A guide to the
Work in Compressed Air
Regulations 1996
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Introduction

1 The Work in Compressed Air Regulations 1996 (WCA Regulations) (SI 1996/1656) provide a framework for the management of health and safety risks by those undertaking tunnelling and other construction work in compressed air. They replaced the Work in Compressed Air Special Regulations 1958. They also amplify general duties under the Health and Safety at Work etc Act 1974 (HSWA) and the Management of Health and Safety at Work Regulations 1992.

2 The WCA Regulations 1996 address such issues as: safe systems of work; medical surveillance; compression and decompression procedures (including HSE approval of procedures); control of oxygen; medical treatment; emergency procedures; fire precautions; provision of information, instruction and training; and maintenance of health and exposure records. Many of the duties are placed upon compressed air contractors to reflect the practical operation of the industry and in recognition of the fact that the contractor in charge of the compressed air operations is best placed to manage and control the health and safety risks of such work.

Scope of the Work in Compressed Air Regulations 1996

3 The application of the Regulations is limited to the construction industry, excluding such areas of work as diving, hyperbaric medicine (except for applications relating to construction work in compressed air), aircraft testing and clean rooms. The lower limiting pressure of 0.15 bar excludes work at very low pressures where the risk of decompression illness is negligible.

4 Wherever work is carried out in compressed air, all the major provisions of the Construction (Design and Management) Regulations 2007 (CDM Regulations) will apply because the number of people required to carry out and manage such work will bring it within the application of those Regulations. For most, but not necessarily all compressed air projects, the compressed air contractor will be the principal contractor under the CDM Regulations.

5 Because of the particular risks and conditions involved in work in compressed air, the WCA Regulations 1996 provide standards and requirements additional to those in Part 4 of the CDM Regulations for emergencies, fire precautions and welfare of any person engaged in work in compressed air.

6 This guidance should be read in conjunction with the relevant sections of the current version of BS 6164 “Code of practice for health and safety in tunnelling in the construction industry”.

7 The application of compressed air is only one of a number of ground improvement techniques available for tunnelling, pipe-jacking or shaft sinking. Others include dewatering, grouting or ground freezing. None of the techniques is without health and/or safety risks. Dewatering and grouting can be susceptible to changes in ground permeability while the success of ground freezing can be dependent on the groundwater regime. Experience has shown that whilst the application of compressed air can be particularly useful in stabilising finer grained soils, it has been used successfully to control water ingress in a wide range of ground types. Work in
compressed air can offer more flexibility than other ground improvement techniques when the work to be undertaken turns out to be more extensive than first envisaged.

8 The risks arising from the use of some ground improvement techniques, for example dewatering, are predominantly safety-related while both safety and health risks arise from the use of other ground improvement techniques such as grouting or work in compressed air. No technique is without risk. Comparing the overall risk arising from different techniques can therefore be difficult. However, the likely worst-case consequences which could arise from each technique are usually foreseeable.

9 The major advances in hyperbaric technology that have arisen over the past 30 years in response to the demands of offshore commercial diving are now becoming available for use also in tunnelling. While the maximum exposure pressure permissible under Regulation 11(2) is 3.5 bar, work in compressed air at higher pressures has been successfully undertaken elsewhere in Europe. Work at such pressures is outwith the scope of this guidance but would obviously be informed by this guidance. A compressed air contractor seeking to work at pressures higher than 3.5 bar in the UK would have to apply for an exemption under regulation 21 and also seek the approval of HSE for a decompression regime, under regulation 11.

10 The nature of compressed air working has changed to reflect developments in tunnelling technique. Periodic short excursions into the head of a tunnel boring machine for inspection and maintenance have become common and long periods of tunnelling in compressed air using hand excavation techniques have ceased to be the norm.

11 To reflect the more intermittent use of compressed air brought about by the highly mechanised nature of modern tunnelling and the reliability of power supplies and air supply systems now available, some flexibility is introduced in respect of the requirements for personnel overseeing the work in compressed air. The requirements for safe systems of work are set out under regulation 7.

Health risks associated with work in compressed air

12 When compressed air is used, all reasonably practicable steps should be taken to minimise both the number and severity of exposures.

13 There are three types of health problem which can be brought about by working in compressed air:

a) barotrauma, where a change in surrounding pressure causes direct damage to air-containing cavities in the body directly connected with the surrounding atmosphere, principally ears, sinuses and lungs;

b) decompression illness, which predominantly occurs as a condition involving pain around the joints, or, more rarely, as a serious, potentially life-threatening condition which may affect the central nervous system, the heart or the lungs; and
c) dysbaric osteonecrosis, which is a long-term, chronic condition damaging the long bones, hip or shoulder joints.

**Oxygen decompression**

14 Routine oxygen decompression was introduced in 2001 and is generally accepted to give significant medical benefits compared to air-only decompression, particularly at higher pressures and with longer duration exposures.

**Use of gases other than air**

15 This guidance addresses the use of mixtures including oxygen, nitrogen or helium, other than natural air, as the breathing mixture for people in the working chamber. It is envisaged that the use of such mixtures would normally take place in a working chamber which was pressurised with air but the people at work would have their breathing mixture supplied by line fed masks. Project-specific decompression procedures would be required and approval for these would have to be sought by the compressed air contractor from HSE, in accordance with Appendix 18. The only work that should be carried out in these circumstances would be inspection or maintenance.

**Guidance**

16 Methods of complying with the WCA Regulations are, in some cases, prescribed by the Regulations. This guidance gives further advice on how to comply with the WCA Regulations and is divided into sections corresponding with each individual regulation (reproduced in *italics*). Detailed advice on technical and medical aspects of work in compressed air is mainly contained in the appendices. This guidance has been prepared following widespread consultation with HSE, employers, trade unions, professional bodies and medical organisations. This Guide brings together in a single text, a revision and update of HSE’s Guidance document L96 “A guide to the Work in Compressed Air Regulations 1996 Guidance on Regulations” which covers changes in compressed air working practice and hyperbaric medical principles since 1996 as well as previously published HSE guidance on oxygen decompression and the use of non-air breathing mixtures.

