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STL-1168-2008

Gas Dispersion

COMPETENCE
IN GAS DETECTION

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COMPETENCE
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Risk Management Program

Wherever toxic or flammable chemicals are being manufactured, processed, stored or shipped, there will always be a chance of an accident or a substance release. Even small releases of substances can cause harm to people, damage the environment or even destroy property. History informs us that accidents do happen and when they happen they can be catastrophic.

Learning from history

Recognising that accidents do happen, Governments worldwide publish Directives and enforce these Directives through legislation to mitigate against accidents.
In Europe the Seveso II Directive (98/82/EC) is an example of one such Directive. In the USA, the Risk and Management Program (RMP) is another example of how Governments are trying to protect the public and environment.

Government Directives require that companies, who hold excess amounts of dangerous substances, perform a Hazard Assessment. The main demands of most Hazard Assessments are to detail Prevention, Preparedness and Emergency Response Plans.

Gas detection systems play a major role in the prevention or mitigation of a major accident or incident. Prompt detection of a toxic or flammable release allows people to be informed early enough to make their escape, or where the release is explosive, to automatically switch off ignition sources. Other countermeasures may include the activation of local and remote alarms, isolation of process fluids by automatically closing valves or initiating additional emergency response services.
Gas detection systems do not prevent the initial release. Gas detection systems only respond to a release event.

In order to determine the magnitude of any Emergency Response Plan it is necessary to simulate a large scale gas release. This simulation will determine the boundaries or end point where a release of a toxic substance will no longer be harmful to people or where explosive gas/air mixtures will no longer ignite. Knowledge of gas dispersion is fundamental to conduct a simulation.

Analysing accidents

The gathering of data from all accidents is very important. Data gathered from accidents enables investigators to give reasons of why accidents occur and the consequences of such accidents. There are three main reasons for why accidents occur.

Major accidents do not just happen, they are a combination of minor events, including small gas releases, which collectively result in a major accident or incident. The impact of large scale accidents can be reduced or even avoided by early detection or a gas or substance release, with appropriate action being initiated. A well designed gas detection system, where the position of the gas detectors are optimised will act as a first line of defense against the dangerous release of toxic or explosive substances. A prompt detection system is a valuable asset.

The figure on the bottom details the most common substances involved with industrial leakages. It shows that there are a handful of substances which are most difficult to handle safely.

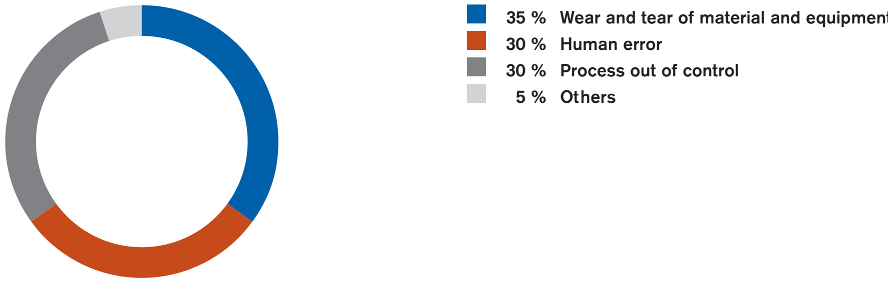
The role of gas detection systems

A gas detection system is not simply a handful of gas detectors spread across an industrial plant. The choice of detection technology, quantity of detectors and routine service and maintenance of the entire gas detection system are all important. However, the real challenge is to identify the possible migration path of any gas release based on a variety of factors wind direction, ambient temperatures, terrain, process pressures etc, which establishes the correct location of gas detectors. It is not practical to saturate an industrial plant with gas detectors, nor is it sensible to install only a single gas detector in a large area. There must be a compromise between cost and risk reduction.

There are two main types of gas detectors; a point gas detector which monitors the immediate vicinity of the gas detector, or an open path gas detector which monitors a much larger area between two points. Each type of gas detector has its own strengths and weaknesses.

It is also important to choose the correct measuring technology as some gas detectors may be poisoned by other chemicals in use, or be susceptible to high humidity or give invalid readings due to cross sensitivities. In all applications it is important to avoid spurious gas alarms.

Reason for accidents



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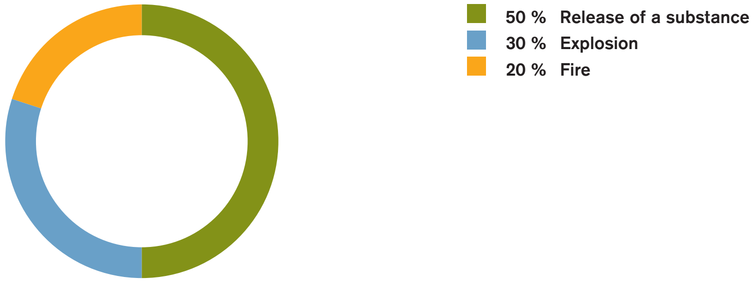
Accident consequences



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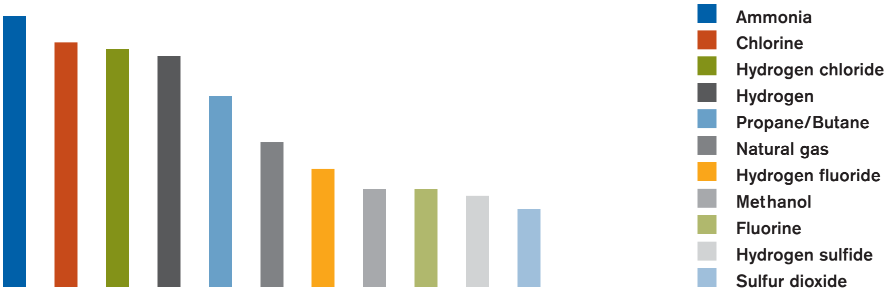
Chemicals involved in accidents; decending order. (MARS database 1984-2004)



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Accidental release of toxic and flammable matter

Industrial plants are not designed to leak toxic or flammable gases. However, each piece of equipment used in a process line does have a potential to leak, especially if service routines are not maintained. In each industrial plant there are thousands of devices and pieces of equipment used, such as e.g. gauges, valves, pumps, compressors, storage vessels, etc. Each joint or connection point is a potential source of release. The goal is to detect an accidental release before it develops into a major hazard.

