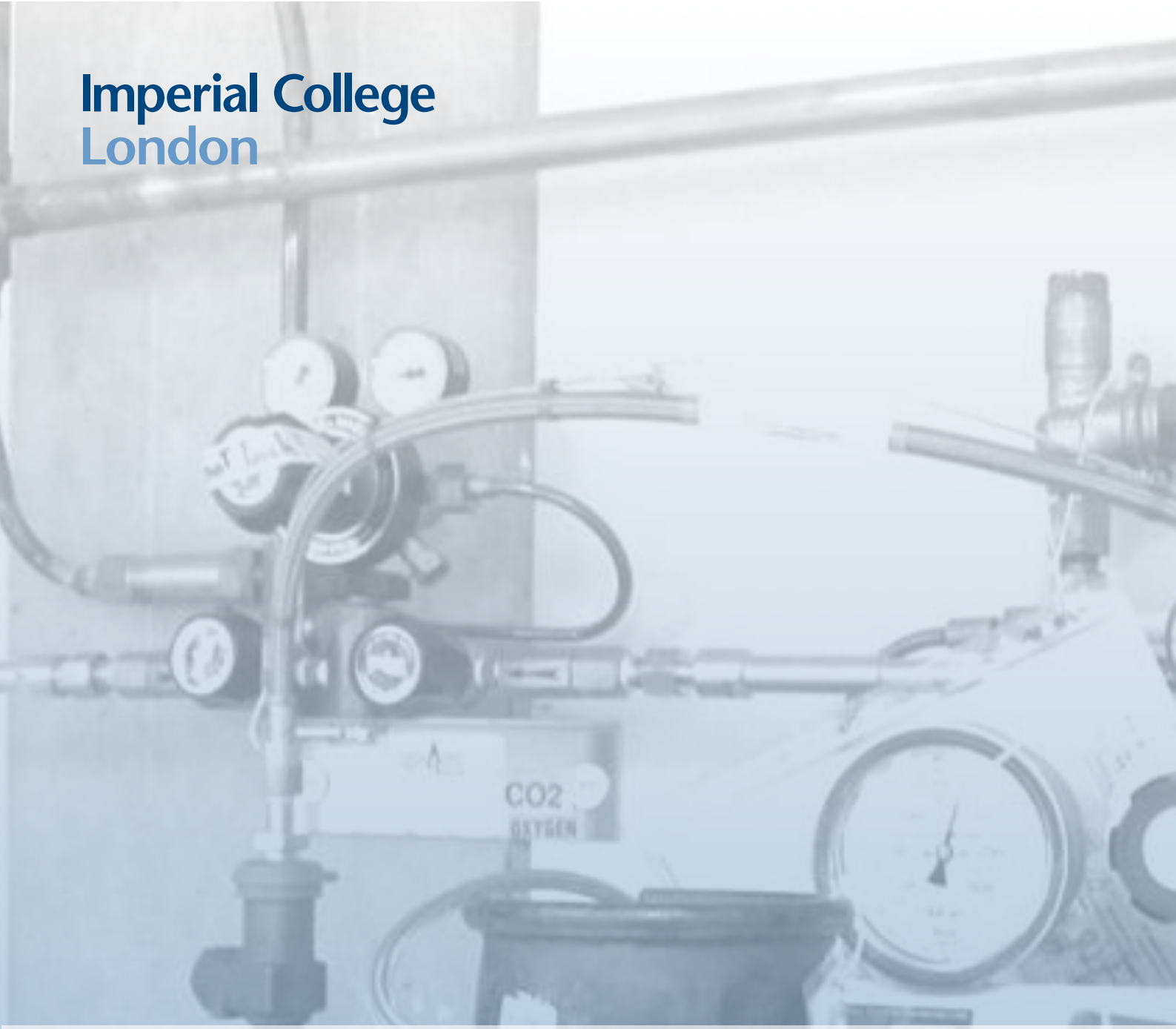
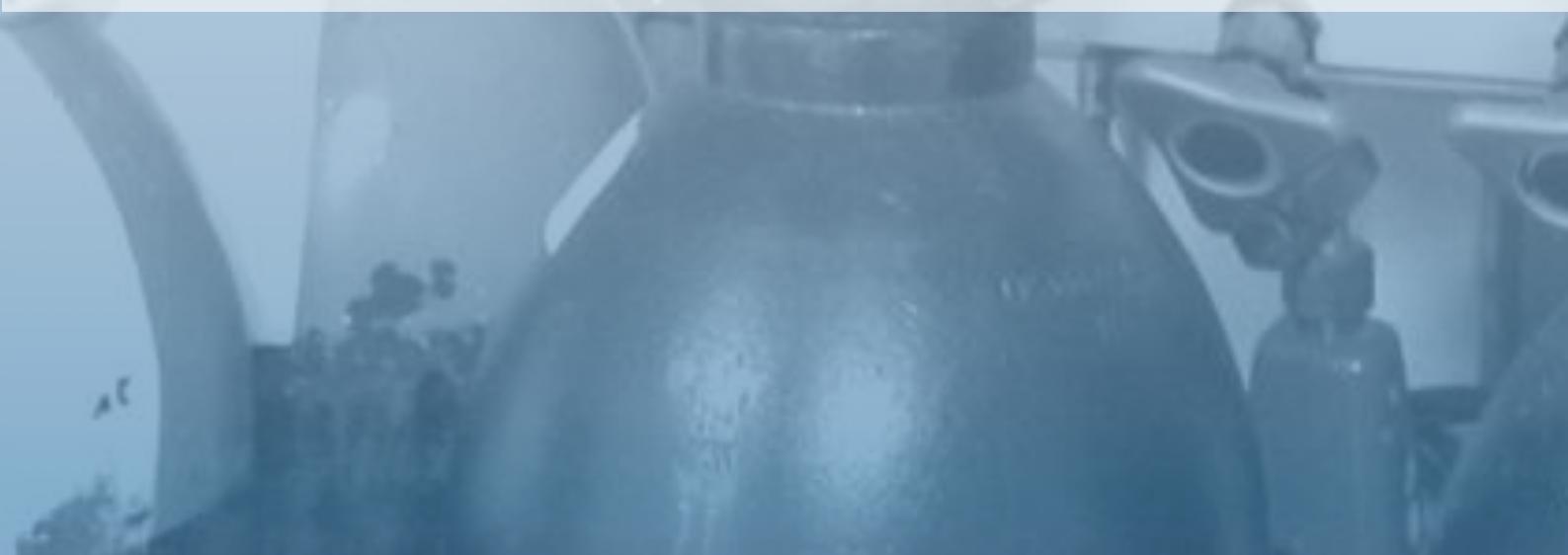
Imperial College
London



Code of Practice

Safe handling, use and storage of compressed gases



REVISION LOG

DATE	REVISION	PAGE
2002	First released as guidance	All
2011	Complete review and amendment. Released as Code of Practice	All

TABLE OF CONTENTS

INTRODUCTION

INTRODUCTION

1. Compliance with the College Compressed Gases Policy is mandatory, and this Code of Practice (CoP) is a supporting document that may be used to assist in achieving the objectives outlined within the policy. There are sections of the CoP that will be relevant to Capital Projects, Facilities Management, Laboratory Managers, Safety Officers and anyone involved in the risk assessment process.
2. The CoP does not specifically cover work with cryogenic liquids, though they are occasionally mentioned in passing throughout the document. This subject is addressed in far more detail in a separate Code of Practice *Liquid Nitrogen – Storage, Use and Transportation Within College Premises*. The CoP also excludes mains natural gas, air compressors and gas generators.
3. Working safely with compressed gases is a complex subject. As such, this CoP is not intended to be exhaustive with regard to its coverage. It addresses the salient points and further information may be found in the numerous references provided in the 'INFOBOXES'.