**Regulation 1 Citation and commencement**

*These Regulations may be cited as the Work in Compressed Air Regulations 1996 and shall come into force on 16th September 1996.*

**Regulation 2 Interpretation**

(1) *In these Regulations, unless the context otherwise requires -*

“the 2007 Regulations” means the Construction (Design and Management) Regulations 2007*(a)*;
“airlock” means an enclosed space capable of being pressurised and which is used for the compression or decompression of any person or any material when such person or material is passing into or, as the case may be, out of a working chamber;

“appointed doctor” means a registered medical practitioner appointed for the time being in writing by the Executive for the purposes of these Regulations;

“approved” means approved for the time being in writing for the purposes of these Regulations;

“compressed air contractor” means a contractor appointed under regulation 5;

“contract medical adviser” means a registered medical practitioner appointed under paragraph (1) of regulation 9 and who is competent to give the advice referred to in that paragraph;

“decanting” means the rapid decompression in an airlock to atmospheric pressure followed promptly by rapid compression in an alternative airlock and subsequent decompression to atmospheric pressure;

“employment medical adviser” means an employment medical adviser appointed under section 56 of the Health and Safety at Work etc. Act 1974;

“the Executive” means the Health and Safety Executive;

“project” means a project which includes work in compressed air;

“work in compressed air” means work within any working chamber, airlock or decompression chamber which (in each case) is used for the compression or decompression of persons, including a medical lock used solely for treatment purposes, the pressure of which exceeds 0.15 bar;

“working chamber” means an enclosed space in which work is carried out and which is accessible only through an airlock.

(2) Any reference in these Regulations to pressure in bar means that pressure above the surrounding atmospheric pressure.

(3) In these Regulations, unless the context otherwise requires, any reference to -

(a) a numbered regulation is a reference to the regulation in these Regulations so numbered;

(b) a numbered paragraph is a reference to the paragraph so numbered in the regulation in which that reference appears.

(a) SI 1996/1592.
Guidance

17 In addition to the interpretation given in Regulation 2, the following terms are used in this document:

‘registered medical practitioner’ means a medical practitioner who is registered with the General Medical Council of the UK (GMC), and is licensed to practise within the UK. The requirements of the GMC may alter in the future so it is important that the medical practitioner is legally entitled to practise medicine within the UK;

‘tunnelling’ includes pipe-jacking and shaft or caisson sinking;

‘oxygen’ implies 100% pure oxygen;

‘breathing mixture’ implies any non-air respirable mixture such as oxygen and nitrogen (nitrox); oxygen and helium (heliox) or oxygen, nitrogen and helium (trimix);

‘gas’ implies either ‘oxygen’ or ‘breathing mixture’.

Apart from in paragraphs 40–76 which deal with requirements for competent persons, the word ‘competent’ is implied but not stated when referring to people with duties under these Regulations.

18 Any breathing mixture containing more than 23% oxygen by volume should be treated as if it were oxygen.

Regulation 3 Application

(1) These Regulations shall apply to and in relation to work in compressed air which is construction work within the meaning of regulation 2(1) of the Construction (Design and Management) Regulations 2007 and which is carried out in the course of a project which is notifiable within the meaning of regulation 2(3) of those Regulations.

(2) These Regulations shall not apply to any diving project within the meaning of regulation 2(1) of the Diving at Work Regulations 1997.

(a) SI 2007/320
(b) SI 1997/2776.

Guidance

Scope of the Regulations

19 These Regulations apply to all people employed in tunnelling, pipe-jacking and shaft and caisson sinking operations carried out in compressed air, including the use of tunnel boring or shaft excavating machinery and similar operations, as part of construction work.
20 The Regulations apply to all employers whose employees work in compressed air. This applies regardless of employment status and will include professional staff who may be working for, or on behalf of, the client.

21 If there is any doubt whether it is the WCA Regulations or the Diving at Work Regulations (DWR) 1997 which apply to work in a pressurised chamber or environment, the test to be applied is that construction work is subject to the WCA Regulations if the primary purpose of the compressed air is to control the ingress of groundwater and/or to stabilise the ground, while the DWR apply if the primary purpose of the compressed air is to provide a breathing medium in an underwater environment. Therefore, WCA Regulations will apply to work in compressed air within the head of a tunnelling machine; however, DWR will apply to work in an air-pressurised underwater habitat accessed using underwater breathing apparatus.

22 The Work in Compressed Air (Special) Regulations 1958 covered work in non-construction related pressurised applications such as gas holders and aircraft testing, but have been revoked.

23 Hyperbaric oxygen treatment carried out other than in the ‘adequate facilities’ required by regulation 12 is not covered by these Regulations.

**Regulation 4 Duties**

(1) Any duty imposed upon a compressed air contractor under these Regulations is a duty in relation to the work in compressed air in respect of which that compressed air contractor has been so appointed.

(2) Regulation 10 (other than sub-paragraphs (3)(c) and (6)(a)) and paragraphs (7)(a) and (8) of regulation 11 shall apply to a self-employed person as they apply to an employer and an employee as if that self-employed person was both an employer and his own employee.

**Regulation 5 Appointment of compressed air contractor**

(1) The principal contractor for any project shall appoint as the compressed air contractor in respect of the work in compressed air included in that project a contractor competent to execute or to supervise the execution of such work.

(2) Nothing in paragraph (1) shall prevent the appointment of the principal contractor himself as the compressed air contractor provided he is competent to perform the relevant functions imposed by these Regulations.

(3) In this regulation, “principal contractor” and “contractor” have the meaning assigned to them by regulation 2(1) of the Construction (Design and Management) Regulations 2007.
Guidance

24 The compressed air contractor will be responsible for the management and supervision of the work in compressed air and is appointed by the principal contractor. The compressed air contractor can be the principal contractor or a separate, specialised contractor but the contractor so appointed should be competent to discharge the duties under these Regulations.

25 Because of the key role of the compressed air contractor, all employers on a site whose employees work in compressed air should ascertain who has been appointed as the compressed air contractor.