Invisible gas hazard

Unfortunately, many gas releases are invisible to the human eye. This means that we have little experience about how gas releases behave and where the released gas eventual disperses. We can base our judgement on the behavior of gas releases on smoke clouds from fires which we have good experience of. However, this technique has its limitations because fires generate their own thermal energy which is different to the motive force behind a gas release. What we do understand is that gas releases have a high concentration within their initial central core and with turbulence at their fringes a lower gas concentration can be measured. Distance dilutes a gas release until the release reaches a boundary or end point where harmful effects are unlikely.

Software simulation

In recent years gas dispersion software to predict the movement and dispersion characteristics of gas releases over large areas has become available. These software packages are not accurate at characterising gas releases within a few metres of the release source because there is simply insufficient information available close to the source to generate an accurate dispersion model. Near-source dispersion models must therefore rely more on the thermodynamic conditions and physical properties of the gas components released than on meteorology or site-specific conditions. Simply using gas density as the only parameter may lead to dangerous misinterpretation of the predicted gas dispersion.

Stages of matter

To fully understand the characteristics of any gas cloud we must first understand matter. The three stages of matter are
- Gas
- Liquid
- Solid

If the temperature of a substance is greater than its boiling point, then the substance is in its gas phase. The volume of a gas will change as temperature and pressure changes. An increase in temperature will expand any gas increasing the volume and decreasing the density. The result of this is that the warm gas cloud will rise. Gases which are stored and compressed in a vessel have a higher density. At higher densities or pressure many gases change state and take up a liquid state.

Many solids and liquids below their boiling point have a tendency to evaporate to a gaseous state which is called vapour. There is a limit to the amount of vapour which can be in the gaseous state. This limitation is a function of temperature and pressure. The vapour concentration can never exceed the substance's specified value called the saturation vapour pressure. With changing ambient conditions, saturated vapours can condense.

Condensation can either form small droplets suspended in the air or form a liquid layer on cold surfaces. Small droplets in the air move freely and are called aerosols. When aerosols become too heavy or large they fall to the ground like rain. Aerosols are not a gas but the liquid phase of a substance.

Although pure water is not a gas at room temperature, water in the vapour phase mixes readily with dry air, until the partial pressure of the water vapour reaches the saturation water vapour pressure at the current temperature. Such moist air is lighter than dry air at the same temperature, because the molecular mass of water is lower than the average molecular mass of dry air. The maximum concentration of water vapour (saturated vapour pressure) in air at 20 °C / 68 °F is 23000 ppm. At 10 °C / 50 °F it is only 12000 ppm and at freezing point only 6000 ppm. It almost doubles every 10 °C / 18 °F temperature increase. When cooling down the surplus will condense as clouds, fog or rain.

Property of gaseous matter

The density of a substance is the ratio between its mass and the volume it occupies. All substances in a pure form have a different but specific density. The weight of a substance is related to the substance's density. If the densities of all individual substances are compared with air then we find that there are substances heavier than air, lighter than air or neutral with air. Substances which are lighter than air show buoyant characteristics and generally float upwards; such as hydrogen and helium which are used in balloons. Gases which are heavier than air are affected by gravity, thus flow towards and along ground level.

If the density of a gas is neutral with air, then this gas will move with air and be pushed and pulled by air currents. Neutral gases have no self motive force.

When comparing relative densities it is important to remember that the information given in reference tables supports pure substances which are at the same temperature as the surrounding air e.g. 20 °C / 68 °F. If a gas is heated then its density decreases and the motive force dictates that the gas cloud will rise; this is why hot air balloons float. Whereas, if a gas is cooled its density increases resulting in the gas cloud falling naturally towards the ground; the motive force being the pull of gravity. A rule of thumb is that the density of a substance can change by 3 % for every 10 °C / 18 °F change in temperature.

At room temperature 100 vol.% Methane has a relative density of 0.55 compared with air. This means, it is a light gas and will rise. For transportation and storage Methane is liquefied at – 162 °C / – 260 °F (LNG). If Methane leaks a very cold gas cloud is formed, which, due to the high density of cold Methane, is heavier than air. At – 112 °C / – 170 °F Methane density will be equal to air and when warmed further, the light gas properties will dominate.

As a gas cloud disperses two events occur; the concentration of the gas cloud decreases and with this change the gas cloud density will approach that of air. Therefore, as a gas cloud disperses its behaviour changes and finally becomes neutral with air. A diluted gas will never separate again from air to produce higher concentrations.

DENSITY

Substance	Formula	Rel density		Boiling temperature	
Hydrogen	H_2	0,07	gas	– 253 °C	– 423 °F
Helium	He	0,14	gas	– 269 °C	– 452 °F
Methane	CH_4	0,55	gas	– 162 °C	– 260 °F
Ammonia	NH_3	0,59	gas	– 33 °C	– 27 °F
Hydrogen fluoride	HF	0,69	gas	19 °C	66 °F
Acetylene	C_2H_2	0,90	gas	– 84 °C	– 119 °F
Hydrogen cyanide	HCN	0,93	vapour	26 °C	79 °F
Carbon monoxide	CO	0,97	gas	– 192 °C	– 314 °F
Nitrogen	N_2	0,97	gas	– 196 °C	– 321 °F
Ethylene	C_2H_4	0,97	gas	– 104 °C	– 155 °F
Air at 20 °C / 68 °F	–	1,00	gas		
Formaldehyde	HCHO	1,04	gas	– 21 °C	– 6 °F
Nitrogen monoxide	NO	1,04	gas	– 152 °C	– 242 °F
Ethane	C_2H_6	1,04	gas	– 89 °C	– 128 °F
Air at 0 °C / 32 °F	–	1,07	gas		
Methanol	CH_3OH	1,10	vapour	65 °C	149 °F
Oxygen	O_2	1,10	gas	– 183 °C	– 297 °F
Phosphine	PH_3	1,17	gas	– 88 °C	– 126 °F
Hydrogen sulfide	H_2S	1,18	gas	– 60 °C	– 76 °F
Hydrogen chloride	HCl	1,26	gas	– 85 °C	– 121 °F
Fluorine	F_2	1,31	gas	– 188 °C	– 306 °F
Propylene	C_3H_6	1,45	gas	– 48 °C	– 54 °F
Ethylene oxide	C_2H_4O	1,52	gas	11 °C	52 °F
Carbon dioxide	CO_2	1,52	gas	– 79 °C	– 110 °F
Propane	C_3H_8	1,52	gas	– 42 °C	– 44 °F
Nitrogen dioxide	NO_2	1,59	vapour	21 °C	70 °F
Methylchloride	CH_3Cl	1,74	gas	– 24 °C	– 11 °F
Acrylonitrile	CH_2CHCN	1,83	vapour	77 °C	171 °F
Acrolein (Acrylaldehyde)	C_2H_3CHO	1,94	vapour	57 °C	135 °F
n-Butane	C_4H_{10}	2,01	gas	– 1 °C	30 °F
Sulfur dioxide	SO_2	2,21	gas	– 10 °C	14 °F
Chlorine	Cl_2	2,45	gas	– 34 °C	– 29 °F
Benzene	C_6H_6	2,70	vapour	80 °C	176 °F
Hydrogen bromide	HBr	2,79	gas	– 67 °C	– 89 °F
Phosgene	$COCl_2$	3,41	gas	8 °C	46 °F
Bromine	Br_2	5,52	vapour	58 °C	136 °F