RESPONSIBILITIES

RESPONSIBILITIES

Capital Projects

4. Capital Projects have the following responsibilities:
    - Ensure that any piped gas system fitted as part of a capital project is installed in accordance with all relevant industry standards.
    - Select and employ competent contractors.
    - Ensure that users receive appropriate training in the operation of relevant parts of the new system.
    - Ensure that suitable commissioning of the system is carried out and that the relevant handover documentation is provided. Information will typically include the following:
        - Details of maximum and minimum design temperature and pressure.
        - Details of maximum flow at design pressure.
        - Operating instructions.
        - Maintenance instructions.
        - Written Scheme of Examination (WSE)
        - Test certificates.
        - System schematic or flow sheet.
        - Schedule of protective devices and their function.
        - Copy of the declaration of conformity.
    - Ensure that the handover documentation is forwarded to Facilities Management and user representatives.

Facilities Management

5. Facilities Management have the following responsibilities:
    - Where piped systems are installed by FM (outside the scope of a capital project), FM shall comply with all of the responsibilities listed above under Capital Projects.
    - Ensure that piped systems are recorded on the College insurance inspection database.
    - Arrange insurance inspections at intervals defined within the WSEs.
    - Ensure that copies of the relevant handover documentation are provided to the user representatives.

Academic Departments

6. Academic departments have the following responsibilities:
    - Where piped systems are installed by the academic department (outside the scope of a capital project), the department shall comply with all of the responsibilities listed above under Capital Projects.

RESPONSIBILITIES continued

- Use piped systems in accordance with the operating instructions.
- Cooperate with Facilities Management with regard to arrangements for insurance inspections.
- Ensure that any known defects to piped systems are reported promptly by the users to their supervisor or line manager.
- Ensure that no unsolicited modifications are carried out to piped systems that are likely to render them unsafe.
- Ensure that relevant planned preventative maintenance schemes are in place for piped systems.
- Ensure that any accidents or incidents involving compressed gases are reported via the established College system.
- Provide on-the-job training to users (to include routine users checks and emergency procedures).
- To undertake, document and review risk assessments associated with the storage, use and transportation of compressed gases within the departments own area.
- To manage cylinder stores / cages that belong to the department.
- Ensure that pressure regulators are maintained in good condition, are within their lifespan and that any regulators that fail their annual inspection are taken out of service and repaired or replaced.
- Ensure that any new regulators acquired meet the required standards and are obtained from reputable suppliers.
- Ensure that any related equipment such as cylinder trolleys, racks and supports are maintained in good order.
- Maintain operating instructions and other documentation relating to piped systems and compressed gases where it can be readily accessed.
- Maintain local training records.
- Provide assistance and advice to end users via local safety advisers.

Compressed Gases Service Providers

7. Compressed gases service providers shall comply with the terms and conditions of the service contract at all times.

Safety Department

8. The Safety Department has the following responsibilities:
    - Provide expert advice and support.
    - Organise centralised training (via Learning & Development where appropriate).
    - Liaise with the Puchasing Department with regard to any central contracts that are in place for regulator inspection and maintenance.
    - Conduct periodic inspections and audits.

RISK ASSESSMENT

RISK ASSESSMENT

9. All aspects of work involving compressed gases must be subject to the risk assessment process and this CoP assists with the practical task of completing the risk assessment. The CoP may be used in conjunction with the risk assessment template: ***Risk assessment for an activity involving compressed gases / cryogenic liquids.*** The process follows the familiar steps:
    - Identify the hazards associated with the compressed gases (considering the intrinsic properties of the gases concerned and the general hazards arising from stored energy).
    - Identify who may be harmed.
    - Decide upon suitable precautions or control measures to manage the risk. The preferred hierarchy should be to:
    - Prevent or minimise the risk of a gas release at source.

- Disperse or dilute the gas before it reaches a critical level.
- Have warning systems and / or emergency procedures in place.

However, as with all control measures, a combination of precautions is usually the case in practice.

- Document the risk assessment.
- Review it periodically (or immediately in the case of an adverse incident).

The remainder of this CoP examines the hazards and particularly, typical control measures in some detail.

HAZARDS

HAZARDS ASSOCIATED WITH COMPRESSED GASES

Rapid release of energy

10. Physical impact resulting from the energy generated by a sudden and rapid release of compressed gas. This could happen irrespective of the type of gases involved.

Blast resulting in flying debris

11. Physical impact from parts of gas cylinders that fail or any flying debris resulting from a cylinder or pipework failure.

Impact from falling cylinders

12. Impact from falling cylinders may occur during transit or during storage if not properly secured.

Exposure to a released gas

13. Specific hazards will vary according to the nature of the gas but inhalation and skin or eye contact are all issues. Non-toxic, non-corrosive gases may cause asphyxiation if they are able to displace oxygen from the local atmosphere.
14. Information on the hazardous properties of gases can be found on the material safety data sheet (MSDS), usually in Section 3.
15. The consequences of exposure to compressed gases will be dependent on both the intrinsic hazardous properties and the concentration of the gas in the atmosphere. Inert gases such as nitrogen can reach relatively high concentrations before sufficient air is displaced to cause a problem. On the other hand, some gases with toxic properties such as chlorine have very low Workplace Exposure Limits (WELs) assigned to them and the airborne concentration of the gas must not be permitted to exceed these levels. Information on WELs can be found on the MSDS under 'Exposure Controls' (normally Section 8).
16. Other factors that can influence exposure are the physical properties of the gas:
    - **Relative Density.** This is the ratio of the density of the gas to a reference gas (usually air, which is taken as = 1). Gases with a relative density of >1 are therefore heavier than air and will accumulate at low levels. Conversely, gases with a relative density of <1 are lighter than air and will accumulate at high level. Some general predictions can therefore be made as to what will happen if released into a confined space such as a laboratory.
    - **Odour.** Many gases such as ammonia, chlorine, hydrogen sulphide and nitrogen dioxide have characteristic odours that can provide a warning of their existence. In some cases, the odour threshold may be below the WEL – the average person is able to identify ammonia at a concentration of

INFOBOX 1

Workplace Exposure Limit: an occupational exposure limit set under COSHH in order to protect the health of workers. Airborne contaminants expressed as ppm or mg/m3 and averaged over a specified time period (8 hours or 15 minutes).

