NILTOX BREATHING AIR PURIFIERS AND MONITORS

PURE COMPRESSED AIR FOR BREATHING

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1 BREATHING AIR PURIFICATION AND MONITORING

2 AIR QUALITY

Compressed air breathing apparatus should be supplied with breathable air that meets the criteria of BS4275:1997 - Guide to Implementing an Effective Respiratory Protective Device (RPD) programme, and in BSEN12021:1999 - Compressed Air for Breathing Apparatus:

Box 1

BS4275:1997 Table C.1 and BSEN12021:1999. Paraphrased below:

CARBON MONOXIDE	5	ppm
CARBON DIOXIDE	500	ppm
OIL	0.5	mg/m^3
ODOUR/TASTE	none significant	
ALL OTHER TOXICS	10% of EH40	
OXYGEN	20% - 22%	
WATER-LIQUID	nil	

WATER VAPOUR : For air up to 40 bar the pressure dewpoint should be at least 5°C below the likely lowest temperature. Where conditions of usage and storage are not known the pressure dewpoint should not exceed –11°C.

Between 40 bar and 200 bar the water content should not exceed 50 mg/m^3. For air above 200 bar the water content should not exceed 35 mg/m^3. The water content of the air supplied by the compressor for filling cylinders should not exceed 25 mg/m^3.

DEWPOINT in EN132 is defined as the :

" TEMPERATURE OF AIR AT A SPECIFIED PRESSURE BELOW WHICH CONDENSATION WILL OCCUR "

The results of water vapour content tests carried out at 1 bar absolute should be corrected to take into account the effect of the higher working pressure. See BS6754:1986. An approximation to the actual dewpoint at working pressures up to 40 bar can be found by applying the following simplified formula :-

Dw = Dt x Pw

Where :-

Dw = Density of water vapour corrected for the higher working pressure in g/m^3

Dt = Density of water vapour given by the test device measured at atmospheric pressure when the temperature is 20°C, with the result converted to g/m^3 when necessary.

Pw = Working Pressure of the compressed air system in bar absolute.

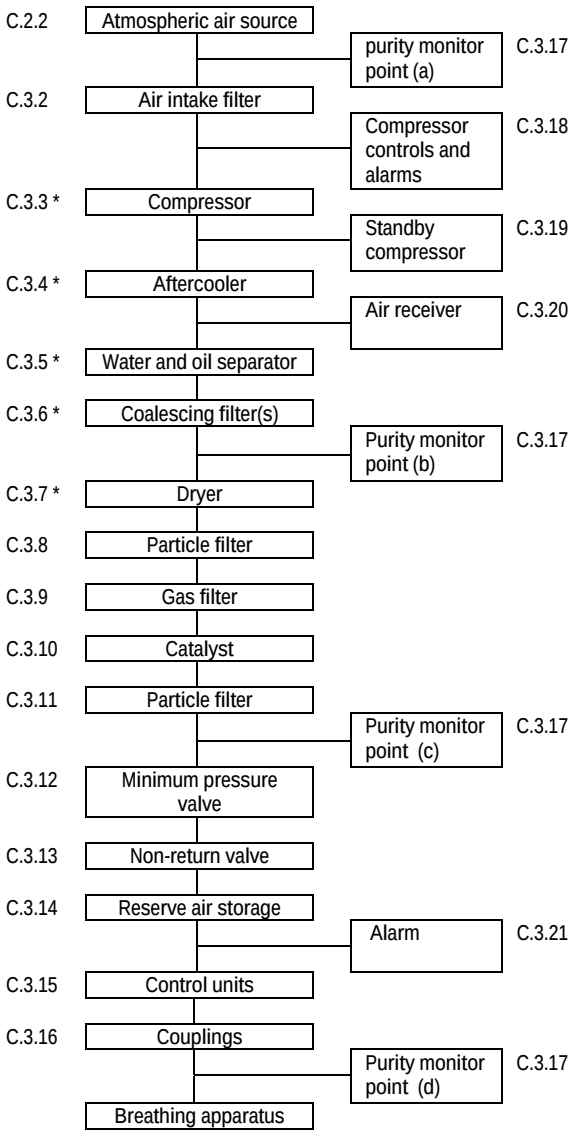
By matching Dw to the density column in Annex C of BS6754:1986 the corresponding temperature can be found. For compliance with this standard the result should be at least 5°C below the lowest likely ambient temperature.

3 ELEMENTS OF A BREATHING AIR SYSTEM

BS4275:1997 Fig C.1 shows the components needed in a compressed air system. A copy of the standard will be required for a full description, but brief details are given here:

Box 2

BS4275:1997. Fig C.1 Elements of a compressed air system



* *condensate drainage points needed for these items*

4 COMPONENT SELECTION AND SIZING

It is assumed that the compressor and associated equipment already exists or has already been chosen. This document deals with air quality, and although BS4275 gives details of each component it still requires a competent person to ensure proper selection of components to control the risk.

5 COMPETENT PERSON

A brief description of a competent person is given in BS4275:1997 3.10. The Pressure Systems and Transportable Gas Containers Regulations 1989 apply to compressed air systems and in the ACOP A competent person is described as someone with qualifications to Incorporated or Chartered Engineer status.

The EMPLOYER is LEGALLY LIABLE for ALL decisions made by the competent person.

6 THE COSHH RISK ASSESSMENT

A COMPETENT PERSON should be consulted when planning or installing a compressed air system. BS4275:1997. C.2.1.

The risk assessment for compressed air systems follows the same procedure for selecting breathing apparatus but here the object is to establish a continuous and reliable air supply that contains oxygen in the range 20% to 22% and to quantify foreseeable contaminants in the compressed air so that suitable air treatment components can be sized correctly.

The question of what is foreseeable based on a blinkered view fails to address the problem. A thorough risk assessment of what could have been foreseen by reading a few publications in the public domain is more likely to lead to the design of a compliant system. See sections 36 and Table 10

7 OXYGEN DEFICIENCY

Under normal conditions dry atmosphere at ground level contains 21% oxygen at a constant partial pressure of 213 mbar. Water vapour is always present causing a slight reduction in oxygen by an amount that does not normally matter.

The oxygen concentration can further be lowered by a reduction in atmospheric pressure (at high altitudes), some types of compressed air dryers and filters could remove oxygen, or by oxygen being consumed by a combustion process.

The loss of oxygen could then mean an even more dangerous amount of toxic gas being present. A person could survive indefinitely in an atmosphere that only had a 2% reduction in oxygen. A person would be dead in minutes if the loss of oxygen was caused by 2% of carbon monoxide being present.

A risk assessment will reveal if oxygen deficiency is possible, but more likely any health risk will come from long term exposure to small amounts of toxic contaminants - which for breathing air has been set at 10% of the Occupational Exposure Limts of EH40.

8 FORESEEABLE CONTAMINANTS

The obvious contaminants are given in BS4275:1997 Table C.1, namely :

Carbon monoxide *1
Carbon dioxide *2
Oil mist *3
Water *4

*1, *2 & *4 because they are likely to be found in the atmosphere as well being generated by hot compressor oil. Note that oil-free compressors are not immune because they can draw in toxic contaminants generated by burning oil from hot bearings.