🟦 **Buoyant gases**
🟩 **Neutral gases**
🟧 **Dense gases**
⬜ **Vapours**
🟦 **Reference**

List of substances sorted by relative density compared to air.

Atmospheric dispersion

When a gas leaks from a process there is a boundary between when the gas is influenced by its process characteristics or thermodynamics (i.e. pressure, temperature, etc.) and the point where it becomes influenced by the ambient conditions (i.e. wind speed, terrain, temperature, etc.) It is extremely complicated to model a gas release due to the number of variables acting upon the released gas. It is not accurate to base a gas dispersion model on gas densities alone. Even on a calm day, the average wind velocity is 3 m/sec. which is enough to displace gases even though the wind can not be felt.

Depending upon the temperature of the leaking gas additional thermal effect may be experienced. A hot gas will tend to warm the surrounding air and create thermal currents which rise. Alternatively, cold gases will generate downward thermals.

Buoyant gas

If a gas release has a steady state then it immediately generates a cloud or a plume. If this cloud or plume is more than 2 % less dense than air then the release is said to be buoyant and will want to rise naturally. Hot gases react in an identical manner. The relative motion of a rising gas cloud generates turbulence at its fringes, resulting in rapid mixing of the gas and air. This mixing expands the rising gas clouds laterally. As the gas clouds rises, dilutes and expands laterally its density decreases, resulting in the gas cloud becoming neutral with respect to air. Once the gas cloud looses its buoyancy, then natural ambient conditions become dominant and the gas cloud can move anywhere.

To detect such a release, the recommended location for a gas detector is above and close to any potential release point, keeping the predominant wind direction in mind. Additional baffles or collecting cones can be used to direct the buoyant gas towards the gas detector. Due to the characteristics of a buoyant gas release it is often found that gas measurements are unstable due to the frequently changing gas concentrations within the gas cloud.

Typical examples of buoyant gases are Methane, Ammonia and Hydrogen. Statistically, only 20 % of all gas releases are of a buoyant nature. Like all gas releases the final stage of the gas cloud is when it becomes neutral with air.

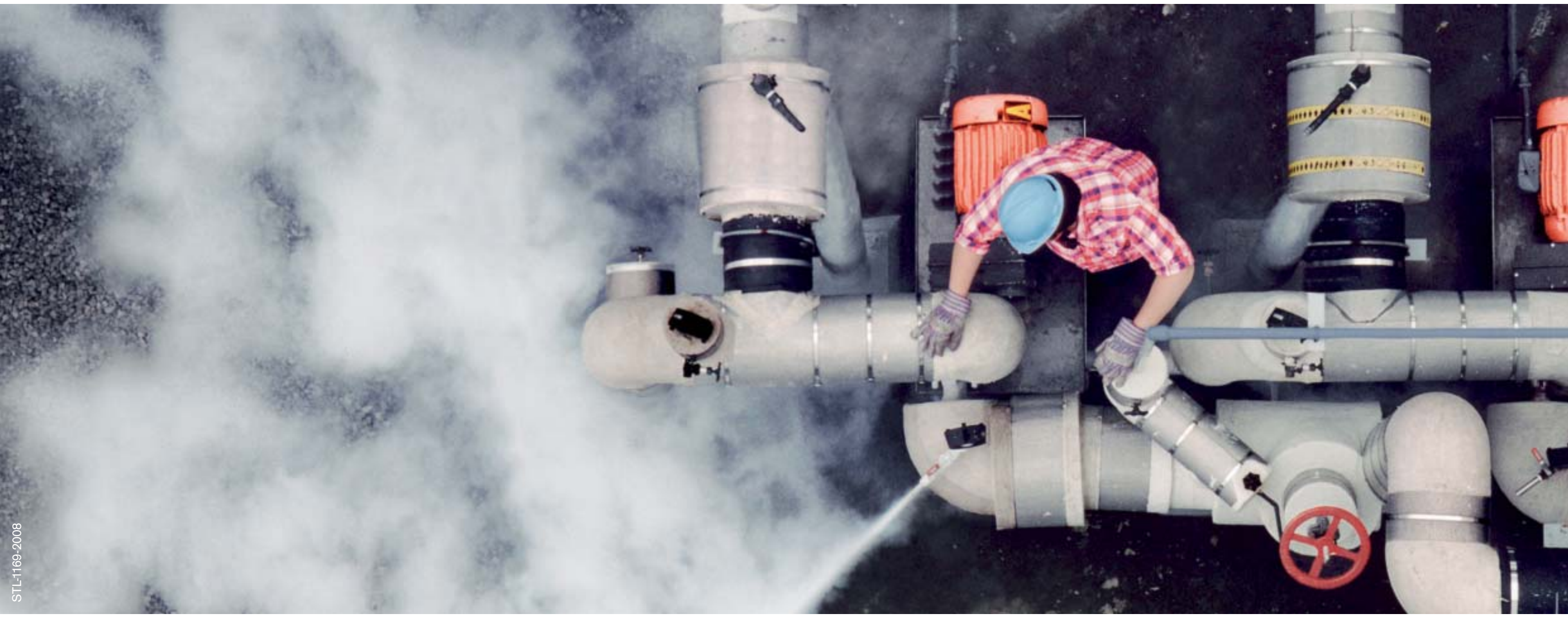
Neutrally buoyant gas

A neutrally buoyant gas has almost the same density as air. Typical gases with neutral buoyancy are Ethylene, Ethane, Carbon monoxide and Ethanol. Neutrally buoyant gases do not have any intrinsic movement of either up or down. Gas clouds are driven by wind or artificial air streams. Neutrally buoyant gas clouds mix extremely quickly with the surrounding atmosphere due to turbulence and vortexes. When toxic gases mix with air down to their work-place limits in the ppm range, they have reached density equilibrium with air and will behave neutrally buoyant.