Material Safety Data Sheets for all gases produced by BOC can be downloaded from the link on the Safety Department web page: http://www3.imperial.ac.uk/safety/subjects/gasesandcryo

MSDSs are also provided by BOC at point of delivery of the product.

Common gases used in the College can be found in Appendix E.

HAZARDS continued

about 4ppm and the short term exposure limit is set at 35ppm. In addition to odour, it is possible to visually perceive some gases (though you are likely smell them first). Chlorine, for example, is described as a 'greenish' gas. Odour detection is not a control measure in itself - it is an indication that something is wrong with the system, equipment or process. if odours are detected, shut down the equipment, system or process.

Physical properties are usually found in Section 9 of the MSDS 'Physical and Chemical Properties'.

Fire resulting from the escape of a flammable or pyrophoric gas

17. Flammable gases present the obvious risk of fire (and explosion) and some gases such as acetylene and hydrogen have very wide flammable ranges when mixed with air. Hydrogen also burns with a clear flame that can be hard to detect. Flammable gases that have ignited may flashback to the source of the gas via the pipework and measures must be taken to prevent this (see Control Measures). Pyrophoric gases such as silane may ignite spontaneously on contact with air. All compressed gas cylinders, whether they contain flammable gases or not, present a risk of rupture and explosion if exposed to fire (as opposed to being the cause of the fire). Oxidant gases will support combustion in the event of a fire starting. Flammability data may also be found in the MSDS under 'Physical and Chemical Properties'.
18. As with all other substances, in addition to the MSDS, gas cylinders will bear appropriate signage on the cylinder itself.

CONTROL MEASURES - STORAGE AND USE

CONTROL MEASURES - STORAGE AND USE

Dedicated gas cylinder stores

19. The general principles outlined below apply to areas that are designated for free-standing cylinder storage and must be considered in the risk assessment for such a facility. However, the principles equally apply to cylinders connected via piped systems to outlets elsewhere.
    - Storage locations should be external to buildings. The Building Manager responsible for the area must be consulted before any new storage location is determined.
    - Maintain adequate separation distances between gases with different properties (tables are available to determine distances – see INFOBOX 2). Alternatively, employ fire walls (minimum 30 minutes fire resistance) to reduce the separation distances.
    - Maintain adequate separation distances between the cylinders and other features such as site boundaries, building openings, air intakes etc. (guidance is available – see INFOBOX 2).

FIGURE 1

SAFETY SIGNAGE

From left to right:
Smoking prohibition, Hazard warning (compressed gases), access control signage, yellow, amber and red

- Store cylinders away from sources of heat. Designate the area a 'no smoking' area and ensure that signage is posted.
- Ensure that suitable hazard warning and access control signage is present (see Figure 1)
- Ensure that good natural ventilation is present. Roofing may provide a degree of weather protection providing that adequate ventilation is maintained.

STORAGE AND USE
continued

- Ensure good access so that cylinders can be manoeuvred in and out with minimum difficulty. The floor surface should be even with adequate drainage. Suitable support racking should be present.
- Ensure that there is adequate lighting. If flammable gases are present, it should be determined whether protected electrical equipment is required.
- Ensure that adequate fire fighting equipment is provided as identified.
- The location must be secure and accessible only to authorised personnel.
- Where the siting of a gas store may have a potential impact on other occupants of the premises (e.g. NHS Trusts on the medical campuses), then the site partner must be informed and if necessary, consulted on the proposed location.

Storage in laboratories and associated areas

20. The following points apply:

- Only store compressed gases in indoor locations if external storage is not possible.
- Keep the absolute minimum number of cylinders in laboratories. Avoid the tendency to keep a stock of 'spares'. Cylinders attract a rental charge and therefore, there is a cost implication if they are held for long periods or not returned promptly when empty.
- Cylinders come in a range of different sizes—use the smallest capacity cylinders available for your needs.
- Separate cylinders from populated workspaces and do not allow them to obstruct emergency escape routes.
- Ensure that the area benefits from good general ventilation (see next section). if you are unsure of the specification for air changes within your area (normally expressed as number of air changes per hour), the Building Manager should be able to provide this information.
- Ensure that appropriate signage is present on the doors (see Figure 1 - the 'No smoking' sign will not be necessary since the interior of all College buildings are no smoking).
- Ensure that cylinders are stored upright (unless they are specifically designed to be stored any other way) and are adequately restrained by chains or straps unless they are specifically designed to be free-standing.
- Ensure the area is adequately lit.
- Keep sources of ignition and combustible materials away from the area where cylinders are kept.
- Ensure that the area is as secure as possible and that cylinders can only be accessed by those authorised to use them.
- Consider the provision of gas monitoring / detection.

INFOBOX 2

Further information on general cylinder storage: *BCGA Guidance Note N2: Guidance of the storage of gas cylinders in the workplace*

VENTILATION

Ventilation

21. Good ventilation is a key element of gas safety. If a gas release cannot be prevented in the first place, good ventilation will help to disperse released gases and minimise the extent to which they accumulate.

22. External storage locations are generally designed with natural ventilation in mind. However, with regard to keeping small quantities of cylinders in the workplace (laboratory or workshop), it is often undesirable for numerous reasons (safety, security, contamination control and cleanliness) to leave doors and windows open. In many cases, particularly in modern laboratories, windows are fixed and it is not possible to open them. In such cases, we are dependent upon mechanical ventilation.

23. New laboratories at the College are designed to have a minimum of six air changes per hour. Some areas may

INFOBOX 3

Further information on ventilation issues:

1. BCGA Guidance Note GN11: *Reduced Oxygen atmospheres.*

2. Safety Department Guidance Note 015: *Liquid nitrogen – storage, use and transportation within College premises.*

have higher ventilation rates, but with the ever increasing requirement for energy savings, any rates above this baseline level will need to be rigorously justified for future projects. This can certainly be justified in circumstances where other standards exist, for example, Home Office requirements for CBS facilities. Another example where more sophisticated extraction is required relates to dedicated cryogenic storage facilities, particularly where these are serviced from a piped supply from an external bulk storage tank (see INFOBOX 3).

24. If various parameters such as the cylinder volumes, room volume and air exchange rates are known, it is possible to carry out calculations to determine what will happen in the event of an uncontrolled release. Though this is not an exact science, it does at least give some estimate of the consequences of such an event and should be an integral part of the risk assessment (see INFOBOX 3).

