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Flammable Gas Cylinders for Laboratory Use

A source of flammable gas is occasionally required in teaching and research laboratories to provide heat and flame, for example, Bunsen burners, glass pipette drawing, and sealing glassware. After a recent incident involving an old leaking reticulated building gas supply (OHS Incident Summary Report, 22/10/2002), the safety of many building reticulated systems is being investigated (OHS Unit/Facilities and Services, report pending). Due to the diminishing requirement for flammable gas or lack of a reticulated supply, many departments/buildings now use portable compressed flammable gas cylinders. Inappropriate gas cylinders, their attachments, and poor user practices can also be a safety concern.

This report looks at the flammability risk associated with various gas cylinder sizes and recommends an appropriate choice for the gas for use in laboratories.

Hazard Potential -
The flammable gas in cylinders used for heating, blow torches etc, is generally a combination of propane and butane. Cylinders can vary in size from approximately 170-190g (80 – 100 L at 1 atm) to 9 kg (4700 L at 1 atm). The gas exists as a liquid when under pressure in the low-pressure cylinders.

190 g

340 g

2 kg

Examples of flammable gas cylinders

The torch/burner is mounted directly on the cylinder or attached via flexible tubing (especially the larger cylinders > 2 kg).

Primus 2294 Gas Torch 2.3 kW output

Various Small Gas Torches

The risk of flammable gas is generally considered to be associated with fire/explosion and asphyxiation. The toxic health effects of high vapour pressure alkanes are usually limited to drowsiness and narcosis at high exposure levels (1% or more). This narcotic effect is much lower than the concentrations required for an explosion. Maintaining exposures below the occupational exposure limit (approximately 800 – 1000 ppm, 1900 mg/m^3) would reduce these symptoms.

The gases properties are –

	Propane	**Butane**	**LPG**	**Handigas**™
Boiling Point (deg C):	-42.1	-0.5	-0.5 to -42	-0.5 to -42
Melting Point (deg C):	-189.7	-138.4	-188	-
Vapour Pressure (kPa):	853 @ 21 C.	211 @ 15 C	1050 (propane)	1050 to 265
Specific Gravity:	0.5 (liquid)	0.601 @ 0 C	0.5-0.6	2 (gas / air)
Flash Point (deg C):	-104.44	-60	-81	Not determined
Lower Explosive Limit (%):	2.2	1.9	1.5	1.8
Upper Explosive Limit (%):	9.5	8.5	10.0	9.5
Solubility in Water (g/L):	Slightly	Immiscible	Immiscible	Slight
Expansion ratio (liquid/gas):				1 Kg to 525 L 1 L to 271 L
Occupational Exposure limit: (any available worldwide)	2100 ppm 3790 mg/m^3	800 ppm 1900 mg/m^3	1000 ppm 1800 mg/m^3	800 ppm 1900 mg/m^3
Immediately Dangerous to Life and Health level:	20 000 ppm (LEL)	19 000 ppm (LEL)		

Risk Scenarios -

In order to associate the risk of fire/explosion and toxicity with the use of flammable gas cylinders, several scenarios were constructed. It is assumed that the gas being used is a mixture of propane and butane, and –

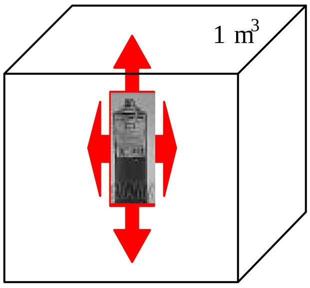
Assumptions used in the calculations and scenarios

- has a Molecular Weight of 44 (propane).
- 1 kg of liquid converts to 525 L of gas at room temperature and pressure.
- The lower explosive limit (LEL) is 1.8 % (v/v).
- The upper explosive limit (UEL) is 9.5%. When the air/fuel mix is between the LEL and UEL, an ignition would result in an explosion (💣).
- The safety effect considers only that of an explosion.
- The occupational exposure limit is in the order of 2000 mg/m^3 (~1100 ppm)
- The rate of release of the gas varies between gas cylinder sizes, so that the total contents are released after the allotted time frame. For example, over 30 minutes, the 190 g cylinder releases gas at 106 mg/s while the 1.25 kg cylinder releases at 694 mg/s.
- The gas released instantaneously mixes with the allotted workspace.
- Actual gas cylinder sizes (which can be purchased) may differ to those listed, due to the variation in composition and manufacturer.

Example calculations can be found in a companion document.

Scenario A –

A small flammable gas cylinder ruptures in a small space (1 m^3). There is no ventilation. This would be similar to a release into a small storage cupboard.