To detect such a release the recommended location for a gas detector is level with any potential release point, keeping the predominant wind direction in mind.

Dense gas

Dense gases and vapours are much heavier than air and collectively form the largest group of all dispersing substances. This group of dispersing substances includes heavier than air gases, vapours from evaporating liquids and cold gas clouds. The motive force for the migration of dense gases is gravity, therefore the dispersion normally follows the gradient of the terrain. A dense gas cloud will fall like a waterfall, flow along the surface like water and can travel long distances before natural dilution occurs or turbulence disperses the cloud altogether. Long dispersion distances create greater areas of danger. Dense gas clouds are not easily distorted by wind, however structures, walls and dikes can alter or control the flow of the moving gas cloud. Dense gas clouds are extremely



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dangerous as the can disappear by entering basements, tunnels, wells etc, which makes countermeasures very difficult. However, as their migration paths are very predictable the location of gas detectors is relatively simple and straight forward. All gas detectors should be mounted close to the ground and in the presumed pathway of the gas cloud. If the gas cloud is made up from cold gases which are normally buoyant at room temperature then the gas cloud will act a little differently. Initially the temperature of the gas cloud will make it behave as a dense gas cloud. As the gas cloud heats up, its characteristics will change from ‘dense’ to ‘buoyant’. Dense, cold gas clouds are sometimes easy to see as they condense water vapour from the surrounding atmosphere to produce visible fog.

Aerosols

An aerosol is not a gas, but a liquid made from small droplets which are suspended in air. The droplets are formed from vapours or gases under certain thermodynamic conditions or by flash evaporation of pressurised liquids. The scattering of light within an aerosol cloud frequently makes the cloud visible to the naked eye. The dispersion of an aerosol may vary between the behaviour of a dense gas or a neutrally buoyant gas. However, as the aerosol droplets absorb temperature from the surrounding environment they will evaporate and generate a gas/vapour cloud.

Substances with a hygroscopic property can form aerosols by absorbing moisture from the surrounding atmosphere. Substances like HCl, HF and SO_3 are typical examples. The gas SO_3 which has a very strong hygroscopic property will absorb moisture from the air immediately upon release. The reaction between SO_3 and water produces droplets of sulfuric acid. As the weight of the sulfuric acid aerosol increases droplets will fall to the ground to produce pools of acidic liquid. For the detection of acid gases it is recommended to position the gas detector low to the ground.

Vapour

Liquids naturally have a vapour pressure which is a function of the temperature.
The process of evaporation requires energy which normally comes from the liquid and the surrounding environment. As a liquid vaporises the temperature of the liquid decreases resulting in a cooling effect, which in turn slows down the evaporation process. The temperature of the vapour is lower than the original liquid, which causes the vapour to act like a dense gas. The concentration of the liberated vapour is not easy to predict as it is a function of the evaporation rate, temperature of the liquid and the surrounding air flow. Gas detectors should be located close to the ground in the presumed pathway of the vapour cloud.

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Source characteristics

To fully understand gas dispersion it is insufficient just to consider the characteristics of how gas clouds disperse. It is necessary to understand that different phases of dispersion occur from different sources.

The characteristics of any substance leak depends upon the following main process conditions

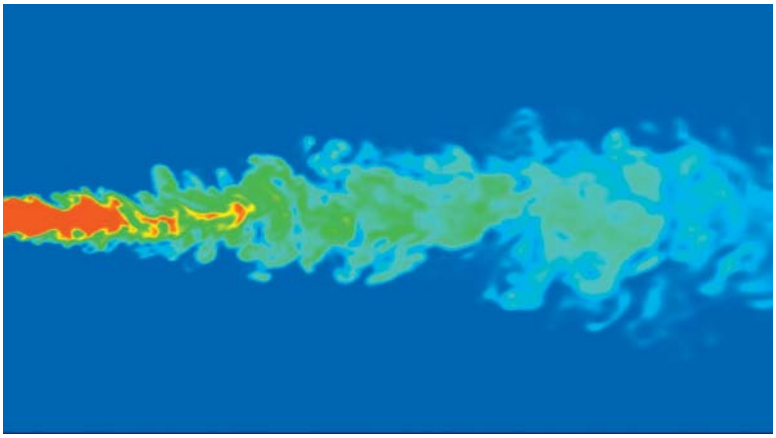
- Gas at different temperatures and pressures
- Gas liquefied under pressure
- Gas liquefied by refrigeration
- Liquids or solvents

Most leakages occur slowly. Process lines corrode, pumps seals age and pressure valves weep slowly. Where leakages of this size are continuous it may be possible to detect reasonable concentrations with localised gas detectors as the gas disperses with air movement. When leak sources continue without repair, there may be an instant when the process leak becomes an accidental discharge.

Gaseous release

An over pressure gas release will produce a gas cloud (concentration at the point of release equals the process concentration) at the release point e.g. pump seal. The density of the gas and the prevailing wind will move the gas cloud in a predetermined manner. Light gases or hot gases having a density lower than air will tend to float, whereas heavy gases or cold gases having a density higher than air will tend to sink. Irrespective of whether the gas cloud is buoyant or dense the uniformity of the gas cloud is not constant and changes dramatically with distance and time.

High pressure gas jet displaying gas concentration by different colours.