*4 Water is not a toxic substance but it can cause corrosion of the RPD and distribution equipment. Wet oily systems also provide ideal breeding grounds for legionella and other microbiological organisms. See HSE publication L8 and BS4275:1997 C.2.1 para 5.

Other contaminants expected in the atmosphere are those commonly monitored by government agencies, such as:

Nitrogen dioxide
Nitric oxide
Sulphur dioxide
Ozone
Particulate matter

Plus contaminants escaping from local manufacturing processes, or blown in on the wind from neighbouring processes.

These foreseeable contaminants should be listed which for each the following information must be known in advance or during use if suitable air treatment equipment is to be selected and maintained:

1 Pressure
2 Temperature
3 Flow
4 Concentration
5 Duration
6 Frequency

Without this information, original selection will depend on guesswork, and maintenance will depend on monitoring.

9 CONTROL MEASURES

Control measures are the specific steps taken under COSHH to prevent exposure. In the context this document, control measures are narrowed down to mean filtering, drying and purifying. Techniques and devices are described later in section 21.

10 FILTER DEFINITION

In respiratory protection circles a FILTER is defined in EN132 as … *a filter intended to remove dispersed solid and/or liquid particles and specified gases and vapours from compressed air passing through it.*

It is therefore essential to establish exactly what the filter is designed to do because a filter in compressed air circles is well known not to remove gases and vapours.

11 PURIFIER DEFINITION

To avoid problems arising from the misunderstood use of 'filter' the term PURIFIER is used here because it has common acceptance in compressed air and respiratory protection circles to mean a device that comprises a number of filter stages plus separators, dryers, absorbers, catalysts, etc, identified as components C.3.5 to C.3.11 in fig C.1 of BS4275:1997.

12 MAINTENANCE

All and purifier materials become saturated, blocked or worn out during use. These materials must therefore be replaced at frequent intervals, or reactivated.

13 SERVICE LIFE

When all foreseeable inlet contamination conditions are known End-of-Service can be estimated and materials can be replaced on a time basis. In practice this knowledge is not available and hence the need for monitoring.

14 MONITORING

Monitoring is fundamental to COSHH and is embodied in legislation - see COSHH ACOP L5 - cl. 67-70. See also HSE publication HSG173 monitoring strategies for toxic substances.

BS4275 C.3.17 recommends continuous monitoring but monthly testing might be acceptable when other control measures are used. The competent person should note that for carbon monoxide (CO) in particular:

A monthly test for CO is proof that CO is a foreseeable risk

and the appropriate control measure as detailed in of BS4275:1997 would be

the inclusion of the catalyst stage C.3.10

15 PURITY TESTING

BS4275 C.3.17 covers monitoring in some detail but does little to help with the selection of monitoring devices.

The are dozens of devices on the market, each using it's own detection technology and each applicable to a specific range of contaminants.

Normally instruments are dedicated to a specific gas, which means one instrument will be required for each gas being detected or measured.

See sections 42, 44, 45 and 46.

WARNING: Compressed air normally contains large amounts of oil and water in mist and vapour form that can overwhelm instruments designed to measure trace quantities of toxic contaminants.

Note also that most instruments normally work at atmospheric pressure, and therefore great care needs to be exercised to avoid accidental over pressure when sampling compressed air systems - and the readings themselves must be corrected to allow for effects of pressure and temperature.

This latter point is particularly important when testing the air for WATER CONTENT because BS4275 Table C.1 has introduced the concept of PRESSURE DEWPOINT.

16 PURITY SPOT CHECK LIMITATIONS

A typical factory compressor might deliver about 30 million litres of air in one month. A gas detector tube typically uses about 300 ml of this air - which equates to a sampling rate of 1 in 100 million.

From which a 'pass' from a single test is assumed to mean that the NEXT 30 million litres will be perfectly safe to breathe.

17 TESTING COSTS

Air testing is not cheap. For example, a semi-automatic gas tube detector device costs about £1,700 plus about £3 per tube for each gas (there are at least 5 gases to test for).

You can do it yourself with a hand operated gas tube detector kit at £250 plus tubes - and it takes about an hour per point to do the test Or you can call in the experts at about £100 per visit plus about £50 per point tested.

Multiply this by the number of points for 12 months and you get some idea of the cost of monitoring :

with no guarantee that protection will be provided between tests.

18 REMOVAL OF TOXIC CONTAMINANTS

All contaminants can be removed by installing suitable purifiers. Every litre of air is then purified.

But remember each filter stage will still require regular testing (if not continuously monitored) to ensure that elements are replaced before saturation occurs.

On balance money spent on better control measures reduces the cost of monitoring. See HSE guide HSG173 para 64.

Detailed guidance on purifier design and selection is given later. See section 21

19 AUTO-REGEN PURIFIERS

It is well known that gases and vapours found in compressed air can be absorbed and desorbed on a cyclic basis by using the pressure-swing process. Thus by using an appropriate range of sorbent materials (in multi-stage beds) it is possible to remove toxic contaminants from compressed air at high pressure, and then desorb these contaminants at low pressure (the pressure-swing).

By using a duplex arrangement of vessels, valves and timers, it possible to build an automatic self-reactivating purifier that continuously delivers pure.

Air purity is now the result of selection and operation of a properly sized purifier - which if fitted with a built-in continuous monitoring device - does away with the need for additional monthly testing.

The money invested in the right sort of automatic, self-reactivating, self-monitoring purifier will pay dividends and thus points to the lowest cost way of providing full protection. See HSE guide HSG173 cl.64.

20 AIR FLOW REQUIREMENTS of BREATHING APPARATUS

Air quality is one thing, but the airflow must be adequate to feed the total number of persons wearing breathing apparatus with enough reserve air to escape to safety in the event of a compressor failure.

Airflow rates depend on the type of breathing apparatus and the physical work rate and are linked to the oxygen needed to meet the physical demands of the body.

More effort means more air.

With loose fitting positive-pressure constant-flow RPD the airflow is largely governed by the amount of outward leakage.

With tight fitting positive-pressure demand-valve RPD the airflow is largely governed by the amount breathed plus a small amount lost through outward leakage.

Note that constant flow and positive-pressure RPD could suffer from inward leakage of external toxic contaminants due to negative pressure inside the mask (suit, hood etc) if the peak inhalation rates (see Tidal Volume Table 6) exceed the air supply flow rates (see Table 7).

Table 1 BREATHING RATES

TYPICAL INHALATION BREATHING RATES		
Physical Effort	Minute Volume (Average Flow)	Tidal Volume (Peak per breath)
	L/m	L/m
Reclining	8	24
Sitting	12	36
Standing	20	60
Walking-slow	30	90
Walking-fast	50	150
Running-level	70	210
Running-uphill	100	300
Sprinting-uphill	120	360

Table 2 RPD FLOW RATES

TYPICAL AIR FLOW RATES for RPD			
TYPE	Flow L/m	scfm	Type
Cooling Suit	1,500	53	PP CF
Full Suit	450	16	PP CF
Blouse	250	9	PP CF
Shot Blast Hood	350	12	PP CF
Heavy Duty Hood	250	9	PP CF
Normal Hood	200	7	PP CF
Lightweight Hood	200	7	PP CF
Helmet/Visor	200	7	PP CF
Face Mask	170	6	PP CF
Face Mask	160	6	PP DM
Face Mask	160	6	NP DM
PP = POSITIVE PRESSURE		CF = CONSTANT FLOW	
NP = NEGATIVE PRESSURE		DM = DEMAND VALVE	

All types of air fed RPD must therefore be supplied with enough breathable air to meet both the average Minute Volume and the peak Tidal Volume of the anticipated work rate.