Regulation 6 Notifications

(1) Subject to paragraph (2), the compressed air contractor shall ensure that no person works in compressed air unless the compressed air contractor has given notice of the work in compressed air to the Executive in accordance with paragraph (4) at least 14 days before the work is to commence.

(2) Where owing to an emergency or to circumstances which could not reasonably have been foreseen it is not practicable to comply with the requirement of paragraph (1) that notice of work in compressed air be given at least 14 days before that work is due to commence, such notice shall be given as soon as is practicable after the necessity for such work becomes known to the compressed air contractor and, in any event, before such work commences.

(3) The compressed air contractor shall ensure that no person works in compressed air unless notice of the work in compressed air has been given in accordance with paragraph (4) to -

(a) any relevant hospital;

(b) local ambulance and fire services; and

(c) any other establishment in the vicinity which has an operable medical lock.

(4) The notice referred to in paragraphs (1) to (3) shall be in writing and shall contain the information set out in Schedule 1 to these Regulations.

(5) Where notice of work in compressed air has been given by virtue of paragraph (3), the compressed air contractor shall ensure that every body to whom such notice has been given is informed without delay of the completion or suspension of that work.

(6) In this regulation, “relevant hospital” means a hospital with an accident and emergency unit to which any person suffering from any acute condition arising from the work in compressed air is likely to be taken.
Guidance

Who to notify

26 Where work in compressed air is about to be carried out, the compressed air contractor must inform the following:

- local HSE office
- relevant hospital - this is one with an accident and emergency (A & E) unit (but not necessarily a hyperbaric facility). It is advisable to copy the notification to the consultant in charge of the A & E unit. The notification should also be copied to the consultant in charge of the hyperbaric unit if there is one at a local hospital;
- local ambulance service;
- local fire service - the notification to the local fire service should include information on any intended storage of oxygen or breathing mixtures on the site and on the use of gas cylinders underground;
- local establishments operating hyperbaric facilities. Lists of emergency hyperbaric facilities are maintained the British Hyperbaric Association.

27 The compressed air contractor may also wish to inform the local police and, if mains power is being used, the regional electricity supply company.

28 Where the escape of air from the workings can be seen as bubbles on the ground surface and be mistaken by the public for a domestic gas leak, the compressed air contractor may wish to advise the local gas distribution network operator, that work in compressed air is taking place.

Hospitals

29 Interpretation of the term ‘relevant hospital’ will need to take account in rural areas of the nearest large town and in urban areas of the possibility that there could be several hospitals to which casualties may be taken.

30 Hospitals near to the site with A & E departments need to be notified because workers who develop symptoms of decompression illness away from the site may be referred or taken to an A & E department. It is important that hospital staff are aware that work in compressed air is being undertaken locally so that decompression illness can be considered if a worker from the site reports they are unwell. Notified hospitals should be made aware that compressed air workers must carry a card or badge advising ambulance and A & E staff to consider serious decompression illness if the worker is found unconscious or is otherwise unable to give a history of their illness. If decompression illness is diagnosed, arrangements should be made for transfer of the worker to a designated medical lock (usually located at the site) for recompression therapy, which is the initial treatment for all decompression illness.
31 The contract medical adviser may need to consider whether it is necessary also to advise hospitals with A & E departments in the areas where compressed air workers live or to which they regularly travel at weekends.

Intermittent working

32 Where work in compressed air is being undertaken intermittently, the compressed air contractor should ensure that those notified under regulation 6 are aware of this and that they are kept informed as necessary of when work in compressed air is taking place.

Suspension and completion of work

33 Although “suspension of the work” is not defined in the regulations, HSE has indicated in the past that it would be considered to be a suspension lasting 28 days or more. Notification of completion of the work in compressed air is also required to be given to those initially notified of the work.

Regulation 7 Safe system of work

(1) The compressed air contractor shall ensure that no person works in compressed air or enters or leaves compressed air except in accordance with a system of work which, so far as is reasonably practicable, is safe and without risks to health.

(2) The compressed air contractor shall ensure that a sufficient number of competent persons are present on site to supervise the execution of work in compressed air at all times when such work is being carried out and, in the case of such work undertaken at a pressure of 0.7 bar or above, for 24 hours thereafter.

Guidance

34 To develop a safe system for work in compressed air, the compressed air contractor will need to carry out an assessment of all risks associated with the work in compressed air and draw up a statement setting out how the risks which cannot be eliminated are to be managed, including a management plan for the work setting out roles and responsibilities. This should be done in conjunction with the contract medical adviser and hyperbaric supervisor, having taken advice from other professional advisers as appropriate, including those fulfilling other roles set out in paragraph 41 below. The statement should be reviewed periodically and added to as necessary. It may form part of the construction phase plan developed by the principal contractor under regulation 23 of the CDM Regulations. All employers on site need to liaise closely with the principal contractor/compressed air contractor to ensure risks on site are assessed and, where appropriate, controlled and relevant information incorporated in the construction phase plan. Sub-contractors bringing potential risk to the work need to inform the principal contractor/compressed air contractor.

35 If, when working in compressed air, the working chamber is only the space around and behind the cutter head of a tunnel boring machine, access to which is
through airlocks on the tunnel boring machine, the compressed air contractor will need to assess the particular risks inherent in such work and ensure that all necessary steps are taken to prevent collapse of the tunnel face or sudden loss of pressure in the working chamber and airlocks. A safer alternative, because of the larger volume of air stored, can be to pressurise a length of the tunnel when entry to the cutter head is required.

36 No person should work alone in the working chamber because of the danger of illness or accident in the isolated compressed air environment.

37 The safe system of work should take account of the need to avoid excessive physical exercise in the initial hours after decompression. The compressed air contractor should, where appropriate, provide transport such as manriding facilities or mechanical hoists to enable people to return to ground level after decompression with the minimum of effort.

38 The safe system of work should take account of the storage and use of oxygen or breathing mixtures as appropriate.

39 The safe system of work should take account of the condition of the ground through which the tunnelling is taking place. In particular, the compressed air contractor should ensure that the ground around the air locks and working chamber is fully capable of resisting the loads imposed on it from the application of compressed air.

