	11
250	5	2	1	3	3	3	25	16	14
300	5	2	2	3	3	3	30	20	17
400	7	3	2	3	3	3	40	26	23

Table D-3—Cold high pressure nitrogen venting angled at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	2	2	1	3	3	3	2	1	1
50	5	3	2	3	3	3	4	3	2
80	7	5	3	3	3	3	6	4	3
100	10	6	5	3	3	3	8	5	4
150	14	8	7	3	3	3	12	8	7
200	21	12	9	3	3	3	16	10	9
250	26	15	11	3	3	3	20	12	10
300	30	17	14	3	3	3	24	15	12

[7] Oxygen percentages listed are oxygen by volume.

[8] The values in these tables shall not be used if the gas venting velocity in any of the operating modes is above or below the velocity specified in the table. When actual venting velocity is outside of the velocity range of the tables, then the distances shall be calculated using the PHAST program or an equivalent method.

400	42	24	18	3	3	3	30	20	16

Appendix E—Warm high pressure argon[9,10]

Table E-1—Warm high pressure argon venting horizontally at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	2	1	1	3	3	3
50	4	2	1	3	3	3
80	6	3	2	3	3	3
100	7	3	3	3	3	3
150	11	5	4	3	3	3
200	14	7	5	4	3	3

Table E-2—Warm high pressure argon venting vertically at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen	19.5 % oxygen	18 % oxygen	17% oxygen
25	1	1	1	3	3	3	1	1	1
50	1	1	1	3	3	3	3	2	1
80	1	1	1	3	3	3	4	2	2
100	1	1	1	3	3	3	5	3	2
150	1	1	1	3	3	3	8	4	3
200	1	1	1	3	3	3	10	5	4

Table E-3—Warm high pressure argon venting angled at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	1	1	1	3	3	3	1	1	1
50	2	1	1	3	3	3	2	1	1
80	3	2	1	3	3	3	3	2	1
100	4	2	2	3	3	3	4	2	2
150	6	3	2	3	3	3	6	3	2
200	8	4	3	3	3	3	8	4	3

[9] Oxygen percentages listed are oxygen by volume.

[10] The values in these tables shall not be used if the gas venting velocity in any of the operating modes is above or below the velocity specified in the table. When actual venting velocity is outside of the velocity range of the tables, then the distances shall be calculated using the PHAST program or an equivalent method.

Appendix F—Cold high pressure argon[11,12]

Table F-1—Cold high pressure argon venting horizontally at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	4	2	2	3	3	3
50	8	4	3	3	3	3
80	11	6	5	3	3	3
100	15	8	7	4	3	3
150	21	12	10	4	3	3
200	28	17	13	5	4	3

Table F-2—Cold high pressure argon venting vertically at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	1	1	1	3	3	3	2	2	1
50	1	1	1	3	3	3	5	3	2
80	1	1	1	3	3	3	7	4	4
100	1	1	1	3	3	3	9	6	5
150	2	1	1	3	3	3	14	9	7
200	2	1	1	3	3	3	18	12	10

Table F-3—Cold high pressure argon venting angled at high velocity

Vent size (mm)	Horizontal separation required (m)			Minimum vertical height required (m)			Minimum vertical separation required above vent (m)		
	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen	19.5% oxygen	18% oxygen	17% oxygen
25	2	1	1	3	3	3	2	1	1
50	4	3	2	3	3	3	4	2	2
80	6	4	3	3	3	3	5	3	3
100	9	5	4	3	3	3	7	5	4
150	12	8	6	3	3	3	11	7	6
200	17	10	8	3	3	3	14	9	8

[11] Oxygen percentages listed are oxygen by volume.

[12] The values in these tables shall not be used if the gas venting velocity in any of the operating modes is above or below the velocity specified in the table. When actual venting velocity is outside of the velocity range of the tables, then the distances shall be calculated using the PHAST program or an equivalent method.