Care must also be taken when sizing hoses (and purifying/filtering equipment) to ensure that the maximum flow rates required by the RPD are met under all operating conditions.

Long pipes and hoses must be large enough to deliver the MAXIMUM flow at the MINIMUM working supply pressure.

21 BREATHING AIR SYSTEM DESIGN

The basic components are listed in BS4275:1997 Fig C.1. A description is given for each component in the text but not much help is given to correctly size or select each component.

22 MIXED CONTAMINANTS

Problems arise when there are mixed contaminants making it difficult to be precise about bed capacity for a particular contaminant. This makes predictions about element life unreliable and therefore places more reliance on monitoring.

23 CONTACT / DWELL TIME

It should be noted that all sorption and catalytic processes require a minimum time for the action to take place. Therefore a minimum bed depth of active sorbent is required. In addition more bed depth is required to allow for progressive saturation - deeper beds mean more protection and longer life - and more time between tests.

24 CARBON and MOLECULAR SIEVES

Zeolites and carbon are 'activated' to make molecular sieves. Carbon is also used as a general-purpose sieve when hydrocarbons (oil) are contaminating the air. Desiccant materials such as silica gel and activated alumina are used as a general purpose sorbent for water vapour.

The activation process produces a hollow lattice structure with mesh sizes of single molecular dimensions. The finished product is available beads, granules, extrusions, sheets, blocks, dust, etc.

These materials remove molecules, not by 'sieving' in the mechanical sense, but by a 'sorption' process in which molecules 'stick' to the surface inside the lattice. Large molecules cannot enter the lattice, whereas very small ones (e.g., O2, N2 & CO) pass straight through the lattice. Those of the same size as the lattice get 'wedged' so to speak., and the lattice fills up. The sorbent is then saturated.

25 CATALYST (CO) REMOVAL

Because of the similar sizes of CO, O_2 and N_2, it is not practical to use molecular sieves to remove CO. Instead an oxide based CATALYST is used. Molecules of CO 'stick' to the surface of the oxide , which is rich in molecules of O_2. At atomic level oxygen combines with CO to make CO_2. The 'heavy' CO_2 molecules now drop off leaving gaps for more CO molecules. Unfortunately the 'gaps' fill up with water molecules that stay there.

..... hence the need for desiccant dried air .....

CO combines with O_2 to produce CO_2 on a one-for-one basis. The amount of CO_2 is not significant when compared to the much safer absence of an equal amount of CO. The CO_2 cane them be removed.

26 ACID and ALKALI GAS REMOVAL

Gases and vapours that are acidic or alkali in nature can be removed by carbon molecular sieves. The sorbents are dosed with acid or alkali salts during manufacture that then neutralise the sorbed contaminants.

CO_2 can be removed by suitable molecular sieves or by sorbent materials like sodalime.

27 WATER REMOVAL

Although not toxic as such, water acts as a breeding ground for micro-organisms and legionella, and causes corrosion or freezing that can cause RPD to fail. In the case of air treatment there is so much water vapour in compressed air that sorbents and catalysts become saturated in a short time - and therefore cease to remove gases and vapours they are designed for.

It is absolutely essential to remove water vapour using desiccant drying techniques.

28 DRYING by DESICCANTS

Desiccant dryers work directly on water vapour by removing water molecules, leaving none to condense in the pipework. Desiccants are replaced when saturated, or they can be reactivated.

Note that desiccants must be protected from oil mists and liquid water.

29 ELEMENT and CARTRIDGE LIFE

Once saturated, the bed ceases to function and break-through occurs. The air passes through the still contaminated.

In practice as the level of inlet contamination is often unknown it is difficult to estimate bed depth in the first place, and bed life in the second place.

Favourable assumptions about inlet air quality lead to very small bed sizes and premature saturation if contamination is higher, more persistent and more frequent than first thought. This can lead to a serious loss of protection between air tests.

For Cartridge Life Estimation see sections 32 and 33

30 SORBENT BED REACTIVATION

Many of the sorbent materials can be reactivated because the process is reversible under controlled conditions.

A reduction of pressure will allow the molecules to boil off, as will an increase in temperature. But not too hot otherwise contaminants could get

baked onto the active surfaces of the sorbent materials. In extreme cases the bed might catch fire.

Pressure swing techniques are used to avoid the use of heat.

Pressure swing purifiers can be made fully pneumatic to avoid the electrical explosion risk when purifiers are required for use in flammable gas areas.

31 INSTALLATION NOTES

Where the practical choice exists, install purifiers in the high-pressure pipeline upstream of pressure regulators, (does not exceed safe working pressure). The purifier is more efficient at high pressure, has a longer life, and is therefore more economical.

Install purifiers in the pipeline where the compressed air temperature has fallen to ambient. The purifier has less work to do at low temperature, and thus has a longer cartridge life.

Install purifiers near the take-off point, or where the user can SEE them and anyone else involved in monitoring and maintenance.

32 CARTRIDGE LIFE - WATER REMOVAL ONLY

Rule-of-Thumb Formula for estimating the life of 'use-once' cartridges for water vapour removal. See section 33 for hydrocarbons. This is a guide only. It is not intended to be a guarantee of performance.

$$\text{Cartridge life (water only)} = \frac{K \times (P+1)}{W \times F} \text{ Hours.}$$

Where:-

K = an empirical constant for the cartridge related to the mass of sorbent. See Table 4
P = gauge pressure in bar
W = water content in g/m³ at working temperature. See Table 3
F = air flow in Litres per minute. See Table 2

EXAMPLE 1: One cartridge where K=9,000, supplying one person wearing a facemask with demand valve (F = 40 average), at 6 bar working pressure, with filtered but undried air cooled to ambient at 20°C (W = 17.31).

$$\frac{9{,}000 \times (6+1)}{17.31 \times 40} = 81 \text{ Hrs}$$

Under the same conditions a 1,200 Litre air cylinder will only last 30 minutes.

EXAMPLE 2: As 1 but constant flow (F = 200).

$$\frac{9{,}000 \times (6+1)}{17.31 \times 200} = 18 \text{ Hrs}$$

Under the same conditions a 1,200 Litre air cylinder will only last 6 minutes.

EXAMPLE 3: An Auto-Regen purifier where K = 10,000, supplying 1 person wearing a constant flow hood (F = 200), at 6 bar working pressure. (W = 0.1192).

$$\frac{10{,}000 \times (6+1)}{0.1192 \times 200} = 2{,}936 \text{ Hrs}$$

Under the same conditions a 1,200 Litre air cylinder will only last 6 minutes.

Thus desiccant dried air will extend cartridge life for many hours. The colour monitor will stay deep blue unless overloaded.

Regen cartridges should be changed on a time basis of 6-12 months use due to the gradual build up of residual saturation caused by other contaminants.