**Competent persons**

40 All people underground should be competent for the environment in which they are working and for the work tasks and activities they are required to carry out. Supervisory staff should be competent with both the work being undertaken and in the techniques of management, communications and supervision. The compressed air contractor’s delegation of duties to competent persons does not detract from the compressed air contractor’s responsibilities under these Regulations.

41 However, there are a number of specific roles which must be fulfilled by people with specific competences to ensure that work in compressed air can be undertaken safely. These roles have developed over time and reflect the application of good hyperbaric practice to the modern tunnelling environment. Whenever people are working in compressed air, there should be a sufficient number of competent persons available to fulfil the roles below:

(a) person in charge, with deputies to cover for shift working – responsible for all aspects of the work in compressed air;

(b) hyperbaric supervisor – responsible to the person in charge for the day-to-day organisation of the compressed air activity;

(c) hyperbaric plant supervisor – responsible to the person in charge for the installation and operating systems of the plant and equipment necessary for work in compressed air;
(d) compressor attendant – responsible to the hyperbaric supervisor and hyperbaric plant supervisor for the day-to-day operation and maintenance of compressed air supply equipment on the surface;

(e) underground plant attendant – responsible to the hyperbaric supervisor and hyperbaric plant supervisor for the day-to-day operation and maintenance of compressed air supply equipment underground;

(f) lock attendant for every lock in which people are being compressed or decompressed – responsible to the hyperbaric supervisor for the safe operation of the airlock;

and in addition for work in compressed air at pressures of 1.0 bar or over:

(g) medical lock attendant – responsible to the contract medical adviser for the safe operation of the medical lock;

(h) medical lock tender – responsible to the contract medical adviser and medical lock attendant for assisting with patient care.

Recommended lines of communication between the roles are shown in Figure 1.
People may undertake more than one role provided they have the necessary competence and time to do so without jeopardising the health and safety of those working in compressed air. The person in charge may allow an individual to perform other tasks on site, provided that the person in charge has taken advice from the contract medical adviser and is satisfied the individual is sufficiently competent and readily available to discharge all of their roles under these Regulations.

Where work in compressed air is being undertaken on a continuous basis over a period of weeks, a number of teams of competent persons, routinely working shifts, will be required to meet the requirements of paragraphs 41–76.

Where the tunnelling techniques used require only intermittent work in compressed air, the competent persons required by this regulation may be brought to site for the duration of that work only.

In both cases, the hyperbaric supervisor and hyperbaric plant supervisor should ensure sufficient competent persons are available on site so that when work in compressed air is being undertaken, it can be undertaken safely.
46 A lock attendant is required to be present whenever any person is in a lock or in the working chamber to which the lock affords direct or indirect access.

47 A lock attendant may be in charge of more than one airlock if only one is for the passage of personnel and the lock attendant can observe all the locks simultaneously.

48 A compressor attendant and for decompression from 1.0 bar or over, a medical lock attendant are required to be available for a period of 24 hours after the last person has been decompressed.

49 Current industry practice is not to differentiate between medical lock attendant and lock attendant by having a pool of attendants able to undertake either role. In these circumstances the hyperbaric supervisor should allocate their duties according to their competence and the needs of the undertaking.

50 For night shift and weekend cover when no work is taking place but the working chamber remains pressurised, a compressor attendant needs to be available on site, unless a control system with an appropriate safety performance level assessed in accordance with BS EN ISO 13849:2006 is in place and suitable arrangements exist for bringing a compressor attendant to site within a time determined by the person in charge in conjunction with the hyperbaric plant supervisor, taking account of ground conditions and risk associated with change of working chamber pressure.

Person in charge

51 The compressed air contractor should nominate the person in charge, (and deputies to allow for shift work), to be his representative routinely on site and in overall charge of the work in compressed air. The person in charge (and deputies) will need an engineering background, be senior members of the compressed air contractor’s site management and have sufficient authority and competence to act on behalf of the compressed air contractor to be able to discharge their duties. Also, they should have had previous experience of work in compressed air, or otherwise be advised by people who have had relevant experience.

52 The person in charge should be responsible for overall management of the work in compressed air including:

(a) organisation of the work in compressed air;

(b) development and implementation of the management plan (see paragraph 34);

(c) development and implementation of the relevant parts of the health and safety plan;

(d) emergency procedures including planning and implementation;

(e) liaison with emergency services during an emergency;
(f) procedures to implement the prohibition of smoking materials, alcoholic drinks and drugs;

(g) arranging for the maintenance of health and exposure records;

(h) delegation of duties to the hyperbaric supervisor, hyperbaric plant supervisor, lock attendants and compressor attendants;

(i) ensuring the provision of information, instruction and training;

(j) designation of people to be responsible for determining the pressure of air in the working chambers; and

(k) liaison with contract medical adviser.

53 Where responsibilities have been delegated to the hyperbaric supervisor, hyperbaric plant supervisor, compressor, lock or medical lock attendants, the person in charge will need to make those working in compressed air aware of the authority delegated to those people. In particular, the person in charge should make clear the names of those who have his authority to determine or vary the working pressure.

Hyperbaric supervisor

54 The role of the hyperbaric supervisor is to be routinely on site when work in compressed air is being undertaken and be responsible to the compressed air contractor for ensuring the effective implementation of the safe system of work. The hyperbaric supervisor should have previous experience of hyperbaric operations in a tunnelling environment and be competent to manage the day to day running of the hyperbaric operations. Normally, the hyperbaric supervisor should also undertake the role of medical lock attendant, but at pressures of less than 1.0 bar, where a medical lock attendant is not required, should undertake the role of lock attendant.

55 Deputies for the hyperbaric supervisor to cover shift working are not required.

56 The hyperbaric supervisor should:

(a) liaise with the person in charge, the contract medical adviser and hyperbaric plant supervisor to ensure the correct implementation of the safe system of work;

(b) ensure that there are sufficient resources and a sufficient pool of competent persons on site to undertake the hyperbaric procedures in accordance with the safe system of work;

(c) supervise the day-to-day operation of all hyperbaric procedures on site including the storage and supply of gas;

(d) ensure that all the emergency procedures are reviewed as necessary and are tested periodically as agreed with the person in charge;
(e) ensure that adequate records of exposure are kept as required by these Regulations.