Appendix G—Equivalent release rates[13,14]

Table G-1—Equivalent release rates for oxygen at 10 °C, venting at 20m/s and 10m/s

Vent size (mm)	Release rate 20m/s	Release rate 10m/s
25	50 kg/h	25 kg/h
50	200 kg/h	100 kg/h
80	450 kg/h	220 kg/h
100	800 kg/h	400 kg/h
150	1 800 kg/h	910 kg/h
200	3 200 kg/h	1 600 kg/h
250	5 000 kg/h	2 500 kg/h
300	7 200 kg/h	3 600 kg/h
350	9 900 kg/h	4 900 kg/h
400	12 900 kg/h	6 400 kg/h
450	16 300 kg/h	8 200 kg/h
500	20 100 kg/h	10 100 kg/h
600	29 000 kg/h	14 500 kg/h
750	45 300 kg/h	22 700 kg/h
900	65 200 kg/h	32 600 kg/h
1200	116 000 kg/h	58 000 kg/h
1500	181 000 kg/h	91 000 kg/h

Table G-2—Equivalent release rates for oxygen at –183 °C, venting at 20m/s and 10m/s

Vent size (mm)	Release rate 20m/s	Release rate 10m/s
25	160 kg/h	80kg/h
50	650 kg/h	330 kg/h
80	1 500 kg/h	7 30 kg/h
100	2 600 kg/h	1 300 kg/h
150	5 900 kg/h	2 900 kg/h
200	10 400 kg/h	5 200 kg/h
250	16 300 kg/h	8 100 kg/h
300	23 400 kg/h	11 700 kg/h
350	31 900 kg/h	16 000 kg/h
400	41 700 kg/h	20 800 kg/h
450	52 800 kg/h	26 400 kg/h
500	65 100 kg/h	32 600 kg/h
600	93 700 kg/h	46 900 kg/h
750	146 000 kg/h	73 300 kg/h
900	211 000 kg/h	106 000 kg/h
1200	375 000 kg/h	187 000 kg/h
1500	584 000 kg/h	292 000 kg/h

[13] Oxygen percentages listed are oxygen by volume.

[14] The values in these tables shall not be used if the gas venting velocity in any of the operating modes is above or below the velocity specified in the table. When actual venting velocity is outside of the velocity range of the tables, then the distances shall be calculated using the PHAST program or an equivalent method.

Table G-3—Equivalent release rates for oxygen at 10 °C, venting at 160m/s

Vent size (mm)	Release rate 160m/s
25	400 kg/h
50	1 600 kg/h
80	3 600 kg/h
100	6 400 kg/h
150	14 500 kg/h
200	25 800 kg/h
250	40 300 kg/h
300	58 000 kg/h
400	103 000 kg/h

Table G-4—Equivalent release rates for oxygen at –183 °C, venting at 90m/s

Vent size (mm)	Release rate 90m/s
25	730 kg/h
50	2 900 kg/h
80	6600 kg/h
100	11 700 kg/h
150	26 400 kg/h
200	46 900 kg/h
250	73 300 kg/h
300	105 000 kg/h
400	188 000 kg/h

Table G-5—Equivalent release rates for nitrogen at 10 °C, venting at 20m/s and 10m/s

Vent size (mm)	Release rate 20m/s	Release rate 10m/s
25	40 kg/h	20 kg/h
50	180 kg/h	90 kg/h
80	400 kg/h	200 kg/h
100	700 kg/h	350 kg/h
150	1 600 kg/h	790 kg/h
200	2 800 kg/h	1 400 kg/h
250	4 400 kg/h	2 200 kg/h
300	6 300 kg/h	3 200 kg/h
350	8 600 kg/h	4 300 kg/h
400	11 300 kg/h	5 600 kg/h
450	14 300 kg/h	7 200 kg/h
500	17 600 kg/h	8 800 kg/h
600	25 300 kg/h	12 700 kg/h
750	39 600 kg/h	19 800 kg/h
900	57 000 kg/h	28 500 kg/h
1200	101 000 kg/h	50 700 kg/h
1500	158 000 kg/h	79 200 kg/h

Table G-6—Equivalent release rates for nitrogen at –195 °C, venting at 20m/s and 10m/s

Vent size (mm)	Release rate 20m/s	Release rate 10m/s
25	170 kg/h	80kg/h
50	670 kg/h	340 kg/h
80	1 500 kg/h	750 kg/h
100	2 700 kg/h	1 300 kg/h
150	6 000 kg/h	3 000 kg/h
200	10 700 kg/h	5 400 kg/h
250	16 800 kg/h	8 400 kg/h
300	24 100 kg/h	12 100 kg/h
350	32 900 kg/h	16 400 kg/h
400	42 900 kg/h	21 500 kg/h
450	54 300 kg/h	27 200 kg/h
500	67 100 kg/h	33 500 kg/h
600	96 600 kg/h	48 300 kg/h
750	151 000 kg/h	75 400 kg/h
900	217 000 kg/h	109 000 kg/h
1 200	386 000 kg/h	193 000 kg/h
1 500	604 000 kg/h	302 000 kg/h