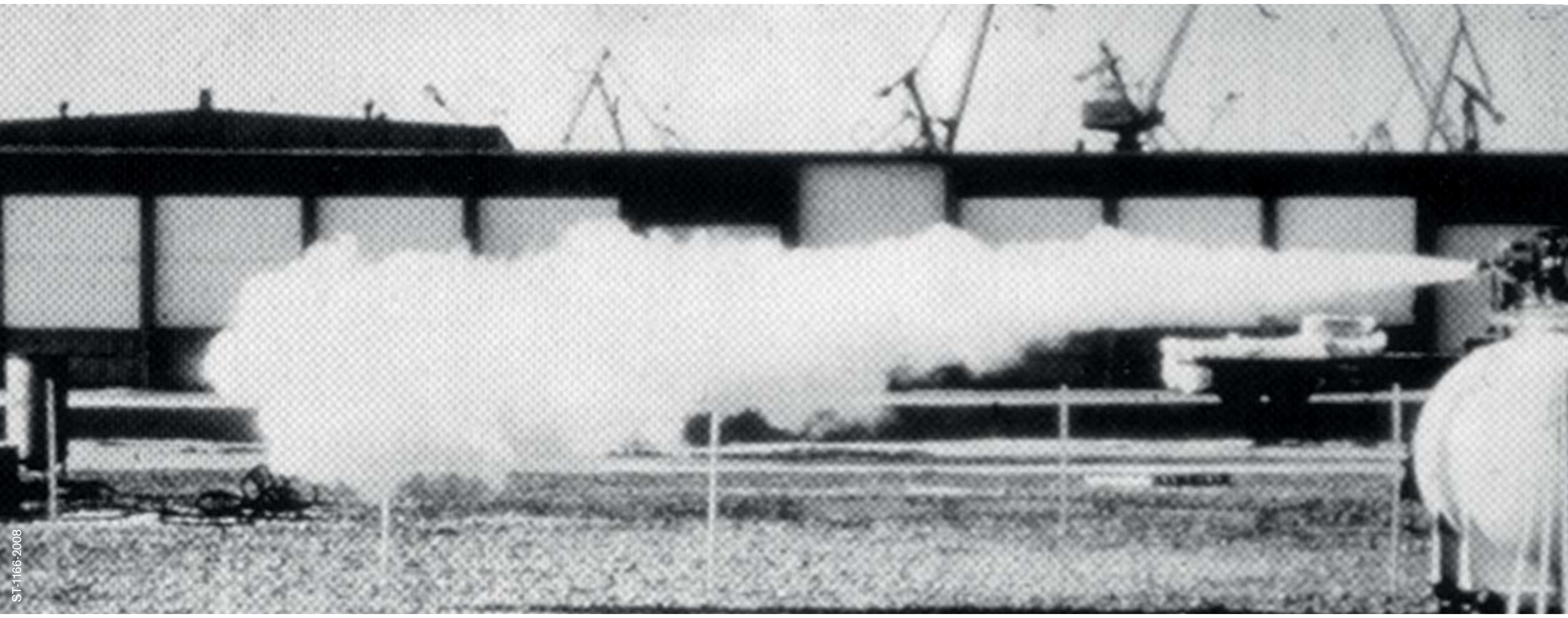


As the gas disperses from its point of release a gas plume is formed. The concentration within the plume changes constantly: it may rise and fall depending upon the movement of the plume. A gas plume can be compared with the characteristics of visible smoke from a chimney.

Plumes of gas moving across a gas detector will generate random gas measurements. Sometimes the gas detector will measure high concentrations, and as the plume meanders, the gas detector may measure low concentrations – random gas values are typical. This type of gas dispersion model is called the Gaussian dispersion. Eventually, the gas plume will completely disperse and its contents become part of the ambient atmosphere.

Medium pressure gas release reacts differently to an over pressure gas release. A thermodynamic effect called adiabatic expansion comes into play. As the high pressure gas escapes, it expands and cools down. The resulting cold gas cloud therefore acts likes a dense gas.

High pressure gas releases will initially produce jets of released gas. The shape and distance of the jet varies, however the format of the jet is reasonably stable, having a high concentration along its axis, with concentrations decreasing towards the edges. The shape of the jet release is



Horizontal jet of pressure liquefied Ammonia. Visible aerosol 0.7 sec after valve rupture.

tapered outwards with distance. Due to the high gas velocities experienced the released gas quickly mixes with air due to turbulence. Quick dilution creates a naturally buoyant gas cloud. Due to the concentrated direction of gas jets the positioning of gas detectors is quite difficult, because jets can form in any direction. Baffles located around possible leak points help to destroy a jet release, thus a more turbulent release occurs which easily disperses across gas detectors.

Liquefied under pressure

The storage of gases in their liquefied phase is very common in industry. The liquefied phase of a gas reduces the total space required for storage and makes transportation of the gas easier. The volume taken by the liquid phase of a gas is reduced by a factor of 100 to 500 depending upon the gas. There are two ways to liquefy gases; the first way is to increase the pressure and the second way is to reduce the temperature.

When a pressurised liquid escapes, there are two phases associated with the leak. First, a jet of liquid will be released which instantly evaporates. This evaporation is called ‘flash’. Second the evaporating liquid pulls energy from itself and the surrounding atmosphere and in turn cools down the leaking fluid. The cooling of the fluid prevents total evaporation therefore an aerosol is produced. If the leak is large enough then cold pools of fluid can accumulate on the ground which will evaporate to produce a gas release. The cold aerosol cloud will act like a dense gas. A pressurised liquid release can often be seen by the naked eye as the cooling effect of evaporation will condense ambient humidity to produce a vapour cloud.

Liquefied by refrigeration

When a gas is refrigerated below its boiling point it will become a liquid. If a refrigerated gas leaks, a cold pool of liquid is formed at ground level. As the cold liquid pulls energy from the surrounding atmosphere the liquid will boil naturally. This is a self controlling process. Limited heat transfer will only allow a certain rate of gas to be generated. The temperature of the liquid and the evolving gases are low, therefore both the liquid and gases will act like a dense gas. Gravity and wind flow will dictate the direction of liquid and gas flow. Like dense gases, the use of dikes or bund walls can be used efficiently to direct or hold the flow of all leakages. The most effective place to mount a gas detector would be inside of the dike or bund wall.

Liquid spillage

The spillage of liquids will always form a pool on the ground unless the surface is absorbent. The vapour pressure and evaporation rate of the liquid will form a vapour cloud at the liquid’s surface. The maximum concentration of the vapour cloud is determined by the vapour pressure of the specific liquid and temperature. At higher temperatures, higher gasconcentrations will be experienced.

The rate of evaporation of any substance is fixed, therefore the concentration build-up is a function of time. If the gas is dispersed by air currents, then only low concentrations will be experienced. Vapours liberated by non-boiling liquids will act like a dense gas e.g. flows along the ground where walls and dikes can effectively control their direction.

Gaseous release inside buildings

The behaviour of a gas release inside a building is completely different to the known behaviour of the same release occurring outdoors. Not only do you have the containment of the gas, resulting in an increase in the potential concentration, but there is an additional hazard of oxygen displacement/deficiency. To position a Gas Detector correctly, it is imperative that the characteristic of the room´s air flow is known. This can be achieved by using smoke tubes.

The indoor difference
For indoor applications, the prevailing wind for an outdoor application is replaced by internal air currents. Air currents within a building can be forced e.g. heating and ventilation systems, by convection from hot process equipment or by thermal effects on the walls and roof from external sunlight. There are many other factors which can affect internal air currents e.g. the movement of people or product.