Table 3 WATER VAPOUR LOADING FACTOR

Method of drying	TEMP	W	BS8573/1
DUTY:	°C	g/m³	class
Desiccant dry	-70	0.0027	1
Desiccant dry	-50	0.0382	
Desiccant dry	-40	0.1192	2
Desiccant dry	-20	0.8835	3
Desiccant dry	-11	1.964	
Freezing point	0	4.487	
Fridge dry	3	5.952	4
Fridge dry	7	7.756	5
Filter *	10	9.405	6
	15	12.840	
	20	17.310	
	25	23.07	
	30	30.400	
	35	39.650	
	40	51.210	
	50	83.08	
Boiling point	100	597.5	
* Actual temp of compressed air at the filter with 100% filter efficiency			
See BS6754 Annex C for full temperature range			

Table 4 WATER MASS FACTOR

WATER MASS FACTOR K	
CARTRIDGE Part No.	K
9CB, NT12C, NT12D	9,000
9DB, 18CD,	9,000
16C, NT16C,	12,000
6CD	3,000
12CD	6,000
18CD	9,000
18CR	10,000
36CR	20,000
50CR	28,000
NT8C	6,000

33 CARTRIDGE LIFE - HYDROCARBONS

Rule-of-Thumb Formula for estimating cartridge life based on the presence of one gas or vapour where NO moisture is present. (See section 32 for cartridge life on water vapour). This is a 'guide' only. It is not intended to be a guarantee of performance.

Table 5 HYDROCARBON FACTOR	
CARTRIDGE Part No.	Z
9CB, NT12C, NT8C	200
9PB, NT12P	500
16CB, NT16C	800
6CD	270
12CD	540
18CD	800
18CR	800
36CR	1600
50CR	2240

Table 6 SOLVENT CLASS CONSTANTS		
SUBSTANCE TYPE	a	b
Acetates	- 500	38
Alcohols *	-4600	71
Alkanes	+ 950	22
Alkyl Benzenes	+1200	24
Amines *	+ 370	33
Ketones	+ 340	29
Mono-chlorides*	+ 320	33
Di-chlorides	- 920	48
Tri-chlorides	- 800	56
Tetra-chlorides	+1900	49
* This type of Low boiling point substance will cause a marked reduction in the life of a cartridge		

Table 7 SUBSTANCE COEFFICIENTS		
SUBSTANCE	Bp	M
Acetone	56	58
Benzene	80	78
Bromochloromethane	68	130
2 Butanone (MEK)	80	72
Carbon tetrachloride	77	154
Cellosolve acetate	156	132
Chloroform	61	120
Cyclohexane	81	84
Cyclohexene	83	82
1,2,Dichloroethane	84	99
Ethyl alcohol (Ethanol)*	78	46
Ethyl acetate	77	88
n-Hexane	6	86
Isopropyl acetate	88	102
Methyl alcohol*		
(Methanol)	65	32
Propyl alcohol*	98	60
Propenol		
(Allyl Alcohol)	97	58
* Low boiling point substances of this type will cause a marked reduction in the life of a cartridge.		

Adding all contaminants together - using the worst case can assess cumulative effects of multiple substances where no chemical reaction takes place.

Liquids, condensates and aerosols must first be removed in total because these represent bulk contamination that would swamp the carbon.

Even without liquids, water vapour can be present in high RH% levels that have a marked effect on the ability of carbon to remove organic vapours.

Compressed air must therefore be continuously dried in order for carbon to function effectively.

$$\text{Cartridge life (no water)} = \frac{Z \times [a+(b \times Bp)]}{\sqrt[3]{C^2 \times F \times M}} \text{ Hrs.}$$

Where:-

Z	=	An empirical constant related to the mass of sorbent in the cartridge for 10% breakthrough.	See Table 5
a & b	=	Are empirical constants related to the solvent class of the substance	See Table 6
Bp	=	Boiling point of substance °C.	See Table 7
M	=	Molecular weight of the substance.	See Table 7
C	=	Concentration of Substance in ppm(v)	
F	=	air flow in Litres per minute.	See Table 2

EXAMPLE: One Housing 9HA containing 9PB/9DB cartridges (Z=500) supplying one person wearing a facemask with demand valve (F = 40 average) with an inlet concentration of 20ppm of carbon tetrachloride.

(a = 1900, b = 49, Bp = 77°C, M = 154, LTEL = 2 ppm).

$$\text{Cartridge life} = \frac{500 \times [1900+(49 \times 77)]}{\sqrt[3]{20^2 \times 40 \times 154}} = 62 \text{ Hrs}$$

34 FACTORS AFFECTING CARTRIDGE LIFE

Cartridge life is governed by the actual amount of contamination in the compressed air passing through the purifier.

Heavily contaminated air will saturate the cartridges very quickly especially condensate that can be picked up when flows are excessive, particularly on start-up when air rushes in to fill the system. Loose water lying in low points of the pipework, if not properly drained, will flood the cartridge. It is possible that the blue colouring agent will be permanently washed out of the purity monitor. Solvents, gases, fumes, vapours, sub-micron dusts, etc, will reduce cartridge life. Desiccant dried air will extend the cartridge life as far as water is concerned but not necessarily for other contaminants.

35 OIL VAPOUR

Excessive oil vapour (smelly air) from hot compressors will saturate the carbon bed very quickly. The air will begin to smell and therefore the cartridge should be changed.

36 **COSHH GUIDANCE - WHERE TO LOOK**

Dealing specifically with the letter of the law, by reference to COSHH:1994 and Management of HSW and the ACOP which brings together a number of requirements contained in other legal documents:-

COSHH Reg 7 "...every employer shall ensure that the exposure of his employees to substances hazardous to health is either prevented or, where this is not reasonably practicable, adequately controlled..."

COSHH Reg 9 "... any control measures...maintained in an efficient state, in efficient working order and in good repair..."

MHSW Reg 6(1) "...the employer shall... appoint one or more competent persons..."

MHSW Reg 3"...to make a suitable and sufficient assessment of...the risks to the health and safety of his employees...for the purpose of identifying the measures he needs to take...to comply with the requirements...of the relevant statutory provisions..."

MHSW to consult safety representatives. The Schedule (4A)

MHSW Reg 4(1) "...to give effect to such arrangements...for the effective planning , organisation, control, monitoring and review of the preventive and protective measures..."

MHSW Reg 4(2) ...to record the arrangements..."

MHSW Reg 8"..to provide his employees with comprehensible and relevant information on...the risks...the preventive and protective measures..the procedures to be followed...in the event of serious and imminent danger...the identity of persons nominated by him..."

MHSW Reg 12 and (paraphrased) for each employee to carry out their duties in a safe manner to themselves and other employees, and to report shortcomings of safety procedures.

COSHH 10(3)(a) "...to keep a suitable record of any monitoring...of the personal exposure...for at least 40 years..."

Regarding compressed air systems used for breathing, a basic assessment will reveal that there is a well-known risk of exposure to carbon monoxide, carbon dioxide, oil and water.

A full assessment is likely to reveal the foreseeable risk of the air becoming contaminated by many other harmful substances, like legionella (wet air lines) and other microbiological organisms, and those generally found in the atmosphere like CO_2 and others regularly monitored by DTI, i.e., CO, O_3, NO, NO_2 & SO_2, plus those generated locally, that when mixed and concentrated by compression, will further increase the hazard by easily exceeding the cumulative limits of EH40 before being added to the contamination already building up in the RPD.