**Hyperbaric plant supervisor**

57 The role of the hyperbaric plant supervisor is to be responsible to the compressed air contractor for ensuring the effective implementation of the safe system of work so far as it depends on plant and equipment, along with ensuring the availability of sufficient competent persons to attend to that plant and equipment.

58 Deputies for the hyperbaric plant supervisor to cover shift working are not required.

59 The hyperbaric plant supervisor should:

(a) normally be a senior mechanical engineer or plant supervisor on the staff of the compressed air contractor or of a specialist subcontractor;

(b) have extensive knowledge and experience of the plant or equipment required for hyperbaric operations;

(c) have knowledge of the operation of tunnelling equipment which could adversely affect the safety of work in compressed air;

(d) be familiar with the hyperbaric system on site;

(e) work closely with specialist suppliers of hyperbaric plant and equipment to ascertain the requirements for safe operation and maintenance of that equipment;

(f) ensure there are enough competent persons available to undertake the role of compressor attendant for compressed air plant on the surface and underground plant attendant where the compressed air plant is underground;

(g) determine the operational and maintenance requirements and the related records to be kept;

(h) liaise with the hyperbaric supervisor.

**Compressor attendant and underground plant attendant**

60 On some tunnel boring machines with integral manlocks, the compressed air is supplied from compressors on the machine and it is current practice to have an underground plant attendant in these circumstances. The requirements for an underground plant attendant should be considered identical to those for a compressor attendant.

61 Compressor attendants need to be competent to operate and routinely maintain the electrical equipment and mechanical plant in their charge. They are required to be immediately available on site, except where the compressed air plant is covered by a control system meeting the requirements of paragraph 50. In this
case, the person in charge in liaison with the hyperbaric plant supervisor will determine the extent to which a dedicated compressor attendant is required or whether a competent member of the compressed air contractor’s maintenance staff is sufficiently readily available to undertake the relevant duties. The compressor attendant or substitute should have access to professional electrical and mechanical engineering advice and supervision.

62 The compressor attendant’s duties include:

(a) daily inspection of the compressed air plant on the surface;

(b) operation and routine maintenance of the compressed air plant within their charge and maintenance of appropriate records;

(c) varying the working pressure in response to instructions from the person in charge or other people designated by him;

(d) notifying the hyperbaric supervisor of any change in pressure;

(e) maintaining records of air pressure and quality of air being supplied to the tunnel;

(f) responding to high/low pressure alarms; and ‘loss of main power’ and ‘duty compressor failed’ alarms;

(g) being able to pressurise and depressurise the medical lock under instruction from the medical lock attendant in an emergency.

63 Where oxygen or a breathing mixture is supplied from the surface, the compressor attendant should be available to assist the lock attendant by operating or monitoring, under his supervision, the above ground parts of the gas supply.

Lock attendant

64 Lock attendants need to be competent to operate the locks in their charge. They should be competent to undertake oxygen decompression procedures and to operate breathing mixture procedures as appropriate. In addition, they should be competent to operate (pressurise and depressurise) the medical lock and its oxygen breathing system under instruction in an emergency.

65 They should be qualified to at least the level of life support technician, air diver with diving supervisory experience or equivalent. They should be medically fit and willing to go into compressed air and should operate under the supervision of the hyperbaric supervisor. Lock attendants should have had experience of the use of hyperbaric oxygen procedures and the use of breathing mixtures as appropriate, in the tunnelling or offshore diving industry where these are being used on site.

66 Lock attendants should ensure that all operations involving the use of oxygen or breathing mixtures including the connecting up of cylinders, the opening and shutting of cylinder valves on line to the manlock, the control of oxygen to the manlock, the control of the use of oxygen in the manlock, the supply of breathing
mixtures to the working chamber and the discharge of exhaled gas are carried out by
them or under their direct supervision.

67 Lock attendants should be competent to vary the air or gas supply pressure
as required by the procedures for compression and decompression and to maintain
records of air or gas pressure and quality of air or the composition of gas being
supplied to the tunnel.

68 Lock attendants should ensure that:

(a) no compression or decompression of any person is carried out except in
accordance with regulation 11;

(b) only people certified fit for work in compressed air are compressed. Fitness
may be indicated by presence on a list of authorised people or by
presentation of a duly completed health and exposure record;

(c) no person is compressed who is obviously under the influence of alcohol or
drugs;

(d) no person is compressed who is suffering decompression illness or is
obviously unfit due to colds or influenza. Such a person will need to be
referred to an appointed doctor;

(e) decompressions are carried out accurately in accordance with the relevant
table and line of the decompression tables being used, and accurate records
are maintained of all compressions and decompressions of people;

(f) manlock decompression charts are kept safe until passed to the person in
charge. For all decompression cycles recorded, the record should be clearly
annotated with the date, shift/time, and names of people being
decompressed;

(g) all clocks, gauges, valves, doors and door seals are in good working order,
and any defects reported to the person in charge;

(h) so far as is reasonably practicable, no alcohol, drugs or materials for smoking
are taken into the compressed air workings; and

(i) any manlock under their control is kept adequately cleaned for oxygen
decompression purposes.

69 Lock attendants should be able to participate in providing the information,
instruction and training given to people working in compressed air, and in addition be
trained in the problems associated with compression, decompression and
decompression illness, and with the keeping of records.

70 It is good practice to ensure that at least one of the compressed air
contractor's fitters or front line supervisors on site is competent to provide short term
or emergency cover for the lock attendants, for example, should one of them be
required to assist with the medical lock.
Medical lock attendant

71 Medical lock attendants should be qualified to the level of life support supervisor and hold the diver medic qualification of the International Marine Contractors Association (IMCA), or hold equivalent qualifications. They should be medically fit and willing to go into compressed air. They should be competent to operate the medical locks available on site and to undertake therapeutic decompression treatments using oxygen. They should be competent to implement the hyperbaric emergency procedures.