Table G-7—Equivalent release rates for nitrogen at 10 °C, venting at 170m/s

Vent size (mm)	Release rate 170m/s
25	380 kg/h
50	1 500 kg/h
80	3 400 kg/h
100	6000 kg/h
150	13 500 kg/h
200	24 100 kg/h
250	37 600 kg/h
300	54 200 kg/h
400	96 300 kg/h

Table G-8—Equivalent release rates for nitrogen at –195 °C, venting at 90m/s

Vent size (mm)	Release rate 90m/s
25	750 kg/h
50	3 000 kg/h
80	6 700 kg/h
100	12 000 kg/h
150	27 000 kg/h
200	47 900 kg/h
250	74 900 kg/h
300	108 000 kg/h
400	192 000 kg/h

Table G-9—Equivalent release rates for argon at 10 °C, venting at 20m/s and 10m/s

Vent size (mm)	Release rate 20m/s	Release rate 10m/s
25	60 kg/h	30 kg/h
50	250 kg/h	130 kg/h
80	570 kg/h	280 kg/h
100	1 000 kg/h	500 kg/h
150	2 300 kg/h	1 100 kg/h
200	4 000 kg/h	2 000 kg/h

Table G-10—Equivalent release rates for argon at –186 °C, venting at 20m/s and 10m/s

Vent size (mm)	Release rate 20m/s	Release rate 10m/s
25	210 kg/h	110 kg/h
50	840 kg/h	420 kg/h
80	1 900 kg/h	950 kg/h
100	3 400 kg/h	1 700 kg/h
150	7 600 kg/h	3 800 kg/h
200	13 500 kg/h	6 700 kg/h

Table G-11—Equivalent release rates for argon at 10 °C, venting at 160m/s

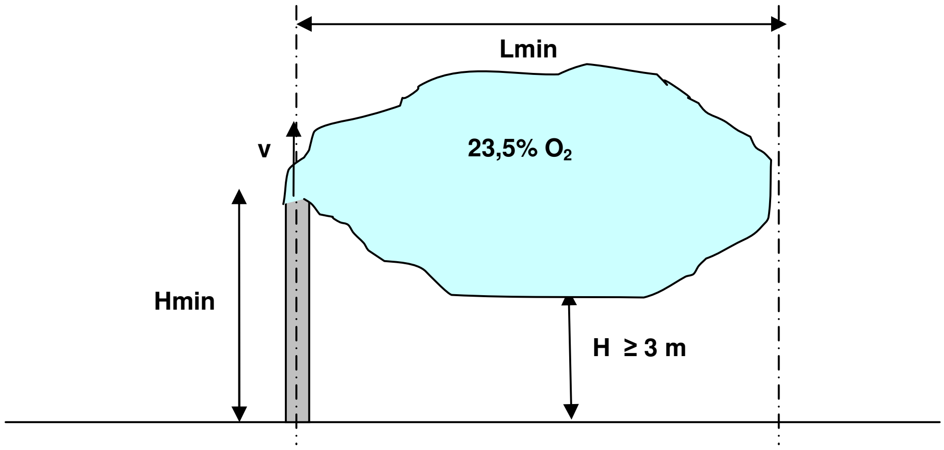
Vent size (mm)	Release rate 160 m/s
25	500 kg/h
50	2 000 kg/h
80	4 500 kg/h
100	8 000 kg/h
150	18 100 kg/h
200	32 200 kg/h

Table G-12—Equivalent release rates for argon at –186 °C, venting at 85m/s

Vent size (mm)	Release rate 85m/s
25	900 kg/h
50	3 600 kg/h
80	8 000 kg/h
100	14 300 kg/h
150	32 200 kg/h
200	57 200 kg/h

Appendix H—Influence of release speed

The following figure illustrates the minimal vertical height that would be required for venting oxygen in safe location for 23.5% oxygen cloud being not lower than 3 m above ground.



The figure illustrates that accounting for a potential decrease of the release speed (for example, reduced flow rate at turndown) can result in requiring a significant increase of the vertical height of the vent in addition to a potential adjustment to the horizontal separation distance requirement.

Depending on the release rate, direction and physical conditions of the gas release being considered, the worst case vent elevations and separation distances can result from any of the weather conditions discussed in 6.3.