GAS MONITORING AND DETECTION

CONTROL MEASURES - GAS MONITORING AND DETECTION

25. Prevention of an uncontrolled release is the first priority in the gas control hierarchy followed by the availability of good ventilation to disperse the gas in the event that the release cannot be prevented. Only when these points have received attention should the issue of gas monitoring and detection be considered. There is often a temptation to readily install gas monitors and detectors without due consideration of what is involved. There can certainly be drawbacks:
    - initial installation can be expensive.
    - ongoing maintenance can be expensive.
    - they can fall into neglect.
    - neglect and lack of maintenance can cause faults to develop. As a result, they may not function when they need to and may also develop 'nuisance' triggering when no gas is present.
    - if users have little understanding of why they are present or little confidence that they function correctly, they will be ignored. Their presence is therefore rendered useless.
26. There are no hard and fast rules for determining when detection should be installed. It is an additional control measure to supplement other controls. However, there are circumstances where detection would be considered appropriate:
    - Where toxic and flammable gases are in use, particularly where low Workplace Exposure Limits are assigned or where broad flammable limits exist. In both circumstances, relatively small releases could present significant problems.
    - In bulk indoor storage facilities where large quantities of asphyxiants such as liquid nitrogen are present, particularly where the storage vessels are fed by a piped system from a large external vessel.
    - In any area where it is very difficult to achieve decent ventilation (though the priority in such circumstances would be to either improve the ventilation or relocate the gases).
27. If the decision is made to install detectors, then there are a number of points that must be addressed:
    - The type of detector must match the gas that is to be detected. For example, a low-oxygen sensor will not detect a CO_2 release before the WEL is exceeded.
    - The sensor(s) must be positioned where they will readily detect a gas release i.e.
        - in close proximity to the potential source of release.
        - at high level for gases lighter than air and at low level for gases heavier than air.
        - unobstructed by large items of equipment.
        - in a position where they can be accessed for maintenance without too much difficulty.
    - The detector must be suitably calibrated and the set-points programmed at a level appropriate to the gas being detected. The set-points would normally be at or below the WEL or 25% of the lower flammable limit for flammables. A weekly test should be carried out by the users to establish that the alarm is still functioning. It is good practice to keep a record of such tests.
    - Alarms—audible and / or visual—must be positioned so that they can be heard / or seen from both within the laboratory (so that occupants can leave) and from outside the laboratory (so that others do not enter).

GAS MONITORING & DETECTION continued

- Alarms must be assessed to determine whether any additional functionality is required e.g. whether the alarm needs to be linked to a solenoid valve that automatically shuts of the gas supply when it is triggered. Alternatively, alarms can be linked to mechanical ventilation to enable the extract to be ramped up in the event of it triggering.
- Alarm panels are best located outside the area of the potential gas release. If necessary, they can then be interrogated from a position of relative safety.
- The system must be subject to a maintenance regime. Some sensors require replacement or recalibration as frequently as every six months.
- All users of the area must receive local training so that they are aware of what the alarms mean and what to do in the event of them sounding. This information should be recorded in local protocols.

28. Portable personal monitors may be considered as an alternative to fixed detection systems. However, the following points should be borne in mind:
    - They may also require maintenance to keep them functioning (though fixed lifetime no maintenance models may be available).
    - They will only provide a warning if the user remembers to wear it.
    - They will only provide a warning once the gas enters the vicinity of the monitor (rather than at the source of the leak if this happens some distance away).

TRANSPORT & DELIVERY

CONTROL MEASURES - TRANSPORT AND DELIVERY

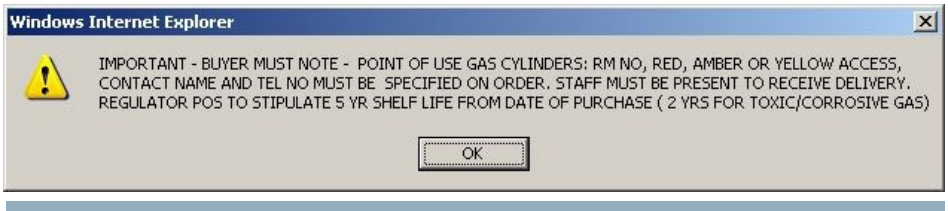
29. BOC provide a product delivery service on the major College campuses and gas users should utilise this service where it exists. By doing so, the responsibility for the manual handling operation is discharged to BOC and therefore means that there should be minimal manual handling for departmental users. The service is described in the flowchart in Appendix A.
30. If cylinders do need to be moved by departmental staff, there are some salient points to consider (see also INFOBOX 4):
    - Wear appropriate PPE (see PERSONAL PROTECTIVE EQUIPMENT below).
    - Keep vertical cylinders secured and never turn your back on a freestanding cylinder.
    - Consider the route of travel in advance and beware of steps and uneven, sloping or slippery surfaces.
    - Never attempt to catch a falling cylinder – get out of the way.
    - Employ trolleys as moving aids and ensure that the trolley is checked and maintained in good condition. Pay particular attention to the wheels and wheel bearings.
    - Do not move cylinders with the regulator attached or while the cylinder is connected to another item of equipment.
31. There are issues associated with transporting cryogenic vessels in lifts. This matter is covered elsewhere (see INFOBOX 3).

INFOBOX 4

Further information on manual handling, transport of cryogenic vessels in lifts and access control:

1. *BCGA GN3 Safe cylinder handling and the application of the Manual Handling Operations Regulations to gas cylinders.*
2. Safety Department Guidance Note 015: *Liquid nitrogen – storage, use and transportation within College premises.*
3. Access Control: http://www3.imperial.ac.uk/safety/subjects/accesscontrol

FIGURE 2



ICIS POPUP BOX

32. Departments that have placed an order for a cylinder delivery must ensure that someone is present in the laboratory or workshop to receive the delivery. This is requested on the ICIS 'popup' (Figure 2) that appears during the ordering process. This is particularly important with respect to restricted and highly restricted areas (designated 'Red' or 'Amber') since BOC staff will not be permitted entry unaccompanied.
33. The use of pallets and vehicles for transporting cylinders is not a mainstream activity as far as College staff are concerned. If cylinders or cryogenic vessels are to be transported off site, this must be carried out in compliance with all regulations relating to the transport of dangerous goods. These regulations are complex and your local safety adviser or the Safety Department should be consulted in all cases.

PRESSURE REGULATORS & ACCESSORIES

CONTROL MEASURES - PRESSURE REGULATORS AND ACCESSORIES

34. Pressure regulators are important – select and obtain the correct equipment at the outset (see Appendix B) and reduce risks with ongoing care and maintenance. Essential points:
    - Ensure the regulator is designed for use with the specific gas (or gas type).
    - Ensure that the regulator is correctly rated to cope with the cylinder pressure.
    - Keep regulators clean and undertake a visual inspection each time prior to use (see Appendix C).
    - Do not force any regulator that does not fit and do not attempt 'home made' repairs or modifications.
    - Ensure the pressure adjusting screw is fully retracted before connecting the regulator to the cylinder. This will ensure that there can be no flow through the regulator when the cylinder valve is opened.
    - Never use oil or grease on regulator threads - particularly with oxygen cylinders, which could result in a violent reaction.
    - Do not use PTFE tape or jointing compounds on regulator threads in an attempt to seal leaks. These are designed to be metal-on-metal connections and if fitted properly should not result in leaks. If a satisfactory connection cannot be made, contact a BOC representative.
    - Regularly check for leaks using an approved leak detection fluid.
    - Immediately replace any damaged or defective regulator.
    - Regulators must be replaced or refurbished every 5 years (every 2 years for corrosive gases). Due to the potential for time-related deterioration of the internal components, this should be the case irrespective of the degree of use that the regulator has seen i.e. it will apply even if the regulator has not been used). This requirement is an industry standard in the UK and is established College policy. Replacement with a new regulator may well prove more cost effective than returning an older regulator to the supplier for an in-depth strip down and replacement of parts. The 5 year period is normally recorded from the date of manufacture and suppliers should take account of this in their stock rotation policy. When purchasing a new regulator, ensure that you are supplied with one having

INFOBOX 5

Further information on pressure regulators and accessories:

BCGA Guidance Note GN7: *The safe use of individual portable or mobile cylinder gas supply equipment*

FIGURE 3

REGULATOR INSPECTION TAGS

These will be placed on regulators by the engineer following their annual inspection. From left to right, Pass, Notice for replacement within a year, and Notice of Immediate replacement.

the requisite five year (or two years for corrosives) shelf life. Keep a record of the date of manufacture and purchase.