72 Medical lock attendants’ duties can require them to:

(a) make an adequate assessment of a person complaining of symptoms suggesting acute decompression illness;
(b) question workers about symptoms in the neurological system;
(c) examine a patient to monitor vital functions;
(d) give first aid;
(e) understand the need to assess regularly the progress of individuals under treatment;
(f) have immediate access to all records of pressures and other relevant information regarding conditions in the working chambers and manlocks;
(g) be available to assist the appointed doctor with routine medical assessments and accompany new starters in the airlock during lock tests; and
(h) operate the medical locks.

Medical lock tender

73 A person undergoing treatment should be accompanied in the recompression chamber by a tender. Medical lock tenders should hold an IMCA diver medic qualification or equivalent and be medically fit and willing to go into compressed air. They should be able to ensure that information on the clinical condition of a worker under treatment can be relayed accurately to the contract medical adviser, and that action is taken on the basis of the advice received back.

74 Medical lock tender is not intended to be a role for which a person is employed exclusively whenever work in compressed air is being undertaken but one which is undertaken when necessary, by a person otherwise employed on site. For example, a suitably competent lock attendant could be called upon as necessary to undertake this role.

75 A medical lock attendant would normally be able to undertake this role.

76 It is also expected that a medical lock tender could enter the working chamber to assist with first aid treatment or with the extrication of a casualty as necessary.
Regulation 8 Plant and equipment

Regulation

(1) The compressed air contractor shall ensure that there is available for immediate use all plant and ancillary equipment which is necessary for the conduct of work in compressed air in a manner which is, so far as is reasonably practicable, safe and without risks to health and that, where necessary, all such plant and equipment is used.

(2) The compressed air contractor shall ensure, so far as is reasonably practicable -

(a) that all plant and ancillary equipment used for the purpose of carrying out work in compressed air is of appropriate design and construction and of sufficient capacity for that purpose;

(b) that all plant and ancillary equipment used for the purpose of carrying out work in compressed air is safe and without risks to health and is maintained in such a condition as to ensure that it remains safe and without risks to health at all times when it is being used; and

(c) that all plant and ancillary equipment used for the purpose of carrying out work in compressed air and which is to contain air at a pressure in excess of 0.15 bar is -

(i) examined and tested by a competent person and rectified of any faults before work in compressed air commences; and

(ii) re-examined and re-tested after any modification or alteration which has the potential to affect the safety of that plant or equipment.

Guidance

77 Compressed air contractors have duties under this regulation relating to the provision of the plant and ancillary equipment required to carry out the work in compressed air in a safe manner. The hyperbaric plant supervisor should play a central role assisting the compressed air contractor to discharge these duties.

78 The plant supplied needs to be of a type intended for use in the harsh environment of a construction site and capable of operating reliably at its rated output for long periods of time. Electrical equipment in the airlocks and working chamber will need to be protected against the ingress of dust and water to at least level IP55 in accordance with EN 60529. Plant should be operated in accordance with the manufacturer’s instructions.

79 The plant supplied and used by the compressed air contractor should include means of supply of electrical energy, air compressors and ancillary equipment
(including filters and coolers as appropriate), air receivers, gas supply, airlocks, bulkheads, control equipment and pipework. With the exception of the supply of electrical energy, these items make up the 'pressure equipment' for work in compressed air.

80 The compressed air contractor is required to ensure that the plant and ancillary equipment fully satisfies the requirements of the Provision and Use of Work Equipment Regulations 1998 as amended and the Lifting Operations and Lifting Equipment Regulations 1998 (LOLER Regulations).

81 In some situations the requirements of the Pressure Systems Safety Regulations 2000 will apply to the compressed air plant and guidance on this is given in Appendix 1.

82 Airlocks, bulkheads, airdecks and other pressure equipment shall be designed and tested in accordance with the requirements of EN 12110. Airlocks, bulkheads, airdecks and their anchoring systems need to be designed by a competent engineer. The installation of these items should be supervised.

83 After installation and again after any significant repair or modification, but before work in compressed air is carried out or starts again, the whole pressure system is required to be examined and tested by a competent person and any faults rectified before work begins. As part of the examination the competent person needs to ensure that the installation has been built or modified in accordance with the design. Persons responsible for the design, construction, installation, maintenance, examination or testing of such plant and equipment will need to consider the guidance contained in the Approved Code of Practice for the Pressure Systems Safety Regulations 2000 (Safety of pressure systems HSE Books 2000 ISBN 978 0 7176 1767 8).

84 As part of the commissioning process, the pressure equipment needs to be functionally tested to a minimum of 105% of the maximum working pressure for a period of not less than 30 minutes before work in compressed air commences. At no time should the working pressure exceed the pressure to which the pressure equipment has been tested. This may result in the pressure equipment having to be periodically re-tested to progressively higher pressures as work proceeds (where, for example, kentledge is added incrementally to an airdeck). On projects where compressed air is used intermittently but the compressed air plant is continuously available for use, testing of the whole pressure system is only required on installation and after significant repair or alteration, unless the maximum working pressure is to be increased.

85 The ability of shaft linings, tunnel linings, jacking pipes and the ground surrounding them, to resist all loads imposed by air or gas pressure up to the maximum pressure envisaged, should be confirmed by the compressed air contractor as part of the safe system of work. Load reversal may occur when air pressure is reduced or removed.
86  The plant and ancillary equipment should be protected against adverse weather conditions and risks such as flooding or inundation. It should be regularly maintained by, or under the supervision of a compressor attendant.

**Power supply**

87  The main supply of electrical energy should normally be from the public electricity supply but may be from independent generating plant. In both cases there needs to be a standby power supply available. The capacity of the standby power supply needs to be sufficient to power all the duty compressors and their ancillary equipment. It should be possible to restore air supply within not more than five minutes of a failure of the main power supply.

88  In the event of failure of the main power supply, a *loss of main power* alarm should be initiated both locally at the site of the compressors and in the site offices.