In such conditions the absence of a suitable purifier or continuous monitoring will mean that exposure has not been prevented or controlled. This will seriously limit the ability of the RPD to provide suitable protection.

Limitations of this nature must be communicated to the employees wearing the RPD - Reg 8 - (and COSHH Reg 12) so that they know the risks they are taking. Proper training to recognise symptoms of gas poisoning, e.g. for CO, loss of breath, headaches, drowsiness, nausea, dizziness etc, - and when affected, to raise the alarm and immediately escape to safety.

Routine procedures for emergency crews to gain entry to areas classified as dangerous to safely secure abandoned plant would then come into operation. Reg 7.

As CO in compressed breathing air is a well known major hazard (as is CO_2 and other toxic substances) it is common practice for filter manufacturers to use disclaimers in their small-print so as to avoid any liability for gassing accidents that could arise from toxic contaminants - yet at the same time deliberately claim compliance with BS4275 by carefully worded sales literature.

With small print to hide behind, the suppliers can totally dismiss the risk. This technique sells a product to the unsuspecting employer on the false premise of complete safety at low cost - but providing no real protection when the going gets tough, and no liability when things go wrong.

This sort of practice will hopefully soon come to an end as employers become wiser and the full implications of BS4275:1997 take effect, but until then the employer takes the risk *because*

the small print
protects the manufacturer

37 **FIRE and EXPLOSION RISKS**

The following publications draw attention to fire and explosion risks that lurk in compressed air systems and hence the likelihood of the transient generation of very toxic combustion substances, particularly carbon monoxide.

Safety devices designed to prevent explosions and fires are normally set to levels that protect the compressor system from serious mechanical damage

due to overheating and overpressure. These safety devices do not protect against the build-up of toxic contamination that can occur at in the period leading up to overheating and overpressure.

Persons breathing this air then face a double hazard because when the compressor shuts down there will be no air at all.

Air and oil temperature thermostats added to detect early signs of overheating are not likely to provide immediate protection unless the sensors are mounted directly on the critical hot spots.

Hence the need for air quality monitoring. But even here grab sample air quality checks (one for each foreseeable substance) might not detect intermittent occurrences unless happening to coincide with the outbreak.

But even very frequent checks are unlikely to reveal contamination caused by uncontrolled transient events caused by vehicle exhausts (especially engine driven compressors), chemical spillage's, bonfires, boilers, local ventilation (of toxic substances), safety relief valves, chimneys, etc. These can occur locally or come from afar on the wind.

The evidence is there:

38 *HSE GUIDE HSG39 COMPRESSED AIR SAFETY*

2(d) "...oil-coke deposits in a system can spontaneously ignite and cause an explosion".

10(e) "...overheating and the build up of carbonaceous deposits, both of which can lead to fires or explosions. Although rare, fires and explosions can also occur as a result of oil or oil vapour being ignited in the pressure system".

24 "...if components run hot, or oil deposits spontaneously ignite, there may be an explosion"

59 Air Dryers, heat regenerated desiccant type "..excessive temperature rises.....have been known to lead to oil mist explosions."

150(d) Maintenance "...excessive oil consumption can often lead to explosions downstream of the compressor".

157 Precautions "...against any toxic vapours liberated during usage of any cleaning or degreasing liquids."

39 *BS6244:1982 (ISO5388) CODE of PRACTICE for STATIONARY AIR COMPRESSORS*

1.1 Potential hazards associated with compressors (f) "...fires and explosions in the pressure system."

6.4 Personal Injury "...The more common potential causes of injury are: (h) production of smoke or toxic vapour arising from accidental ignition of the oil."

6.6.1(c) Temperature "...A failure of cooling ...can result in a sharp rise in temperature ...and is a well known cause of fire ignition... Failure of valves can similarly raise the temperature and cause dangerous conditions."

Note "..."Dieseling" can occur when cooling is poor and the lubrication is rich. Such an explosion can, under special circumstances, propagate along the delivery pipe as a detonation."

6.6.2 Oil-flooded rotary compressors (special precautions)"...Abnormal temperature rise in the oil-filter pads can, however accelerate the oil oxidation with consequent fire risk."

6.7 Crankcase Explosions "...Explosions can and have occurred in the crankcase or gear cases of compressors (see Annex E)"

Annex D4 "..Oil oxidation can lead to the formation of aldehydes with low spontaneous ignition temperature, which therefore are potentially hazardous."

12.3 Electric immersion oil heaters can overheat and cause ignition of the oil.

Annex C.3 "...for an oil fire to occur there must be ..a thickness of oil-coke...about 7 bar pressure.... a temperature around +150ø C"

24.14 "...the minimum spontaneous ignition temperature for air/oil vapour or mist mixtures ...approximately 275 C."

Annex C.5 "...an oil fire in a pressure system can initiate an oil vapour or oil mist explosion."

Annex D.1(c) "...oil leakage into the compression chamber....can result in the formation of oil-coke in the pressure system."

Annex C Note: "...even if no explosion occurs the compressed air will be contaminated by noxious gases from incomplete combustion."

Note that the instantaneous peak temperature at the end of a compression stroke of a single stage 10-bar compressor could be over 300°C in normal conditions.

40 *BRITISH COMPRESSED AIR SCTY:1986: GUIDE to the SELECTION and INSTALLATION of COMPRESSED AIR SERVICES:*

6.3 "...Exhaust fumes present a hazard...discharge from pressure relief devices of other plant must be taken into consideration and changes of wind direction must not be overlooked."

9.2 "...Except where an air dryer is installed, the air at the point of use may be considered as being saturated. Also there will normally be present .....burnt or decomposed oil."

9.2 para 3 "...When extremely clean or sterile air is required consultation with the equipment supplier is essential."

11.4.1(l) "...Do not use air directly from a compressor for breathing purposes.....unless the system has been specifically designed for such a purpose and breathing air filters ....are fitted."

11.4.2(f) "...Do not use the machine in a fire hazard area....do not operate in the vicinity of toxic fumes."

11.4.3(d)(4) "...Be sure any fluid used" (for cleaning) " cannot cause any chemical reactions or explosions..."

41 **CARBON MONOXIDE CONTAMINATION from INTERNAL COMBUSTION ENGINES**

It is well known that internal combustion engines produce lethal quantities of carbon monoxide (CO), but perhaps not so well known is that CO ranges from a possible 0.25% for an efficient diesel engine to a typical 4.5% from an inefficient petrol engine.

Taking the latter for maximum effect it will be seen that for every cubic metre of exhaust there will be 0.045 m^3 of CO. In units of measurement for toxic substances this is equal to 45,000 ppm.

The standard for CO in breathing air is 5 ppm.

In order to ensure that the average level does not exceed 5 ppm at the intake of an adjacent compressor it follows that 9,000 m^3 of totally uncontaminated fresh air will be required to dilute each 1m^3 of exhaust..

Ignoring wind speed and assuming that the CO spreads evenly around the exhaust pipe the diluted exhaust air will occupy a dome shaped space of 16 m radius. This is the same size as a 20,000-ft2 factory x 16 ft high.

As a rule-of-thumb, 1.0 m^3 of exhaust air equates to about 1.0 m^3 of breathing air, which if flowing per minute requires a supply of fresh air of 9,000 m^3 per minute. Otherwise in static conditions (a 9,000 m^3 enclosed space) the concentration will increase by 5 ppm per minute.