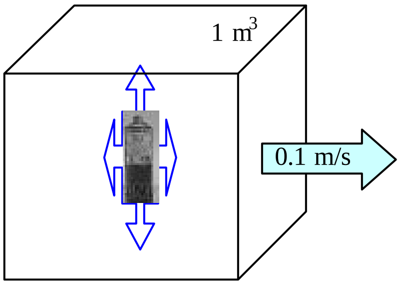


Cylinder Size	**Concentration of Gas**			**Effect**
(g)	(mg/m^3)	(ppm)	(% in air)	
190	190,000	105,600	10	above UEL, 💣
250	250,000	138,900	13	above UEL, 💣
500	500,000	277,800	26	above UEL, 💣
900	900,000	500,100	47	above UEL, 💣
1250	1,250,000	694,600	66	above UEL, 💣

When the gas concentration is above the upper explosive limit (UEL), the risk of an explosion is reduced, since there is inadequate oxygen to support combustion. However in reality, at the boundaries, the fuel to air mixture can exist within the explosive range (LEL < mix < UEL), and therefore, a source of ignition will result in an explosion.

Scenario B –

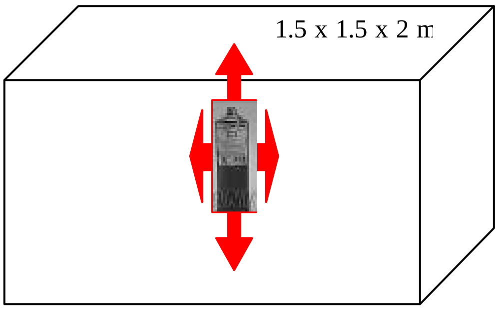
A small flammable gas cylinder leaks into a small space (1 m^3) over a period of 30 minutes. There is some dispersion into still air (0.1 m/s). This would represent a gas torch, where someone has left the valve slightly open.



Cylinder Size (g)	Concentration of Gas after 30 minutes (mg/m^3)	(ppm)	(% in air)	Effect
190	5280		0.3	☺
250	6950		0.4	☺
500	13900		0.7	☺
900	25020		1.3	☺
1250	34750	19310	1.8	💣

Scenario C –

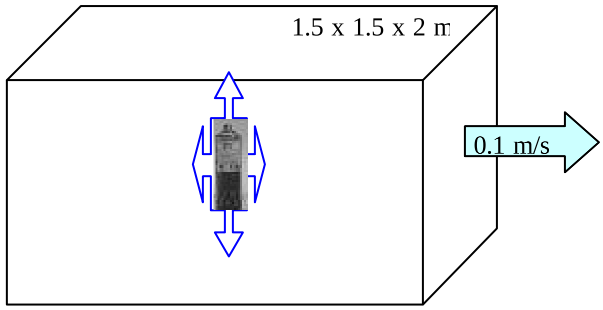
A small flammable gas cylinder ruptures in a small workspace (1.5 x 1.5 x 2 m). There is no ventilation.



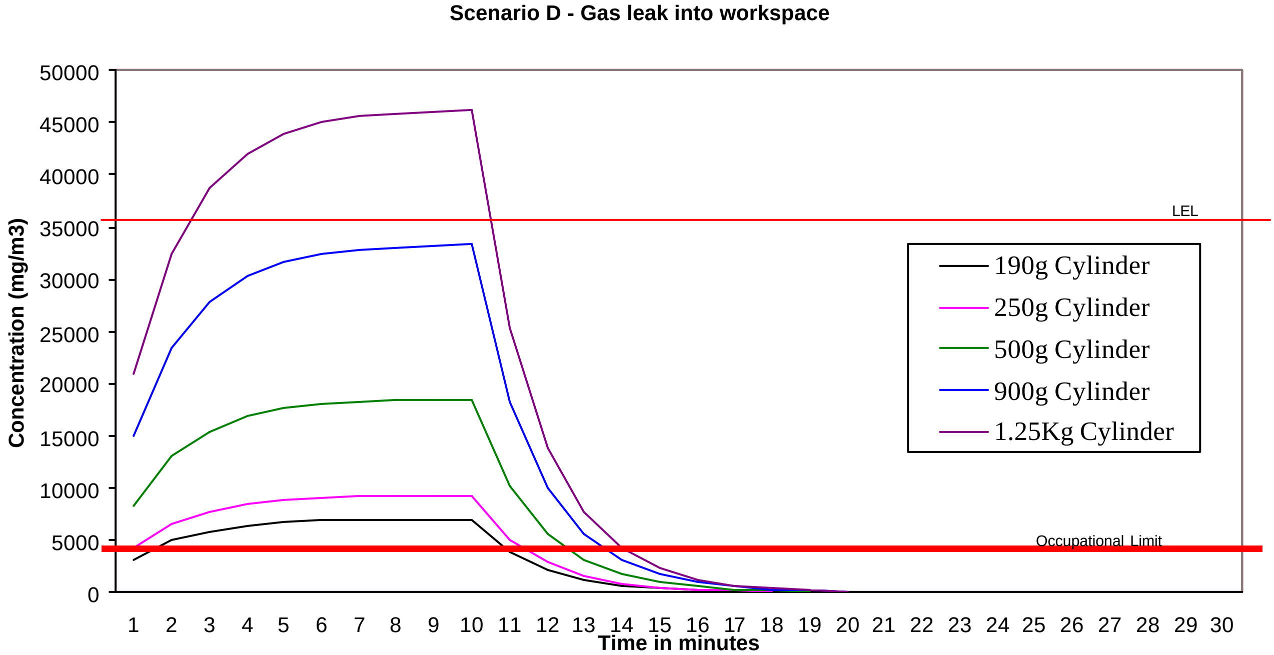
Cylinder Size (g)	Concentration of Gas (mg/m^3)	(% in air)	Effect
190	42,180	2.2	💣
250	55,500	2.9	💣
500	111,000	5.8	💣
900	199,800	10.5	above UEL, 💣
1250	277,500	14.6	above UEL, 💣