- Ensure that regulators are checked and maintained by a competent individual on an annual basis. The service is provided by BOC and all regulators that have been inspected will bear a relevant tag (see Figure 3). BOC also produce summary tables for each department. Failed or out of date regulators must be immediately taken out of service and replaced (see Appendix F).
- Consider installing devices such as flow-stoppers. These devices detect excess flow rates and either shut off or drastically reduce the gas flow. They can be fitted to free standing regulators or as part of a piped system. They may not be suitable for every application but are inexpensive and thus a very cost effective control measure.

PIPED SYSTEMS

CONTROL MEASURES - PIPED SYSTEMS

35. The are many piped gas systems in the College. From a safety perspective, they are advantageous in that they restrict the distribution of cylinders, remove them from populated workspaces (if well located) and minimise manual handling operations. If the source cylinders are located externally to the building, an uncontrolled release is also easier to deal with than a similar event occurring inside a building.
36. Piped systems must be designed, installed and maintained in accordance with all recognised standards and regulations (see INFOBOX 6).
37. Piped systems comprise two components:
    - **The supply system.** This is the part of the installation from the cylinder outlet to the main pressure regulator and must be capable of withstanding the maximum cylinder pressure. The system commonly contains numerous components such as pigtails, purge points, isolation valves, heaters and vapourisers. There are often manual or automatic change-over devices to enable cylinder switching. This section of the installation is often (and preferably should be) located outdoors and the cylinder location kept under the storage conditions described earlier as for a dedicated cylinder store.
    - **The distribution system.** This is the part of the installation from the main pressure regulator to the outlet point and should be operated at a pressure below the maximum supply pressure and must be protected from over-pressurisation resulting from malfunctions within the system. This is achieved by employing pressure relief valves or bursting discs and the discharge from these devices should be directed to a safe place.
38. In addition to ensuring compliant design standards, all installations must be subject to suitable inspection and maintenance regimes and only operated by trained staff. Inspection and maintenance usually takes two forms:
    - Annual inspections in accordance with a **Written Scheme of Examination** (WSE). This is a requirement under the Pressure Systems Safety Regulations and most piped systems will be subject to this. The ethos behind the WSE is to control the risks associated with stored energy and it comprises a formal assessment of the system (or part thereof) with regard to its ability to operate for a further specified period. For newly installed systems, the WSE should be prepared by the installer. Copies should be held both locally by the users and centrally with Facilities Management—the latter can be achieved by registering the installation via the FM Helpdesk. To register a pressure system, use the form in Appendix D. The annual inspections are normally carried out by an engineer employed by the College insurers. The insurers are also able to prepare WSE's retrospectively, though they will levy a charge for this service.

      Note: **Installation of new piped systems** – the designer or manufacturer who supplies or installs a pressure system must provide the College with all the necessary information to permit compliance with the above Regulations. A summary of the required information is given in Section 5 of BCGA CP23. The local Faculty, Campus or Departmental Safety

INFOBOX 6

Further information on piped systems:

1. *BCGA Code of Practice CP4: Industrial Gas Cylinder Manifolds and Gas Distribution Pipework (excluding acetylene).*
2. *BCGA Code of Practice CP23: Application of the Pressure Systems Safety Regulations (PSSR) to Industrial and Medical Pressure Systems Installed at user Premises.*

Officer should be notified whenever a new piped system is to be installed.

- **Planned Preventative Maintenance** scheme. This is normally carried out by a competent external contractor at a suitably determined interval. Maintenance issues may partially overlap with the requirements of the WSE. An important difference is that an insurance inspection under the WSE may identify problems but the insurers will not be bound to carry out remedial measures - they will be flagged on the inspection report and repairs must be effected by the stated re-inspection date. Maintenance records should be held locally by the user.

39. The difference between the two, is that the former essentially provides assurance to the College that the system is suitably designed and continues to operate safely (and also satisfies the College insurers) and the latter provides a means for routine maintenance and repair or replacement of components.
40. With regard to operation, all users must receive appropriate local instruction on how the system works. It is good practice to have instruction cards and schematics available that pertain to the specific system. Training must be recorded and records held locally by the user.

CONTROL MEASURES - PERSONAL PROTECTIVE EQUIPMENT (PPE)

PERSONAL PROTECTIVE EQUIPMENT

41. PPE may be required according to the circumstances:
    - laboratory coats or overalls will protect clothing while moving cylinders.
    - stout gloves and safety footwear will protect the hands and feet while moving cylinders.
    - eye protection should be worn while changing regulators.
42. For certain specialist applications, full breathing apparatus may be required – the need for this should be determined by risk assessment (there are very few sets of operational breathing apparatus within the College). If breathing apparatus is required it must be adequately maintained and operated only by trained and certificated users who have been certified as medically fit for the purpose.
43. All PPE must be adequately stored on hooks, in cupboards or in dedicated mountings (e.g. wall dispensers for safety spectacles, purpose built boxes for breathing apparatus) and not left lying around on benchtops where damage and contamination is a risk.

CONTROL MEASURES - OXY-FUEL EQUIPMENT

OXY-FUEL EQUIPMENT

44. This is a subject in its own right, but there are some key points to consider:
    - The area where the equipment is used should be well ventilated. Combustion fumes can cause health effects and oxygen enrichment should be avoided due to the risk of enhanced combustion in the event of a fire.
    - Appropriate eye protection is essential at all times to protect against heat, glare and sparks.
    - As with all gas equipment, training, user inspection (hoses, blowpipes, torches etc.) and periodic maintenance by a competent party is essential to safe use. Written Schemes of Examination are not required for portable oxy-fuel welding and cutting sets.
    - Flashback arrestors of a type suitable for the gas type and working pressure should be fitted as an additional safeguard.
45. Far more detail may be found in BCGA CP7, including information on process hazards, equipment standards, system set up, maintenance and inspection requirements, using the equipment, closedown procedures and emergency actions.

INFOBOX 7

Further information on oxy-fuel systems:

BCGA Code of Practice CP7: Safe Use of Oxy-Fuel Gas Equipment (Individual Portable or Mobile Cylinder supply).