In order to dilute the CO, an air supply of 9,000 m^3 per minute will be required. This is equal to a windspeed of about 1.2-mph in the open air - not much on a meteorological scale - but in an enclosed pace it means 60 complete air changes per hour. This is a major ventilation problem - even when fresh air is available.

The effects of turbulence, convection, wind speed, recirculation, or stagnation, are complex and will conspire to cause the CO concentration to range from 0 ppm at the very best, to dangerous levels at the worst - and at random unknown intervals

Normally the compressor intake will be within a short distance of the exhaust, especially if an engine driven compressor is used. Even when the inlet is well up-wind of the exhaust, a constant and reliable supply of uncontaminated air will be required - which is usually dependent on wind speed and direction.

Gases can diffuse from concentrated areas to a less concentrated areas, even against the wind, and as compressor suction and convection cause local turbulence, high concentrations of downstream CO can circulate back to the compressor intake.

Relying on the intake air to always be safe to breathe is therefore wishful thinking - and largely dependent on the weather. If the experts at the Met Office with millions of pounds worth of equipment still get their forecasts wrong - there is little chance that the compressed air user with a wet finger in the air will do any better.

Additional steps should therefore be taken to continuously monitor the air for CO, or install suitable purifiers; preferably both.

Please note that there are many other toxic contaminants in engine exhausts that need controlling as well.

42 GAS AND VAPOUR MEASUREMENT

43 OIL FILTER TESTING

Where high efficiency oil filter tests are concerned, accurate measurement of trace quantities of oil pose special problems. Gravimetric methods are not suitable because absolute filters designed to collect oil mist also collect solids that affect the weight. Vapour detector methods are not suitable because they give a total reading of oil and vapour.

A generally accepted method is to collect micro-fine oil droplets on an absolute filter pad from a known volume of air (this could take a few hours). The collected oil is dissolved in a solvent that is then analysed by an Infrared instrument and compared to a calibrated sample. From which the amount of oil in the air can be calculated. Extreme care must be taken not to contaminate the filter during sample collection.

44 MEASURING METHODS

44.1 INFRA-RED

Certain molecules absorb IR radiation and the reduction in radiation is measured, analysed and displayed. High accuracy and sensitivity, and versatile. But costly. Somewhat large, and of limited portability. High pressure cells available. Covers numerous gases. Needs training and skilled operators. Can be used continuously on line or for grab samples. Modern computerised Fourier Transform spectrum analysis makes these instruments very fast and powerful. Mainly a laboratory tool, but compact battery operated portable models with data acquisition facilities are beginning to appear on the market as technology and demand develops.

44.2 GAS CHROMATOGRAPHY

Molecules diffuse at different rates through capillary tubes and appear at the end of the tube in known strict order. The concentration is measured by analysis. Slow. Needs training and skilled operators. Mainly a laboratory tool.

44.3 UV-VIS (ULTRA-VIOLET / VISIBLE)

Much the same as Infrared instruments but uses photoionisation techniques at the Ultra-Violet end of the VISible spectrum. Used for vapours. High accuracy and versatile but costly. Large and of limited portability. Covers numerous vapours. Needs training and skilled operators. Can be used continuously on line or for grab samples. Mainly a

laboratory tool, but compact battery operated computerised portable models are becoming available.

44.4 **CONTINUOUS TAPE**

A carrier tape (usually paper) is impregnated with a suitable chemical that changes colour in the presence of the gas being measured. Photosensitive devices measure the colour. High cost but simple to use. Limited to availability of tapes specific to each gas. Provides analogue record (subject to proper storage).

44.5 **ELECTROCHEMICAL CELLS**

High accuracy and versatile but relatively costly. Previously large and of limited portability, but now coming down in price and weight. Covers numerous vapours. Needs training and skilled operators. Can be used continuously on line or for grab samples. Mainly a laboratory tool, but compact battery operated computerised portable models are becoming available.

44.6 **SEMICONDUCTOR CELLS**

Simple in design. Relatively low cost. Lightweight, battery operated, portable or fixed. Can be used for continuous monitoring. Cells only available for small number of gases. Cells deteriorate in use, and cells need protection from contamination by mists and particles, especially oil and water when used to monitor compressed air systems. However if the air is very dry the cells can dry out very quickly when used in continuous monitoring mode.

44.7 **DETECTOR TUBES**

Chemicals contained within a glass tube change colour when reacting with the specific gas or vapour. Colour density or length of stain is proportional to concentration of gas in a known measured volume.

Simple to use, but low accuracy. Low capital cost, but as tubes are used only once can become costly if frequent tests are required. No power required when used with hand pump. Care must be exercised to avoid misleading results when there is a risk of cross contamination.

44.8 **SAMPLER TUBES**

Similar in construction to colour sorbent tubes. Gases are collected over a period of time. Gases are then desorbed in the laboratory and analysed by IR, GC or ionisation instruments.

44.9 **PARAMAGNETIC DETECTORS**

As the name implies these instruments use magnetic forces to detect and measure the presence of paramagnetic gases, of which oxygen is the main one. They are easy to use and accurate. Relative high capital cost but easy to calibrate. Fixed or portable, but if the latter accuracy is prone mechanical shocks that must be avoided.

particles, especially oil and water when used to monitor compressed air systems. However if the air is very dry the cells can dry out very quickly when used in continuous monitoring mode.

45 **WATER VAPOUR MEASUREMENT**

45.1 **MECHANICAL HYGROMETERS**

Devices that measure changes in a dimension of a material (usually hair) due to sorption of moisture. The movement can be measure and displayed by electrical or mechanical means. Of limited use but very cheap and simple.

45.2 **PSYCHROMETRIC HYGROMETERS**

Devices measure the temperature difference between a 'dry bulb' and a 'wet bulb' and when applied to the psychometric charts a whole range of simultaneous data can be read off. Data is limited to behavior of moisture in air at atmospheric pressure.

45.3 **ELECTRONIC HYGROMETERS**

Devices use change in capacitance caused by molecules of water in oxide film sensors. Simple construction and relatively low cost, but with a tendency to drift over time, therefore needing frequent calibration.

45.4 **SORBENT HYGROMETERS**

Device (see gas tubes above) changes colour due to the presence of moisture. Simple to use, low cost for occasional use. Tubes used only once. Suitable for atmospheres where there is an explosion risk.

45.5 **CHILLED MIRROR HYGROMETERS**

Devices use photometric techniques to detect the first sign of condensation at a known temperature. These instruments are probably the most sensitive and accurate available today. They are used as reference sources by calibration laboratories.

46 **PARTICLE COUNTERS and AEROSOL PHOTOMETERS**

Aerosol science is advancing rapidly and there are numerous instruments available to detect, characterise, count, measure and weigh particles (liquid or solid). The subject is too complex to be covered here but briefly the basic requirement for breathing air is to ensure that inhalable particles (0.1 - 10.0 micron) do not enter the nose and mouth, and respirable particles (0.1 - 5.0 micron) do not enter the lungs, and of those that do, must not exceed individually or collectively one tenth of EH40 (5.0 mg/m^3).

47 **ODOUR THRESHOLDS**

Table 8 ODOUR THRESHOLDS for GAS and VAPOUR

Reliance on the sense of smell to detect safe levels of gases and vapours can be dangerous.