Appendix I—Oxygen adjustment mathematics

Generally, dispersion programs are designed for the release of materials not found in air. For example, when methane is vented the assumption is that the background concentration of methane prior to the release is zero. However, when oxygen is vented, a background concentration of approximately 21% oxygen is present in the air.

The levels of concern that are published for oxygen enrichment or asphyxiation include the background concentration in the air. For example, 23.5% oxygen is a level of concern for possible ignition. If this level of concern was entered into the dispersion programs as the level of concern, the program would calculate a 23.5% concentration assuming that the original concentration was 0.

The number to enter into the dispersion programs is not simply the difference between the level of concern and the background concentration. As the material is released, material is being added to the air. The following oxygen adjustment mathematics account for the added material.

There are two options:

- calculation for oxygen dispersion in air; and

- calculation for the dispersion of an asphyxiant in air.

Oxygen dispersion in air:

Inputs: Oxygen mole fraction in air: O2AIR (typical value = 0.21)
Oxygen mole fraction released: O2RELEASE
Oxygen mole fraction of concern: O2LEL (typical value = 0.235)

Output: Oxygen mole fraction for dispersion programs: O2LOC

Derivation of equation:

X = moles of air
Y = oxygen moles released

Moles oxygen initial + Moles oxygen released = Moles oxygen final (1)

(O2AIR)(X) + (O2RELEASE)(Y) = (O2LEL)(X+Y) (2)

X * (O2LEL - O2AIR) = Y * (O2RELEASE - O2LEL) (3)

$$Y = \frac{(\text{O2LEL} - \text{O2AIR})}{(\text{O2RELEASE} - \text{O2LEL})} X \quad (4)$$

$$\text{Final concentration} = \frac{\text{moles released}}{\text{total moles}} \frac{\text{oxygen moles}}{\text{moles released}} \quad (5)$$

$$\text{Final concentration} = \frac{Y}{(X+Y)}\,\text{O2RELEASE} \qquad (6)$$

$$\frac{Y}{(X+Y)}\,\text{O2RELEASE} = \frac{\dfrac{(\text{O2LEL - O2AIR})}{(\text{O2RELEASE - O2LEL})}\,X}{X\left[1+\dfrac{(\text{O2LEL - O2AIR})}{(\text{O2RELEASE - O2LEL})}\right]}\,\text{O2RELEASE} \qquad (7)$$

$$\frac{Y}{(X+Y)}\,\text{O2RELEASE} = \frac{(\text{O2LEL - O2AIR})}{(\text{O2RELEASE - O2AIR})}\,\text{O2RELEASE} \qquad (8)$$

Asphyxiant dispersion in air

Inputs: Asphyxiant mole fraction in air: N2AIR (typical value = 0.79)
Asphyxiant mole fraction released: N2RELEASE
Oxygen mole fraction of concern: O2LEVEL

Outputs: Asphyxiant mole fraction for dispersion programs: N2LOC

Derivation of equation:

X = moles of air
Y = asphyxiant moles released

Moles asphyxiant initial + Moles asphyxiant released = Moles asphyxiant final (9)

(N2AIR)(X) + (N2RELEASE)(Y) = (1-O2LEVEL)(X+Y) (10)

X * (N2AIR + O2LEVEL -1) = Y * (1 - O2LEVEL - N2RELEASE) (11)

$$Y = \frac{(\text{N2AIR} + \text{O2LEVEL} - 1)}{(1 - \text{O2LEVEL} - \text{N2RELEASE})}\,X \qquad (12)$$

$$\text{Final concentration} = \frac{\text{moles released}}{\text{total moles}}\,\frac{\text{asphyxiant moles}}{\text{moles released}} \qquad (13)$$

$$\text{Final concentration} = \frac{Y}{(X+Y)}\,\text{N2RELEASE} \qquad (14)$$

$$= \frac{\dfrac{(\text{N2AIR} + \text{O2LEVEL} - 1)}{(1 - \text{O2LEVEL} - \text{N2RELEASE})}\,X}{X\left[1+\dfrac{(\text{N2AIR} + \text{O2LEVEL} - 1)}{(1 - \text{O2LEVEL} - \text{N2RELEASE})}\right]}\,\text{N2RELEASE} \qquad (15)$$

$$= \frac{(\text{N2AIR} + \text{O2LEVEL} - 1)}{(\text{N2AIR} - \text{N2RELEASE})}\,\text{N2RELEASE} \qquad (16)$$