CONTROL MEASURES - FLAMMABLE, PYROPHORIC AND TOXIC GASES

FLAMMABLE, PYROPHORIC AND TOXIC GASES

46. All of the sections of this Code of Practice are relevant to the use of flammable, pyrophoric and toxic gases. However, the intrinsic hazards presented by these gasses warrant some specific attention.
47. **Internal locations.** It is standard industry practice to keep these gases (particularly pyrophoric and very toxic gases) enclosed in ventilated gas cabinets. Where gases are not

FLAMMABLE, PYROPHORIC AND TOXIC GASES
continued

held in gas cabinets, it must be demonstrated that there is adequate ventilation and atmospheric monitoring to ensure that a safe environment is maintained. There should be a means of warning in the event of ventilation failure. Clearly marked isolation valves should be present as close as possible to the vessel (this should be operable from both outside and inside the room). Gas cabinets, like all forms of LEV, must be installed and commissioned by a competent installer. They must also be subject to thorough maintenance and testing at a frequency of not less than 14 months by a competent tester. Users must be trained in the operation of gas cabinets (including alarms).

48. **Restricted access and minimising holdings.** It is particularly important to restrict access to these areas (see Access Control - INFOBOX 4) and to minimise the number of cylinders present. The location of flammable and pyrophoric gases must be approved by the College Chief Fire Officer, notified to the Building Manager and recorded on the Building Risk Register. This is an integral part of the fire risk assessment for the building.
49. **Purge gases.** Appropriate purge gases must be present to enable purging of the system under all circumstances that require this e.g. during supply container changeover and prior to maintenance on the system.
50. **Flow limitation.** Automatic shut-off and / or flow limiting devices should be present on the supply system.
51. **Flashback arrestors.** These devices must be employed in all circumstances where flammable gases are used, not just oxy-fuel systems.
52. **Monitoring and detection.** This consideration is of increased importance with gases of these types.
53. The above represents only a brief summary of requirements. Users of flammable, pyrophoric or toxic gases must refer to BCGA CP18.

INFOBOX 8

Further information on flammable and special gases:

1. *BCGA Code of Practice CP18:The Safe Storage, Handling and Use of Special Gases in the Micro-electronics and other industries.*
2. *BCGA Code of Practice CP6:The Safe Distribution of Acetylene in the Pressure Range 0-1.5 Bar.*
3. *BCGA Code of Practice CP33:The Bulk Storage of Gaseous Hydrogen at User Premises.*

DISPOSAL OF GAS CYLINDERS

CONTROL MEASURES - DISPOSAL OF GAS CYLINDERS

54. Empty working cylinders should be returned in good time (rental costs have already been mentioned) and unwanted 'legacy' cylinders (which are sometimes difficult to identify and may be in a state of deterioration) should be disposed by an appropriate means and not hoarded because of the difficulty that is sometimes associated with the process. In order of preference:
    - Arrange for the cylinder(s) to be returned to BOC—they will accept all cylinders that originate from their own organisation.
    - If BOC are not the supplier, attempt to identify and contact the supplier / manufacturer with a view to collection. The Safety Department maintain a list of gas suppliers and their contact details.
    - Register the cylinder(s) as hazardous waste with Facilities Management via the established procedure. Arrangements will be made to try to dispose of the cylinder via the College hazardous waste contractors. There will be a recharge to the department for this service.

EMERGENCY PROCEDURES

CONTROL MEASURES - EMERGENCY PROCEDURES

55. The following emergency procedures are generic responses. The relevant sections of the MSDS for the specific gases being used must always be consulted and used to inform the emergency procedures part of the risk assessment. The relevant sections of the MSDS are First Aid Measures (Section 4), Fire Fighting Measures (Section 5) and Accidental Release Measures (Section 6).

Fire

56. Cylinders under pressure may explode when exposed to fire, irrespective of the type of gas contained within. There are certain general actions that should be taken:

EMERGENCY PROCEDURES
continued

- Operate the planned fire drill for the area in question. The evacuation area may need to extend beyond the confines of the building where the fire is present, particularly if gases such as acetylene are present. Depending upon the location, this may also mean evacuating or partially evacuating the premises belonging to neighbours adjacent to College properties. This decision will be made by the College Chief Fire Officer in conjunction with the emergency services.
- College staff should not attempt to fight fires involving (or near) gas cylinders with fire extinguishers unless it is small enough to be dealt with very quickly—activate the fire alarm call point and get out of the building.
- If possible, isolate the gas supply to the area affected but do not take any risks. If the building receives piped gas supplies from an external location, it may well be possible to isolate these from a safe distance.
- Local knowledge and information contained within building risk registers should be made available to the emergency services upon arrival.
- Inform BOC as soon as possible (see contact numbers in Appendix A).
- As with any fire, do not re-enter the building until clearance has been given. Cylinders that have been heated can remain dangerous even after the fire has been extinguished.

Uncontrolled release of gas

57. Isolate the supply (if this can be done safely). If gas detection is present, this may alert the users to a problem before the gas reaches a critical level.
58. If the supply cannot be safely isolated, evacuate the area. Prevent others entering the affected area and display signage if necessary.
59. Increase the ventilation if this is an option. This will cause the gas to disperse more quickly.
60. Do not re-enter the area until it is certain that the gas has cleared or reduced to a 'safe' level. It may be possible to estimate how long it will take the gas to clear by calculation or it may be possible to physically measure the concentration using a gas detector. Do not re-enter the area alone.

First Aid

61. Whatever the nature of the gas, the objective will always be to distance an affected person from the source of the gas to an uncontaminated area so that they are able to breathe clean air. Be aware of the exposure symptoms caused by the specific gases that are being used—headaches, nausea, increased respiration etc. may all be indicators of exposure.
62. Corrosive gases may cause chemical burns to the skin and eyes as well as inhalation problems. Such exposures will need to be treated in the same way as any other chemical burn.
63. Be aware that there may be delayed adverse affects.
64. An unconscious casualty will need to be removed to an uncontaminated area for further treatment (and medical assistance if necessary) but rescuers must not put themselves at risk. If there has been a release or a suspected release, rescuers will need to wear breathing apparatus (see previous section on PPE). Dealing with an unconscious casualty is therefore very difficult and the emphasis must be on preventing exposure in the first place.

Incident Reporting

65. Any incident involving compressed gas cylinders, regulators or associated pipework (irrespective of whether any injury or exposure occurred) must be reported via the established College system. Examples include:
    - any failure of a regulator or other system component.
    - significant release of gas due to leakage (e.g. flexible tubing becoming disconnected).
    - bursting disc releasing in the cylinder collar (this happens occasionally with carbon dioxide cylinders).