Some gases have no detectable odour even at high concentrations (e.g. carbon monoxide), and for those that do have a strong odour (e.g. ethyl mercaptan), there is a significant variation of the odour threshold between individuals.

Olfactory cells can become overloaded or confused by the presence of other odours and moisture, thereby causing loss of perception that can result in faulty judgment.

Proper instrumentation used by trained personnel should be used to measure concentration levels for control purposes.

A competent person might find the following table of average figures useful for a rough assessment.

CHEMICAL SUBSTANCE	APPROX ODOUR THRESHOLD ppm	EH40 / 98			CHEMICAL SUBSTANCE	APPROX ODOUR THRESHOLD ppm	EH40 / 98	
		ppm	LTEL STEL MEL				ppm	LTEL STEL MEL
acetaldehyde	2	20	L		ethyl silicate	85	-	-
acetic anhydride	5	5	S		ethylene diamine	10	-	-
acetone	100	750	L		ethylene dibromide	25	-	-
acetonitrile	40	40	L		ethylene oxide	700	5	M
acetylene	620	Asp	L		formaldehyde	1	2	S & M
acrolein	0.4	-	-		furfural	0.4	-	-
acrylonitrile	20	2	L & M		hydrazine	4	-	-
acrylaldehyde	0.4	0.1	L		hydrogen chloride	10	5	S
allyl alcohol	0.8	2	L		hydrogen cyanide	5	10	S & M
allyl chloride	6	-	-		hydrogen selenide	0.3	0.05	L
allyl glycidyl ether	10	-	-		hydrogen sulphide	0.1	10	L
ammonia	5	25	L		isopropyl alcohol	200	-	-
aniline	0.5	-	-		maleic anhydride	0.5	1 mg/m3	M
benzene	5	5	L & M		mesityl oxide	12	15	L
biphenyl	0.04	0.2	L		methanethiol	0.002	0.5	L
bromine	0.01	0.1	L		methanol	100	200	L
butane	2.7k	600	L		methyl acetate	200	200	L
butan-1-ol	25	50	S		methyl alcohol	100	-	-
butan-2-one	25	200	L		methyl ethyl ketone	25	-	-
n-butyl alcohol	25	50	S		methyl mercaptan	0.002	-	-
n-butyl amine	2	5	S		naphthalene	0.3	10	L
carbon disulfide	1	10	L & M		nickel carbonyl	3	-	-
carbon monoxide	100k	50	L		nitroethane	100	100	L
carbon tetrachloride	70	2	L		nitrogen dioxide	5	3	L
chlorine	0.05	0.5	L		nitromethane	100	100	L
chlorine dioxide	0.1	0.1	L		ozone	0.015	0.2	S
chlorobenzene	10	50	L		pentane	1000	600	L
chloroform	200	2	L		perchloroethylene	5	-	-
3-chloropropene	6	-	-		phenol	0.05	5	L
1,2-diamenoethane	10	-	-		phosgene	0.5	0.02	L
1,2-dibromoethane	25	0.5	M		phosphine	0.02	0.3	S
1,1,dichloroethane	100	200	L		propan-2-ol	200	400	L
1,2,dichloroethane	100	5	M		pyridine	10	5	L
dichloromethane	300	100	L & M		styrene, monomer	0.1	100	M
diisobutylketone	50	-	-		tetracarbonyl nickel	3	0.1	S
dimethylformamide	100	-	-		tetrachloro ethylene	100	50	L
diphenyl	0.04	-	-		tetraethyl orthosilicate	85	10	L
epichlorohydrin	25	-	-		toluene	5	50	L
ethanol	10	1000	L		toluene diisocyanate	0.4 mg/m3	-	-
ethanethiol	0.001	0.5	L		1,1,1,trichloroethane	100	200	L
ethyl acetate	10	400	L		trichloroethylene	20	100	M
ethyl alcohol	10	-	-					
ethyl mercaptan	0.001	-	-					

M = MEL = Maximum Exposure Limit S = STEL = Short Term Exposure Limit L = LTEL = Long Term Exposure Limit

Table 9 CARBON SORBENT CAPACITY	code	Activity	% of weight of carbon used
The weight of a substance in the gas and vapour phase present in the compressed air that can be absorbed by plain activated carbon and expressed as a percentage of the weight of carbon used in the filter.	H	High	20% - 40%
	M	Medium	10% - 25%
	L	Low	under 10%
	P	Poor	under 2%
This is a guide only and relates to dry air in normal conditions of temperature and pressure for a single gas. Numerous other gases and vapours can be removed from compressed air by impregnated carbons and alternative materials. Details available on request.			

acetic acid	H
acetic anhydride	H
acetone	M
acetonitrile	M
acetylene	L
acrolein	M
acrylic acid	H
acrylonitrile	H
adhesives	H
aldrin	H
allyl chloride	H
amines	L
aminotoluene	H
ammonia	P
amyl acetate	H
amyl alcohol	H
amyl ether	H
anaesthetics	M
aniline	H
animal odours	H
antiseptics	H
asphalt fumes	H
benzaldehyde	H
benzene	H
benzene vapours	M
benzyl alcohol	H
benzyl chloride	H
body odours	H
bromoform	H
bromine	H
butadiene	M
butanal	M
butane	L
butanol	H
butanone	P
butene	L
2-butoxyethanol	H
butyl acetate	H
butyl alcohols	H
butyl cellosolve	H
butyl chloride	H
butyl ether	H
butyl glycol	H
butyl mercaptan	H
butylene	L
butyne	L
butyraldehyde	M
butyric acid	H
camphor	H
caproaldehyde	H
caprylic acid	H
butyl glycol	H
butyl mercaptan	H
butylene	L
butyne	L
watchthisspace	?
butyraldehyde	M
butyric acid	H
camphor	H
caproaldehyde	H
caprylic acid	H
Carbolic acid	H
carbon dioxide	P
carbon disulfide	M
carbon monoxide	P
carbontetrachloride	H
carbonyl sulfide	L
cellosolve	H

cellosolveacetate	H
chlorex	H
chlorine	M
chlorobenzene	H
chlorobutadiene	H
chlorodifluoro-methane R22	L
2-chloroethanol	H
chloroform	H
chloronitropropane	H
chloropicrin	H
cigarette and cigar smoke	H
cleaning-compounds	H
combustion-odours	M
cooking odours	H
creosote	H
cresol	H
crotonaldehyde	H
cumene	H
cyclohexane	H
cyclohexanol	H
cyclohexanone	H
cyclohexene	H
cyclopentadiene	H
decane	H
degreasing-solvents	H
deodorizers	M
detergents	H
dibromoethane	H
dichlorobenzene	H
dichlorodifluoro-ethane	H
dichlorodifluoro-methane R12	M
dichloroethane	H
1,2 dichloro-ethane	H
dichloroethyl-ether	H
dichloroethane	H
dichloroethylene	H
dichloroethyl-ether	H
dichloromono-fluoroethane	M
dichloronitro-ethane	H
dichloropropane	H
dichlorotetra-fluoroethane	M
diesel fumes	H
diethyl acetone	H
diethyl amine	M
diethyl aniline	H
diethyl disulfide	H
diethyl ether	M
diethyl ketone	H
diethylamine	M
diethyldisulfide	H
dimethyl amine	L
dimethyl aniline	H
dimethyl disulfide	H
dimethyl sulfate	H
dimethyl sulfide	H
dimethyl formamide	H
dioxane	H