In an open plant, a gas cloud can spread in all directions and has no boundary. Within a building, a gas cloud can only consume a fixed and finite volume, thus the concentration of the leaked gas will increase. Given sufficient time, even the smallest of leaks can exceed the LEL (explosive) or TLV (toxic) levels within the entire room volume.

An additional hazard, in buildings, is the replacement of ambient Oxygen by a leaking gaseous substance. Gases which displace Oxygen are not limited to gases which are either explosive or toxic, but include nonflammable and non toxic gases such as Nitrogen, Helium, Argon or Sulfur hexafluoride (SF_6).
At a concentration of 10 vol.% Argon in the air the Oxygen concentration drops by 2 vol.% from 20.9 vol.% to 18.9 vol.%.

Where there is a risk of Oxygen depletion, additional gas detectors must be installed.

The location of gas detectors inside a building is not a simple and straight forward task. It may be sensible to locate a gas detector adjacent to a potential source of release. This would give the earliest warning. However, it must be remembered that leaks occur in all directions. This would mean many sensors across a three dimensional grid. Installing a grid format of sensors in a room may be more practical and economic, however this type of installation stretches the alarm response time as the gas must travel to the sensor.

The correct location of a gas detector can only be determined if the air movement within the building/room is analysed. The first step is to identify all of the possible sources which generate air movement e.g. ventilation systems, hot surfaces, movement of people and product, thermal radiation etc. The second step is to simulate the air movement by using smoke tubes, taking care to monitor dead spaces like corners, roof voids and sumps.

TECHNICAL DATA

Room class	Driving force	Air exchange rate	Flow	Dilution efficiency	Gas dispersion	Recommended placement
Air tight	Density, convection, motion	0.1 /h	< 20 cm/sec diffuse	Low	Dense gas descending	Ground
					Light gas buoyant	Ceiling
Thermal sources	Machine, heater, heat exchanger, lumination	> 0.2 /h	> 20 cm/sec	Good	Ascending, convection	Ceiling above thermal source
					Circulating streamline	In the stream
Active ventilation	Ventilation, air condition, openings	Calculated	> 1 m /sec	High	Following streamline	In the stream
						Duct

Gaseous release inside buildings

Different scenarios which are typical for gas leaks within a building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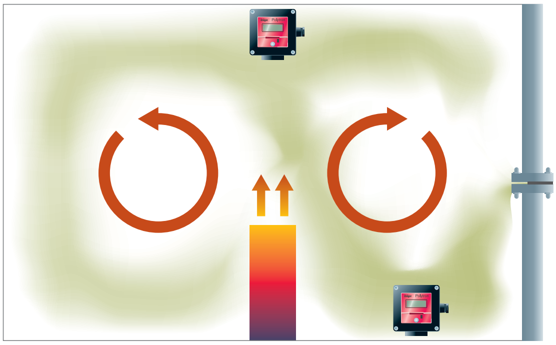
Air tight room; light gas „blue", dense gas "yellow".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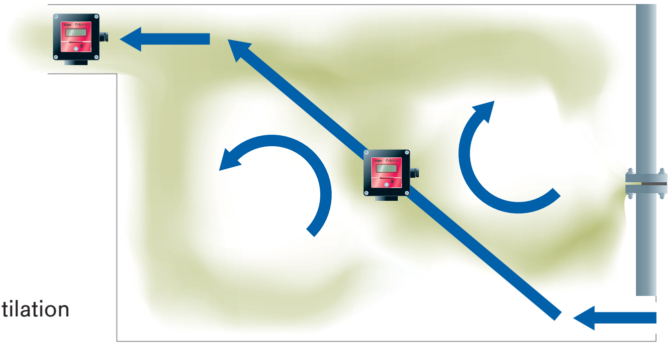
Thermal source developing convection currents.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Room with ventilation system.

Air tight rooms
An air tight room means that there is very little air exchange between the volume of the room and the outside. This is typical for large warehouses which store chemicals, gases and other goods. Within such a room, air movement does exist, however it's so small that it has no influence or motive force to move or dilute a gas cloud. The exchange of air with the outside can be as low as 0.1/h. This means that 10 % of the air volume within the room will be exchanged with the outside air through natural gaps in the room. This exchange is not enough to dilute any gas release, therefore insufficient to guard against a gas hazard. With very little air movement within a room, a gas release will behave as a buoyant, neutral or dense gas depending on its density.

Examples of gas releases in an air tight room
a) An evaporating pool of solvent will create a dense cloud at floor level
b) Carbon dioxide will fall to the ground and accumulate at the lowest point
c) Methane will rise to the ceiling
d) Ammonia will disperse and rise to the ceiling

Gas mixtures have different dispersion characteristics with respect to their particular contents.

Hydrogen does not always rise just because it is lighter than air. In a galvanic process Oxygen and Hydrogen can be generated at the same time and at the same location. Oxygen is heavier than air (relative density 1.1) and Hydrogen is lighter than air (relative density 0.07). An undisturbed mixture of Oxygen and Hydrogen, up to a concentration of 10 vol.% Hydrogen remains denser than air and will fall to the ground. The LEL of Hydrogen is 4 vol.%, therefore at floor level there exists an explosive level of Hydrogen.

The location of a gas detector in an air tight room is totally dependent on the relative density of the leaking substance, including the combined influences of gases in mixtures.

Thermal sources

There are many heat dissipating sources within a room, especially machinery rooms. The energy from the heat source heats up the surrounding air which rises to the ceiling. This warm air will spread sideways towards the walls. As the air cools it begins to fall down towards floor level, thus creating a circular motion. This circular air current is so strong that it carries gases irrespective of their density. The turbulent characteristics of the circular air currents encourage any leaking gas to mix with the air resulting in dilution of the concentration. The concentration will increase with time.

Gas detectors should be installed at ceiling height above the heat source, or where the air current can be defined.