INFORMATION, INSTRUCTION AND TRAINING

CONTROL MEASURES - INFORMATION, INSTRUCTION AND TRAINING

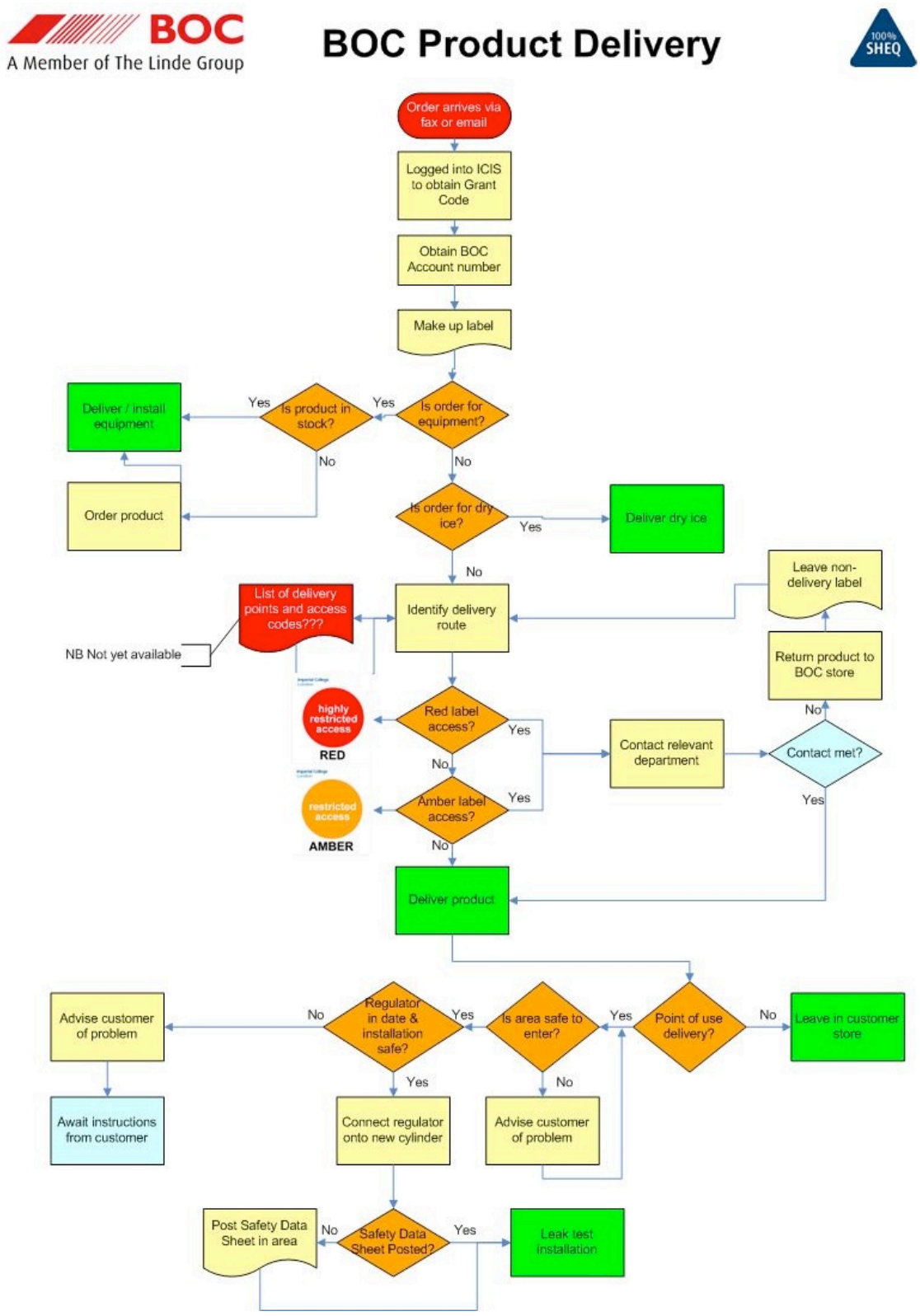
66. All users of compressed gases must receive adequate information, instruction and training. This takes several forms:

INFORMATION, INSTRUCTION AND TRAINING

- Provision of information. Users must be able to access Material Safety Data Sheets and risk assessments for the activity. They must understand the hazards associated with the gases they are using and the controls necessary to maintain safety. Better still, they should be actively involved in the risk assessment process from the outset.
- Formal training. The College offers a number of formal training courses on the use of compressed gases. This includes an E-Learning course: *Using Gas Cylinders Safely within Universities* and a practical course on connecting pressure regulators.
- Further details of courses may be found on the Learning and Development website: http://www3.imperial.ac.uk/staffdevelopment/safety
- On-the-job training. This includes practical instruction (and if necessary adequate supervision) on the use of specific apparatus in the area where the individual is expected to work. This must include instruction on what to do if something goes wrong.

67.

Appendix A - BOC Product delivery flowchart



BOC ONSITE SERVICES:

Mark Komorowski, Onsite Facilities Manager - 020 7594 8745, Mark.Komorowski@boc.com

Appendix B - Purchasing Pressure Regulators

Stipulating standards for the purchase of pressure regulators is not straightforward, but the following guidelines can be applied:

1. Look for evidence of compliance with BS EN ISO 2503: 2009 *Gas welding equipment -Pressure regulators for gas cylinders used in welding, cutting and allied processes up to 300 bar.* Though this standard specifically refers to gas welding equipment, regulators for use with laboratory gases should be designed and constructed to the same standard and many suppliers will specify this in their sales documentation.

2. Look for evidence that pressure gauges comply with BS EN ISO 5171: 2010 Gas welding equipment -Pressure gauges used in welding, cutting and allied processes. This standard ensures that in the event of failure of the gauge , it will vent in a direction away from the face of the gauge.

3. Ensure that regulators are suitable for the cylinder pressure - usually 300 bar (4350 psi). This may not be the case, for example, with regulators purchased from the USA.

4. There is no absolute requirement for CE marking of cylinders unless used for medical applications.

5. Use reputable suppliers - preferably those in the UK who ideally supply equipment of European manufacture.

Appendix C - Pressure regulators - User inspections

Appendix D - Pressure systems registration form

Imperial College London

FACILITIES MANAGEMENT HELPDESK Pressure System Registration Form

Are you using this form to DEREGISTER a pressure system? If yes, only complete highlighted sections	Yes	No
Details of pressure system		
Age of system (approximate)		
Description of system (e.g. nitrogen gas manifold)		
Name of manufacturer / installer		
Serial / identification number (if known)		
Working pressure (psi or bar litres)		
Details of equipment location		
Department name		
Division name		
Room number		
Floor number		
Campus location	.	
Details of maintenance provider		
Company name and address		
Telephone number		
Contact in company including email address		
What is the frequency of visits? (e.g. quarterly)		
When is the next service visit due?		
Section/Department/Division contact details		
User's contact details	Name Extension number Email address	
Department Safety Co-ordinator	Name Extension number Email address	
Deputy Safety Co-ordinator or Head of Section	Name Extension number Email address	
Faculty Safety Manager (FSM) or Campus Safety Manager (CSM) or Departmental Safety Officer (DSO)	Name Extension number Email address	
Date this form submitted to FM		

Email the completed form as an attachment to FM Helpdesk: fm.helpdesk@imperial.ac.uk

Important: Please copy this form to local FM contact, Department Safety Co-ordinator, FSM / CSM / DSO and User

For urgent enquiries ring the FM Helpdesk on ext 48000 (020 7594 8000).