dipropyl ketone	H
dodecane	H
epichlorohydrin	H
ethanal	L
ethane	L
ethanol	M
ether	M
2-ethoxyacetate	H
2-ethoxyethanol	H
ethyl acetate	H
ethyl acrylate	M
ethyl alcohol	M
ethyl amine	M
ethyl benzene	H
ethyl bromide	H
ethyl chloride	L
ethyl ether	M
ethyl formate	M
ethyl glycol	H
ethyl glycol-acetate	H
ethyl mercaptan	M
ethyl silicate	H
ethylcellosolve	H
ethylene	L
ethylene-chlorhydrin	H
ethylene chloride	H
ethylene dichloride	H
ethylene glycol	H
ethylene oxide	L
fertilizers	H
fish odours	H
fluorotrichloro-methane	M
food aromas	H
formaldehyde	L
formic acid	M
freon 11	H
freon 112	H
freon 113	H
freon 114	M
freon 12	M
freon 22	L
furfural	H
gasoline fumes	H
glycerol	H
glyceryl triacetate	H
glycol	H
glycol chloro-hydrin	H
glycol monobutyl-ether	H
glycol monoethyl-ether	H
glycol monoethyl-ether acetate	H
glycol monomethyl-ether	H
glycol monomethyl-ether acetate	H
heptanes	H
heptene	H
heptylene	H
heptyne	H
hexamethylene di-isocyanate	H
hexanal	H
hexanes	M

hexanol	H
hexene	M
hexylene	M
hexyne	M
hospital odours	H
hydrazine	M
hydrogen	P
hydrogen bromide	P
hydrogen chloride	P
hydrogen cyanide	P
hydrogen floride	P
hydrogen iodide	M
hydrogen selenide	P
hydrogen sulphide	P
i-valeric acid	M
iodine	M
indole	H
iodoform	H
isophorone	H
isophorone di-isocyanate	H
isoprene	M
isopropanol	M
isopropyl acetate	H
isopropyl alcohol	M
isopropyl ether	H
isopropylamine	L
jet fuel	H
kerosene	H
kitchen odours	H
krypton delay	L
lactic acid	H
liquid fuels	H
liquid odours	H
lysol	H
menthol	H
mercaptans	H
mesityl oxide	H
methanal	L
methane	P
methanol	L
2-methoxyethanol	H
2-methoxyethyl-acetate	H
methyl acetate	M
methyl acrylate	M
methyl alcohol	M
methyl bromide	H
methyl chloride	L
methyl butyl-ketone	H
methyl cellosolve	H
methyl cellosolve-acetate	H
methyl chloride	L
methyl cyanide	M
methyl cyclo-hexane	H
methyl cyclo-hexanol	H
methyl cyclo-hexanone	H
methyl ether	M
methyl ethyl-ketone	H
methyl formate	L
methyl glycol	H
methyl iodide	H

methyl isobutyl-ketone	H
methyl mercaptan	L
methyl meth-acrylate	H
methyl n-butyl-ketone	H
methyl phenol	H
methylchloroform	H
monochloro-benzene	H
monofluorotri-chloromethane	M
n-amyl ether	H
n-butanol	H
n-butyl alcohol	H
n-propanol	H
n-propyl alcohol	H
naphtha	H
naphthalene	H
neo-pentane	M
nicotine	H
nitrobenzene	H
nitroethane	H
nitrogen dioxide	P
nitroethane	H
nitroglycerine	H
nitromethane	M
nitropropane	H
2-nitropropane	H
nitrotoluene	H
nonanes	H
o-dichlorobenzene	H
octalene	H
octanes	H
octene	H
oils/grease	H
ozone	H
p-phenylene-diamine	H
palmitic acid	H
paradichloro-benzene	H
pentanal	H
pentanes	M
pentanol	H
pentanone	H
pentene	M
pentylene	M
pentyne	M
perchloroethylene	H
perfumes	H
pesticides	H
petrol vapours	H
petroleum naphtha	H
phenol	H
phosgene	M
poultry odours	H
propane	L
propanol	H
propenal	M
propene	L
propenoic acid	H
propionaldehyde	M
propionic acid	H
propyl acetate	H
rpopyl alcohol	H
propyl chloride	H

propyl ether	H
propyl mercaptan	M
propylene glycol	H
propylene oxide	L
propyne	P
putrescine	H
pyridine	H
rancid oils/fats	H
resins	H
ripening fruit	H
rubber	M
skatole	H
stale odours	H
styrene	H
sulfur	H
sulfur gas	M
sulphur dioxide	P
sulphur trioxide	P
tar odours	H
tetrachloroethane	H
tetrachloro-ethylene	H
tetrachlorophenol	H
tetraethyl-silicate	H
tetrahydrofuran	M
thiophene	H
tobacco smokes	M
toilet odours	H
toluene	H
toluene di-isocyanate	H
toluidine	H
1,2,4-trichloro-benzene	H
trichloroethane	H
1,1,1-trichloro-ethane	H
trichloroethylene	H
trichlorofluoro-methane	H
triethanolamine	H
trifluorobromo-methane	L
trimethyl amine	L
turpentine	H
undecane	H
urea	H
uric acid	H
valeric acid	H
valeraldehyde	H
valericaldehyde	H
varnish fumes	H
vinegar	H
vinyl acetate	H
vinylcyanide	H
wood alcohol	M
xenon delay	L
xylene	H

49 REFERENCE

Table 10 REFERENCES

DOCUMENT	Abridged Titles	Source
BCAS	Compressed Air Guide	BCAS
BS4275:1997	RPD Guidance	BSI
BS6244:1982	Compressor Maintenance	BSI
BS6754:1986	Compressed Air Dryers	BSI
BSEN12021:1999	Compressed Air for Breathing Apparatus	BSI
COSHH ACOP - L5	COSHH Code of Practice	HSE
CR529 CEN	CEN Report on RPD	BSI
EH40	Occupational Exposure Limits	HSE
EH41	Asbestos	HSE
EH43	Carbon Monoxide	HSE
EH53	Radioactivity	HSE
EN132	RPD Definitions	BSI
EN 134	Nomenclature of RPD Components	BSI
HS(G)39	Compressed Air Safety	HSE
HS(G)53	RPE Guide to Users	HSE
HS(G)70	Control of Legionella	HSE
HSG173	Monitoring Strategies	HSE
ISO8573	Compressed Air Quality	BSI
L5	COSHH ACOP	HSE
L8	Legionella ACOP	HSE
LR1000AP	Atmospheric Pollution	
RIDDOR 1985	Guidance HS(R)23	HSE
Statutory Instruments		
HSW Act 1974	Health & Safety at Work Act.	HMSO
SI 1994-3246	COSHH Regs	HMSO
SI 1992-3163	RIDDOR	HMSO
SI 1992-2966	PPE At WORK Regs	HMSO
SI 1989-2169	Pressure Systems Regs	HMSO
SI 1992-2051	Mgt Of H&S at Work Regs	HMSO
SI 1997-1713	Confined Spaces Regs	HMSO
SI 1992-3139	PPE Regs	HMSO
SI 1991-2749	Simple Pressure Vessel Regs	HMSO