Scenario D –

A small flammable gas cylinder leaks into a small workspace (1.5 x 1.5 x 2 m) over a 10-minute period. There is some dispersion into still air (0.1 m/s).

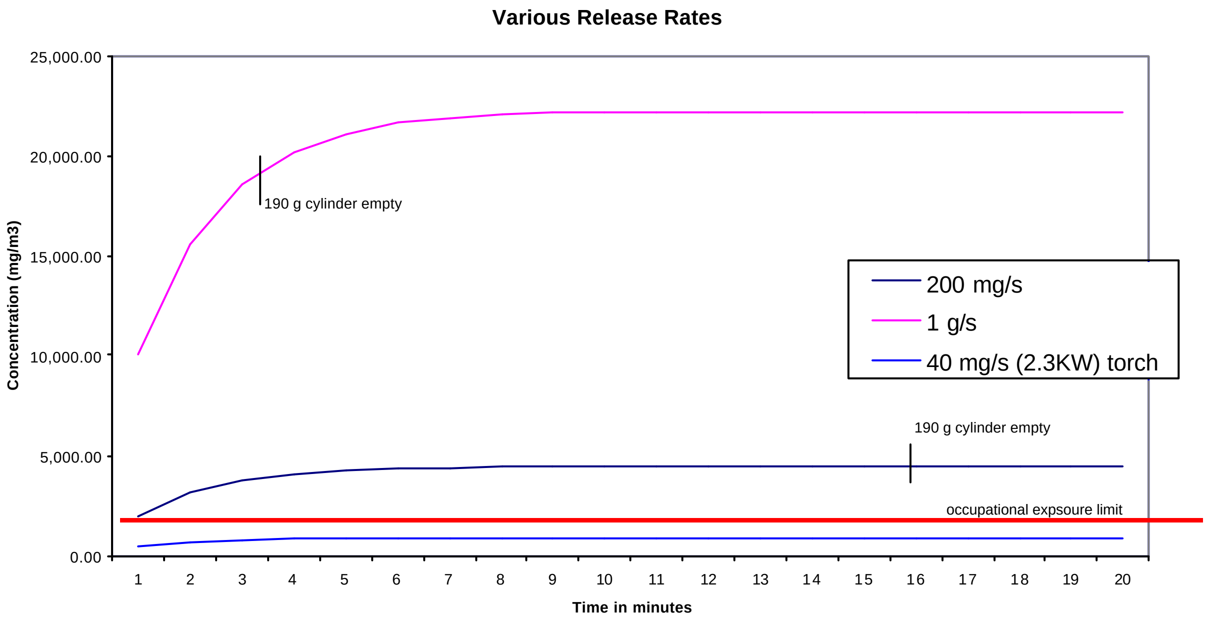


Cylinder Size (g)	Concentration of Gas after 10 minutes (mg/m^3)	(% in air)	Effect
190	7020	0.4	☺
250	9240	0.5	☺
500	18470	1.0	☺
900	33250	1.7	☹
1250	46180	2.4	💣



The above graph shows the concentration over time. Note, after around 5 minutes the concentration has approximated equilibrium. Over the first 10 minutes the cylinder is leaking. After 10 minutes, dilution ventilation/extraction allows the concentration to decay to safe levels.