Appendix E - Common gases used in the College

Gas	Relative Density (Air=1)	WEL (ppm) Short Term	WEL (ppm) Long Term	LFL (%)*	UFL (%)**	Physical Properties	Hazardous Properties
Acetylene	0.90	N/A	N/A	2.4	16	Colourless gas with garlic smell	Extremely flammable
Ammonia	0.60	35	25	16	28	Colourless gas with pungent odour	Toxic, corrosive and flammable
Argon	1.38	N/A	N/A	N/A	N/A	Colourless gas	Asphyxiant at high concentrations
Carbon dioxide	1.52	15000	5000	N/A	N/A	Colourless gas - sharp smell at high concentrations	Asphyxiant with physiological effects at high concentrations
Carbon monoxide	1.0	200	30	12.5	74	Colourless odourless gas	Toxic, extremely flammable
Chlorine	2.5	0.5	N/A	N/A	N/A	Greenish gas with pungent odour	Toxic, corrosive, oxidant - strongly supports combustion
Helium	0.14	N/A	N/A	N/A	N/A	Colourless gas	Asphyxiant at high concentrations
Hydrogen	0.07	N/A	N/A	4	75	Colourless odourless gas	Extremely flammable - burns with invisible flame
Methane	0.60	N/A	N/A	5	15	Colourless gas	Extremely flammable
Nitrogen	0.97	N/A	N/A	N/A	N/A	Colourless odourless gas	Asphyxiant at high concentrations
Oxygen	1.10	N/A	N/A	N/A	N/A	Colourless odourless gas	Oxidant - readily supports and accelerates combustion
Propane	1.50	N/A	N/A	2	10	Colourless gas artificially 'stenched' to give fish like smell	Extremely flammable

*LFL - Lower Flammable Limit (lowest concentration at a given temperature and pressure at which an gas / air mixture can ignite).

**UFL - Upper Flammable Limit(highest concentration at a given temperature and pressure at which an gas / air mixture can ignite).

Appendix F - Gas regulator failure mode matrix

Failure Mode	Action	Timescale
Serious damage or unsafe modification. Regulator will show 'red' fail label supplemented with 'dangerous - do not use' label. 	Imminent danger. Use of regulator must cease and the regulator must be removed. Regulator must be replaced before work can continue. Report as near miss via College incident reporting system. http://www3.imperial.ac.uk/safety/subjects/reportingaccidetns	Immediate action required by owner of the regulator to ensure that it is removed from service and not used. BOC operative must inform the local DSO / CSM / FSM on the day that the fault is discovered.
Regulator being used for wrong gas or gas type not identified on regulator.	Replace with regulator that is approved for use with the gas in question and ensure that labelling of gas type is clear on the regulator.	Dependent upon circumstances*.
Regulator not rated for maximum cylinder pressure generated. Regulator will show red 'fail' label supplemented with 'dangerous - do not use' label). 	Replace with regulator that is rated to cope with maximum cylinder pressure. Report as near miss via College incident reporting system. http://www3.imperial.ac.uk/safety/subjects/reportingaccidetns	Immediate action required by owner of the regulator to ensure that it is removed from service and not used. BOC operative must inform the local DSO / CSM / FSM on the day that the fault is discovered.
Regulator out of date.	Replace with new (or refurbished**) regulator.	At the earliest opportunity. Priority should be given to replacing regulators used with hazardous gases and those that are the oldest.
Previous failure not addressed.	Take action appropriate to the mode of failure in question. Department should investigate reasons for inaction by the regulator owner when fault was first identified.	Dependent upon type of fault.

*Immediate action may be required in certain circumstances e.g:

- regulator has been tampered with to make it fit a cylinder for which it was not designed.
- oxygen regulator being used with other gases.

** It is permissible to refurbish regulators at the end of their lifespan. However, this must be carried out in accordance with BCGA GN7 and CP17 and must be undertaken by a competent person. In practice, this will usually mean returning the regulator to the manufacturer for this to be carried out.

Appendix G - Research department compliance checklist

The following checklist is provided so as to provide those responsible for the safe use of their compressed gas systems, or their Lab Managers, an outline of some of the key points within this Code of Practice. It is not intended to be comprehensive and to look at every aspect of the CoP, just to some of the key items. These questions will, in a similar guise, also be used as part of the College Safety Department iCHECK audits.

The correct answers to these questions are in all cases 'yes', or where appropriate 'N/A'. If you have to answer 'No' to any question then this must be rectified and your DSO/FSM/CSM or member of the Safety Department notified..

No.	Question	Answer
1	Has this Code of Practice been distributed to all Principal Investigators in your department?	Yes □ No □
2	Have all activities involving compressed gases been risk assessed and documented?	Yes □ No □
3	Do all cylinder locations meet with the general principles of this CoP with regard to storage conditions?	Yes □ No □
4	Is ventilation sufficient in areas where cylinders are stored?	Yes □ No □
5	Is gas monitoring and detection necessary?	Yes □ No □
6	Are gas monitors / detectors suitable for the gas types in use?	Yes □ No □ N/A □
7	Are gas monitors / detectors located in suitable positions?	Yes □ No □ N/A □
8	Are gas monitors / detectors subject to a suitable maintenance regime?	Yes □ No □ N/A □
9	Are gas monitors / detectors subject to weekly user tests to determine that they are working?	Yes □ No □ N/A □
10	Does the BOC point-to-point delivery service cover the areas where the cylinders are located?	Yes □ No □
11	Are suitable cylinder trolleys available for departmental staff to use?	Yes □ No □ N/A □
12	Are trolleys checked to ensure that they are maintained in good condition and are fit for purpose?	Yes □ No □ N/A □
13	Is appropriate PPE available for handling compressed gas cylinders?	Yes □ No □
14	Are the correct pressure regulators available?	Yes □ No □
15	Are pressure regulators within their designated shelflife?	Yes □ No □
16	Are pressure regulators subject to an annual inspection by a competent person?	Yes □ No □
17	Are pressure regulators suitably labelled?	Yes □ No □
18	Are piped gas systems recorded on the insurance register and subject to annual insurance inspections?	Yes □ No □ N/A □
19	Are piped gas systems subject to a suitable planned preventative maintenance (PPM) schedule?	Yes □ No □ N/A □
20	Are operating instructions, schematics and other documentation available?	Yes □ No □ N/A □
21	Are flashback arrestors fitted where flammable gases are in use?	Yes □ No □ N/A □
22	Are flammable gases held in ventilated cabinets?	Yes □ No □ N/A □
23	Are gas cabinets subject to annual maintenance and testing?	Yes □ No □ N/A □
24	Are emergency procedures in place and documented in the risk assessment?	Yes □ No □
25	Have gas users been provided with on-the-job training?	Yes □ No □
26	Have staff undertaken formal gas safety training?	Yes □ No □
27	Are training records available and readily accessible?	Yes □ No □

Safe handling, use and storage of compressed gases

First issued 2002
Revised 2011

Imperial College London
Safety Department
Level 5, Sherfield Building
South Kensington Campus
London SW7 2AZ

imperial.ac.uk/safety