Active ventilation

For safety reasons it is common to find rooms where forced ventilation is installed. This is to ensure that there is a constant air exchange to guard against any build up of toxic or explosive gases. The air movement within the room is calculated (rate of change) and the profile of air currents is known, therefore the location of the gas detectors is made easier. There are two options for the location of gas detectors

a) The gas detector can be located in the known air stream within the room, or
b) The gas detector can be located in the ventilation system (outlet)

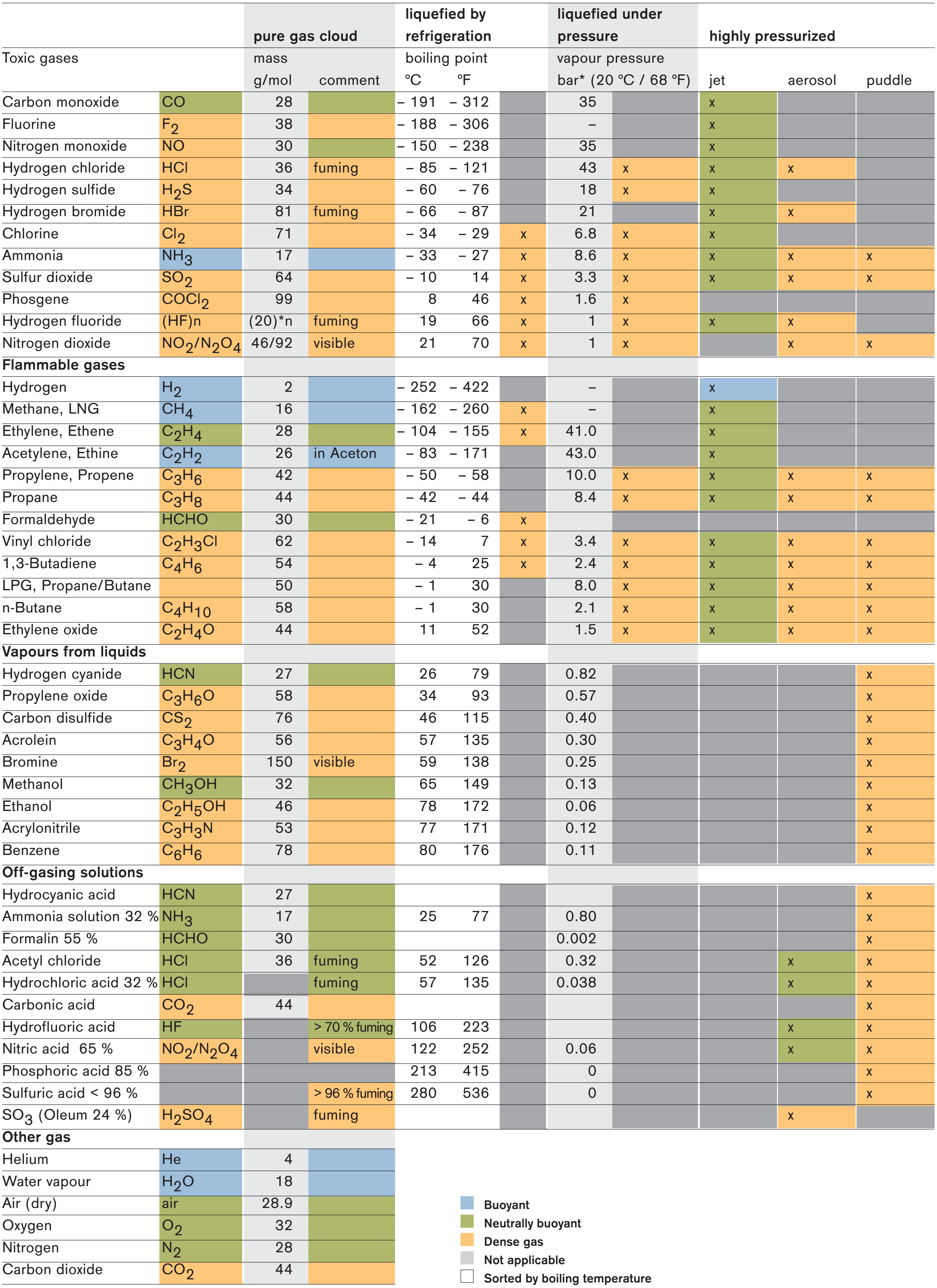
Gas detectors with a lower measuring range will be needed as the constant air exchange will dilute any gas leak. Gas detectors may be required to monitor for gas emissions. In the case of a gas emission the ventilation system may be required to shutdown to contain the gas.

Air flow

Within any controlled environment e.g. inside of a building, it is recommended that an air flow check is performed on a regular basis. The Dräger Flow Check is a device which makes air streams visible by generating a visible aerosol of a neutral buoyant property. The visible aerosol can be released adjacent to any potential leak source and the aerosol can be watched to determine the surrounding air currents. This method of determining air currents is best suited to areas where there are thermal sources or forced ventilation. If a room is totally stagnant, then the Flow Check will only simulate the characteristics of a neutrally buoyant gas.

Air flow within a room will be disturbed by high pressure releases. A high pressure release will increase the gas concentration within a room rapidly. Mechanical baffle plates can be used to disturb any jet release.