This scenario has been recalculated with various rates of gas release (40 mg/s, 200 mg/s, 1g/s) as shown below. A 2.3 kW Output gas torch consumes approximately 40 mg/s, which gives a 500g cylinder approximately 210 minutes of burn time.

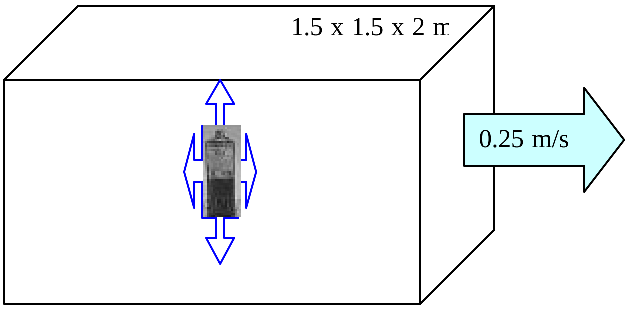


A typical gas torch (leaking) should not result the gas concentration exceeding the occupational exposure limit in a 1.5 x 1.5 x 2 m workspace with diffusion into the surrounding atmosphere.

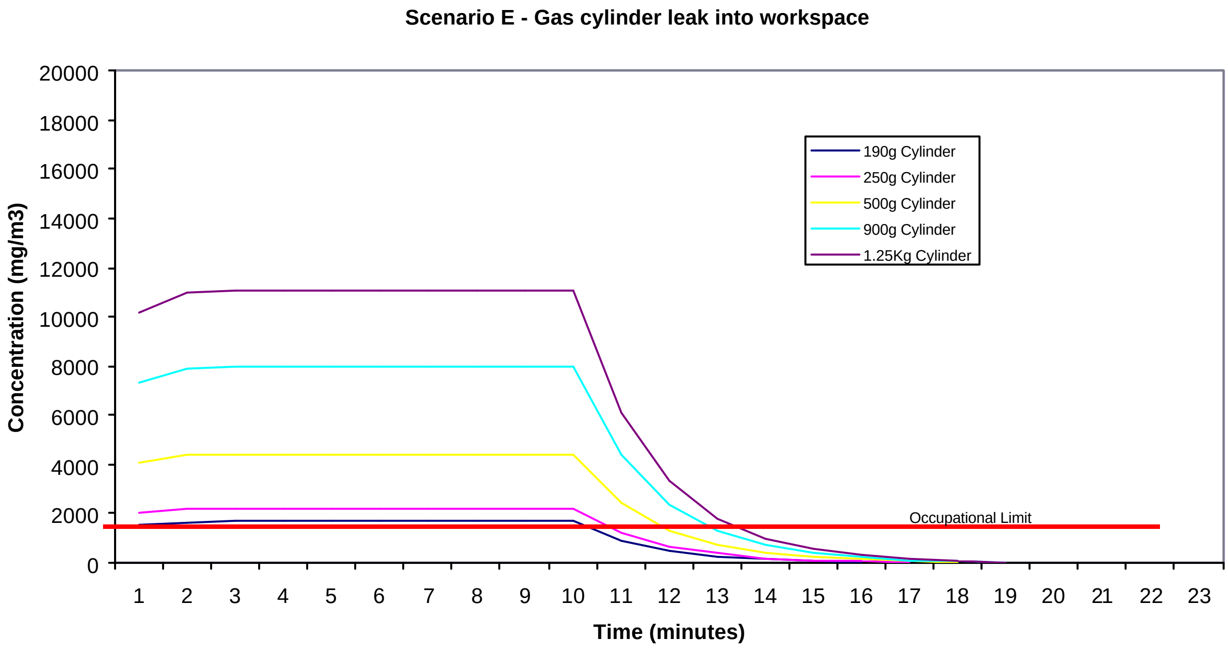
Cylinder Size (g)	Equilibrium Concentration of Gas (mg/m^3)	(% in air)	Effect
Not Applicable	890 (@ 40 mg/s)	0.05	☺
Not Applicable	4400 (@ 200 mg/s)	0.2	☺
Not Applicable	22200 (@ 1000 mg/s)	1.2	☺

Scenario E –

A small flammable gas cylinder leaks into a small workspace (1.5 x 1.5 x 2 m) over a 10-minute period. Ventilation in the room results in an airflow of 0.25 m/s. This is a realistic expectation in a standard chemical laboratory with good airflow.