**Air supply, plant etc**

89  Compressed air should normally be supplied from electrically driven compressors. A standby compressor of capacity equivalent to the largest of the duty compressors needs to be provided. Where more than five duty compressors are in operation, two standby compressors need to be provided.

90  In the event of failure of a duty compressor, a *duty compressor failed* alarm should be initiated both locally at the site of the compressors and elsewhere if deemed necessary by the hyperbaric plant supervisor.

91  The air supply plant and its power supply may be operated through a control system. That control system should be to a required performance level determined in accordance with BS EN ISO 13849-1. In the event of failure of the main power supply, the control system should be capable of switching automatically to the standby power supply within ten seconds of the failure occurring. Simultaneously the control system should initiate a *loss of main power* alarm both locally at the site of the compressors and in the site offices. The control system should automatically restart the compressors as soon as power is restored.

92  The control system should be capable of switching from duty to standby compressors in the event of failure of the duty compressors within ten seconds of the failure occurring. Simultaneously the control system should initiate a *duty compressor failed* alarm both locally at the site of the compressors and in the site offices.

93  If diesel compressors are used the compressed air contractor should consider the need for additional standby compressors to give an equivalent degree of reliability in the air supply. An adequate supply of fuel should be available on site. An emergency supply of fuel, stored separately, should also be available on site. Care needs to be taken to ensure that the air entering the intakes cannot be contaminated by exhaust emissions.
94 Each diesel powered generator or compressor should be fitted with an alarm to indicate when the fuel in its tank falls to 10% of stored capacity or one hour running time on full load, whichever represents the longer time. Where compressors are controlled through a control system, these alarms should be integrated into it.

95 A pressure relief valve, of sufficient capacity to vent to atmosphere the maximum output of the compressor, is necessary between the discharge point of each compressor and the first shut-off valve downstream of the discharge point.

96 On projects where compressed air is supplied to the lock attendant’s station at high pressure (typically 7.0 bar), an appropriate pressure-reducing valve needs to be inserted in the air supply line to limit the pressure of the air supplied to the manlock to tunnel working pressure.

97 All compressed air systems need to be fitted with alarms clearly audible at the compressor attendant’s station and to people in the vicinity of the compressor plant. These alarms need to indicate when the pressure of compressed air being supplied to the working chamber varies from the required pressure by more than a predetermined amount, e.g. 0.1 bar for systems where the air is nominally supplied at tunnel working pressure. The audible alarm for high pressure needs to be readily distinguishable from that for low pressure. These alarms should be integrated into the control system, if fitted.

98 A recording pressure gauge accurate to +/-0.05 bar and recording the pressure of the compressed air supply needs to be located at the compressor attendant’s station. A chart speed slower than one revolution per 24 hours is insufficient.

99 An air supply and an independent backup, each capable of supplying compressed air at a rate sufficient to compress the medical lock at a rate of at least 0.3 bar per minute and to a pressure of at least 1.0 bar above the pressure in the working chamber, need to be available at the medical lock. This air supply should be available for 24 hours after people have ceased to work in compressed air on the site.

100 The compressed air contractor should provide suitable accommodation for housing the plant and for the attendants to oversee and operate it. The compressor attendant needs to be able to monitor and control the compressed air plant and supply of compressed air from that accommodation.

**Supply of air**

101 The air being supplied to the locks and working chamber shall meet the requirements of EN 12021 and current HSE guidance for the diving industry. It should be odourless with an oil content not exceeding 0.5 mg/m³ at normal atmospheric pressure. Guidance on hyperbaric exposure limits is given in HSE publication EH75/2 “Occupational exposure limits for hyperbaric conditions: Hazard assessment document”.
102 It is recommended that air quality be checked at least once a day and the results recorded (see Appendix 2).

103 Compressed air supplied to any airlock, working chamber, manlock or medical lock needs to be drawn into the compressors at a place remote from exhaust fumes and other contaminants.

104 Where necessary the quality of the compressed air can be improved by the use of coolers, scrubbers and filters.

105 The supply of compressed air to the working chamber should be sufficient to maintain an atmosphere in the working chamber such that, the level of any contaminant (other than oil content) does not exceed the exposure limits for that contaminant in the current edition of EH75/2 *Occupational exposure limits*. Ventilation is also required to maintain a comfortable working environment and, therefore, the minimum supply of compressed air needs to be at least 300 litres per minute measured at working chamber pressure for each worker in the chamber.

**Air pipelines**

106 Any pipeline supplying compressed air to the workings needs to be duplicated between the compressed air plant and the lock attendant’s station. Air supply pipelines should have sufficient in-built flexibility to accommodate foreseeable movement and be capable of resisting foreseeable vibration. Pipelines should be protected against impact damage but in the event of damage to one supply line it should be possible to isolate it without interrupting the air supply to the workings. When adding pipes to a pipejack under compressed air, one air pipeline should always be operable while the other is disconnected/connected and threaded through the added pipe.

107 Any pipeline supplying compressed air to an airlock or to the working chamber needs to be fitted with a non-return valve at the point of discharge. Silencers should be fitted to supply or exhaust pipework if the noise from the air pipeline discharge exceeds a sound power level of 80 decibels.

108 The inlet orifice of any pipeline exhausting air from an airlock or the working chamber should be fitted with a suitable mesh guard to prevent injury, due to hands etc being sucked in.

109 The compressed air supply and exhaust pipelines should be laid out in a manner to ensure a circulation of air in the working chamber. When natural circulation due to air loss through the face is insufficient, induced circulation by such means as the use of a snorer will need to be considered.

110 The air supply and exhaust pipelines between the lock attendant’s station and the manlock need to be suitably sized to prevent an excessive rate of compression and decompression of the airlocks. They will also need to be appropriately marked with their function.
In an emergency, it is necessary to be able to compress an airlock directly from the air being supplied from the compressors without drawing air from the working chamber.

Any pipeline supplying compressed air needs to be adequately protected from impact damage. Pipelines which are in shafts need to be secured to the shaft wall. Air supply pipelines ought to be marked at regular intervals with an appropriate legend unless their function is obvious.