SUBSTANCE OCCURRENCE IN OPERATIONAL FAULT SITUATION

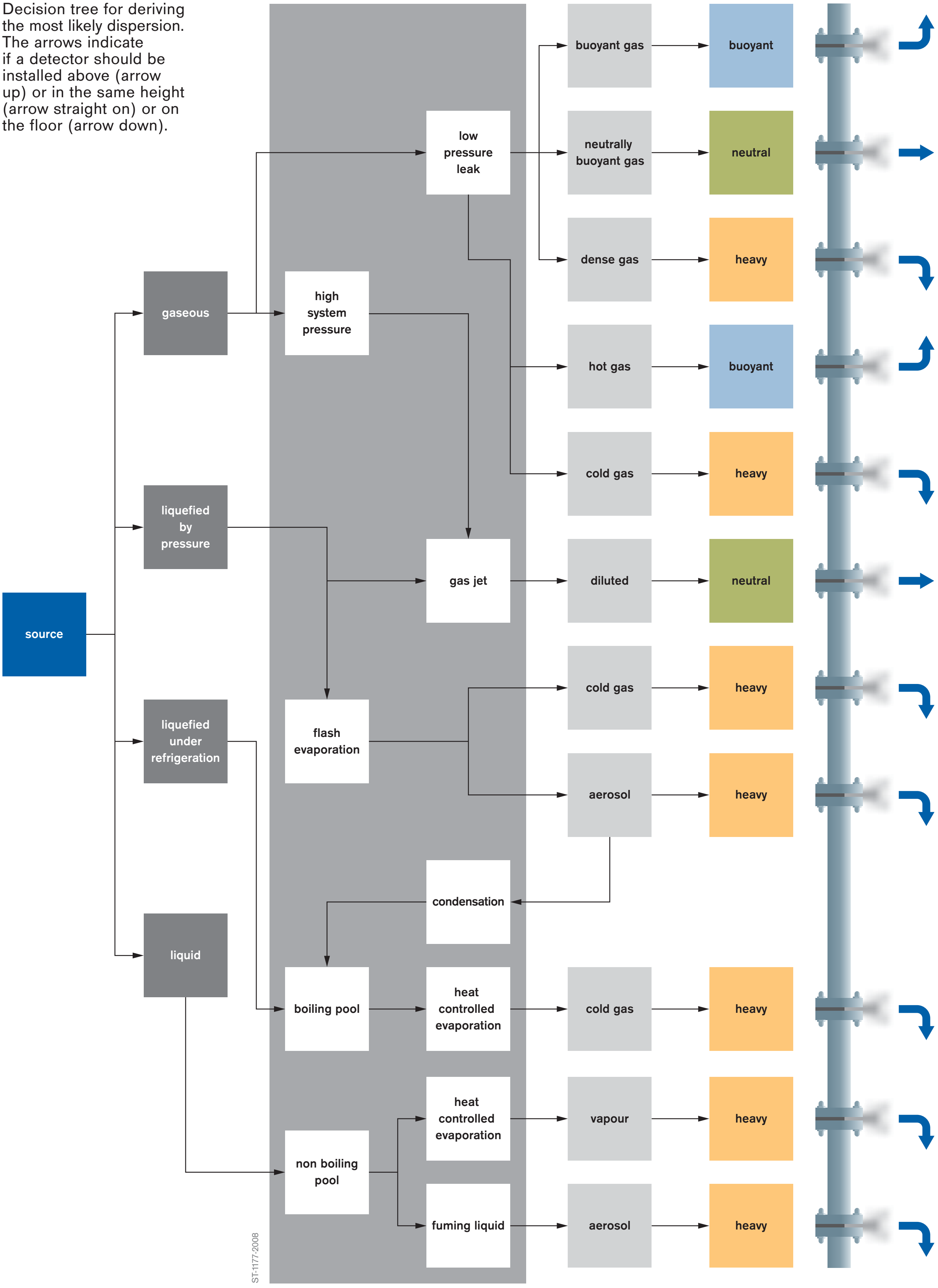


		pure gas cloud		liquefied by refrigeration			liquefied under pressure		highly pressurized		
Toxic gases		mass g/mol	comment	boiling point °C	°F		vapour pressure bar* (20 °C / 68 °F)		jet	aerosol	puddle
Carbon monoxide	CO	28		– 191	– 312		35		x		
Fluorine	F_2	38		– 188	– 306		–		x		
Nitrogen monoxide	NO	30		– 150	– 238		35		x		
Hydrogen chloride	HCl	36	fuming	– 85	– 121		43	x	x	x	
Hydrogen sulfide	H_2S	34		– 60	– 76		18	x	x		
Hydrogen bromide	HBr	81	fuming	– 66	– 87		21		x	x	
Chlorine	Cl_2	71		– 34	– 29	x	6.8	x	x		
Ammonia	NH_3	17		– 33	– 27	x	8.6	x	x	x	x
Sulfur dioxide	SO_2	64		– 10	14	x	3.3	x	x	x	x
Phosgene	$COCl_2$	99		8	46	x	1.6	x			
Hydrogen fluoride	(HF)n	(20)*n	fuming	19	66	x	1	x	x	x	
Nitrogen dioxide	NO_2/N_2O_4	46/92	visible	21	70	x	1	x		x	x
Flammable gases											
Hydrogen	H_2	2		– 252	– 422		–		x		
Methane, LNG	CH_4	16		– 162	– 260	x	–		x		
Ethylene, Ethene	C_2H_4	28		– 104	– 155	x	41.0		x		
Acetylene, Ethine	C_2H_2	26	in Aceton	– 83	– 171		43.0		x		
Propylene, Propene	C_3H_6	42		– 50	– 58		10.0	x	x	x	x
Propane	C_3H_8	44		– 42	– 44		8.4	x	x	x	x
Formaldehyde	HCHO	30		– 21	– 6	x					
Vinyl chloride	C_2H_3Cl	62		– 14	7	x	3.4	x	x	x	x
1,3-Butadiene	C_4H_6	54		– 4	25	x	2.4	x	x	x	x
LPG, Propane/Butane		50		– 1	30		8.0	x	x	x	x
n-Butane	C_4H_{10}	58		– 1	30		2.1	x	x	x	x
Ethylene oxide	C_2H_4O	44		11	52		1.5	x	x	x	x
Vapours from liquids											
Hydrogen cyanide	HCN	27		26	79		0.82				x
Propylene oxide	C_3H_6O	58		34	93		0.57				x
Carbon disulfide	CS_2	76		46	115		0.40				x
Acrolein	C_3H_4O	56		57	135		0.30				x
Bromine	Br_2	150	visible	59	138		0.25				x
Methanol	CH_3OH	32		65	149		0.13				x
Ethanol	C_2H_5OH	46		78	172		0.06				x
Acrylonitrile	C_3H_3N	53		77	171		0.12				x
Benzene	C_6H_6	78		80	176		0.11				x
Off-gasing solutions											
Hydrocyanic acid	HCN	27									x
Ammonia solution 32 %	NH_3	17		25	77		0.80				x
Formalin 55 %	HCHO	30					0.002				x
Acetyl chloride	HCl	36	fuming	52	126		0.32			x	x
Hydrochloric acid 32 %	HCl		fuming	57	135		0.038			x	x
Carbonic acid	CO_2	44									x
Hydrofluoric acid	HF		> 70 % fuming	106	223					x	x
Nitric acid 65 %	NO_2/N_2O_4		visible	122	252		0.06			x	x
Phosphoric acid 85 %				213	415		0				x
Sulfuric acid < 96 %			> 96 % fuming	280	536		0				x
SO_3 (Oleum 24 %)	H_2SO_4		fuming							x	
Other gas											
Helium	He	4									
Water vapour	H_2O	18									
Air (dry)	air	28.9									
Oxygen	O_2	32									
Nitrogen	N_2	28									
Carbon dioxide	CO_2	44									

🟦 **Buoyant**
🟩 **Neutrally buoyant**
🟧 **Dense gas**
⬜ **Not applicable**
☐ **Sorted by boiling temperature**

RECOMMENDATION FOR TRANSMITTER PLACEMENT

Decision tree for deriving the most likely dispersion. The arrows indicate if a detector should be installed above (arrow up) or in the same height (arrow straight on) or on the floor (arrow down).



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