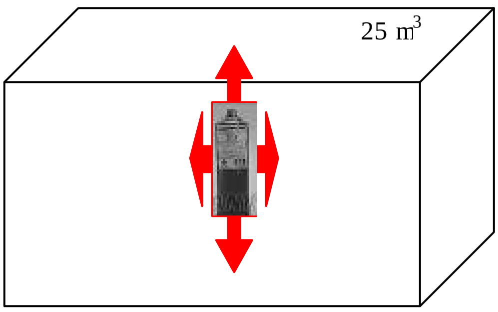
Cylinder Size (g)	Concentration of Gas after 10 minutes (mg/m^3)	(% in air)	Effect
190	1685	0.1	☺
250	2220	0.1	☺
500	4435	0.2	☺
900	7980	0.4	☺
1250	11090	0.6	☺



The above graph shows the concentration over time. Note, after around 3 minutes the concentration has approximated equilibrium. Over the first 10 minutes the cylinder is leaking. After 10 minutes, dilution/extraction allows the concentration to decay. At no time does the concentration reach the lower explosive limit within the space. This assumes instantaneous mixing within the space. However, realistically there would be a fuel/air concentration gradient, increasing towards the gas cylinder. Somewhere along this gradient, the concentration can be expected to be within the explosive range.

Scenario F –

A small flammable gas cylinder ruptures in a small laboratory (25 m^3). There is no ventilation.



Cylinder Size (g)	Concentration of Gas (mg/m^3)	(% in air)	Effect
190	7600	0.4	☺
250	10000	0.5	☺
500	20000	1.1	☺
900	36000	1.9	💣
1250	50000	2.6	💣

In summary, the scenario outcomes indicate -

Scenario	Workspace considered	Ventilation	Release rate	Probability of occurrence	Risk to SAFETY (i.e. explosion)	
A	1 m^3	None	Rupture	Low, except under fire situations	Any size cylinder	Extreme
B	1 m^3	Dispersion	Over 30 minutes	Low	190 g 250 g 500 g 900 g 1.25 Kg	Low Low Low Low Extreme
C	4.5 m^3	None	Rupture	Low, except under fire situations	Any size cylinder	Extreme
D	4.5 m^3	Dispersion	Over 10 minutes	Medium, Realistic ♣ worst case	190 g 250 g 500 g 900 g 1.25 Kg	Low Low Low Medium Extreme
E	4.5 m^3	0.25 ms^{-1}	Over 10 minutes	Medium, Realistic	190 g 250 g 500 g 900 g 1.25 Kg	Low Low Low Low Low
F	25 m^3	None	Rupture	Low. Realistic worst case if lab fills with gas.	190 g 250 g 500 g 900 g 1.25 Kg	Low Low Low Extreme Extreme

♣ This may occur for example, if someone removes the torch from a non-resealable gas cylinder or it is improperly seated.

<u>Conclusions and Recommendations -</u>

With the aid of the risk scenarios, it can be concluded that –

- The rupture of a small gas cylinder would produce an explosive environment (in the presence of an ignition source).
- Upon a leak or gas cylinder failure, it is very difficult to maintain the gas concentration below the occupational exposure limit, unless sufficient ventilation is provided. However, the risk to health would be reduced by an able body person's awareness of the characteristic added odorant, and taking appropriate action.
- A leaking small gas torch (through the valve at ~40 mg/s) would not produce a significant risk to health and safety.

The results tend to suggest that the appropriate fuel gas cylinder size to be safely used within rooms is **less than approximately 500g**. Although, (a single cylinder) of up to 1 kg may be used in large, well ventilated spaces where the risk of ignition has been considered and controlled. This would allow some laboratories (eg. biological labs) to have two 400-500g gas cylinders in use/connected. As a rule, **the fuel gas loading should not exceed 1 kg per 25 m^2 of floor space, in well-ventilated laboratories.**

In addition, it is recommended that –

- Any source of ignition is eliminated in close proximity to the gas cylinder when not being used.
- The laboratory storage of replacement (disposable) gas cylinders be kept to a minimum, and restricted to less than 1.5 kg. This is in addition to those in use. Ideally replacement cylinders should be located in the store.
- Personnel must be shown the correct operation of any gas fuelled apparatus.
- Manufacturer's instructions, maintenance and storage requirements are to be followed.

To improve the University's compliance with recommendations, please inform all relevant staff of these requirements.

References:

Pictures http://tbx.toolbankexpress.com
Material Safety Data Sheets, http://chemserver.anu.edu.au/gold, Propane, butane, LPG
Pocket Guide to Chemical Hazards, National Institute for Occupational Safety and Health, US Dep. of Health and Human Services, June 1990.
SI Chemical Data, 2 ed, Aylward & Findlay, 1988
BOC Gases, Gas Catalogue
BOC Gases, MSDS (#62, 6/96) for Handigas™