All electrical or pneumatic control lines for the regulation of the compressed air supply need to be protected from mechanical damage and from the effects of adverse weather. In particular, pneumatic control lines need to be positioned so that water will not collect in the lines and freeze in the event of sub-zero temperatures.

**Storage and supply of oxygen or breathing mixtures**

Oxygen should normally be supplied from cylinders. Liquid oxygen, if used, should only be stored on the surface. Under no circumstances should liquid oxygen be taken underground.

Oxygen, nitrogen, helium and any breathing mixtures derived by mixing these gases should be fit for respiration and meet the requirements of BS 8478.

Gases and breathing mixtures should be obtained from a reputable gas supplier. Cylinders should be clearly marked with their contents. The breathing mixture should be analysed and checked for composition before being put into supply.

For fixed manlocks on the surface at the top of a shaft, the oxygen or breathing mixtures should be stored on and supplied from the surface.

Oxygen should be stored in a secure and clearly designated, purpose-built storage area. The storage area may be roofed over but otherwise should be open to the atmosphere and away from any intake to the compressors. Breathing mixtures should be stored separately but under similar conditions.

Otherwise oxygen should be supplied from the surface or from cylinders brought temporarily into the tunnel or on to the tunnel boring machine at the compressed air contractor’s discretion. The option that minimises the risk from the presence of oxygen in the tunnel should be adopted. Only the minimum volume of oxygen required for decompression should be taken underground. Cylinders should only be in the tunnel for the time required for working or to complete the decompression cycle. Arrangements need to be made to supply oxygen during a shift for the decompression of visitors to the workings or for emergency decompressions.

Where the manlock is fixed in the tunnel or the working chamber is the cutterhead of a tunnel boring machine, breathing mixture may be supplied from the surface or from cylinders brought temporarily into the tunnel or on to the tunnel boring machine at the compressed air contractor’s discretion. The option that
minimises the risk from the presence of oxygen in the tunnel should be adopted. Only the minimum volume of breathing mixture required for the planned work should be taken underground. Cylinders should only be in the tunnel for the time required for the work to be carried out.

121 The oxygen supply system should meet the performance criteria set out in Appendix 16. The system should be equipped with gauges, valves, pressure reduction and flow-limiting devices etc, and laid out in accordance with Appendix 16 Figures 10 or 11. Systems for supplying breathing mixtures should be laid out in a similar way except that the gas should be piped to line-fed masks in the working chamber.

122 The system should be designed to minimise leakage in the event of a line break. It should also be designed to minimise the risk of fire from adiabatic compression by minimising flow velocity and pressure in all pipework during use; allowing supply lines to be kept pressurised but with line valves shut when oxygen is not being used and the use of slow opening valves except for emergency shut-off valves. In addition, the system should be capable of being constantly monitored for leak tightness through the location of pressure gauges on all sections of pipework.

123 The pressure of oxygen in the cylinders should not exceed 230 bar. For the supply of oxygen from surface storage, there should be a pressure-reducing valve on the surface close to the point of storage. Downstream of the pressure-reducing valve, the oxygen supply pressure should be the minimum pressure consistent with proper operation of the masks in the manlock but should not normally exceed 10 bar. Breathing mixtures should be similarly conveyed to the working chamber at a pressure not normally exceeding 10 bar.

124 The size of all fixed pipework should be optimised to minimise its diameter and to provide the required flow at minimum pressure and at a safe flow velocity. This is particularly important for oxygen pipework. All pipework should be pressure tested to 1.5 times maximum safe working pressure before use.

125 Care should be taken in connecting up cylinders and pipework to prevent the ingress of any dirt into the oxygen or breathing mixture supply system.

126 Oxygen pipework should be routed separately from electrical cables.

**Transport of cylinders**

127 Gas cylinders and associated valves, gauges etc taken underground for use with a tunnel boring machine, manlock or working chamber should be contained in a secure, purpose-built cage or frame capable of providing mechanical protection against impact damage during handling in the shaft or tunnel. They should be transported on a train or vehicle, used specifically for that purpose while gas is in use.

128 The train or vehicle transporting the gas cylinders should normally be battery rather than diesel powered. It should be provided with a full onboard fixed fire protection system. When parked in a tunnel, the parking brake should be securely
applied. In addition, the train or vehicle should be chocked or otherwise prevented from moving in the event of failure of the parking brake when the gradient is sufficient to allow a run-away. A mechanical barrier should be provided to protect the train or vehicle from being struck by other trains or vehicles if they were to run away.

129 Lifting of the cylinder cage or frame on and off the train should be carried out using mechanical lifting equipment that satisfies the requirements of the LOLER Regulations.

**Working chamber**

130 The breathing mixture supply pipework in the working chamber should terminate in self-sealing couplings. Sufficient feed points should be available to those working to have safe access to all parts of the working chamber while still having access to the breathing mixture supply. The line feed to those working in the chamber should have the capability of being connected to two supply points simultaneously and with non-return terminations on both supply lines. Sufficient feed points should be provided to allow for rescue as well as normal working.

131 The temperature in the working chamber should, so far as is reasonably practicable, be maintained at a comfortable level for the work to be done. The compressed air environment increases the normal effects of cold and heat by allowing greater heat loss from the body in cold conditions but reducing heat dissipation by sweating when warm. Being cold can increase the risk of decompression illness and in hot conditions there is a real risk of heat stress developing. It is difficult to specify a range of air temperatures which need to be maintained. It is important, therefore, to ascertain workers’ subjective opinions of the thermal environment by direct questioning. In cold and wet conditions, opportunities to stop work and to warm up, possibly including the provision of hot food and drink, need to be considered. If heat stress is a possibility, extra rest breaks and the provision of cool refreshments may help. In some cases cooling of the air supplied to the chamber may need to be introduced. It is recommended that the wet bulb temperature in a working chamber should not be allowed to exceed 27 °C and that the temperature of the air supplied should, wherever possible, not exceed 21 °C. (See regulation 18 for further information.)

**Airlocks - general requirements**

132 Airlock doors will normally open towards the side of higher pressure so that they are held shut by the action on the door of the air pressure.

133 An airtight seal between the airlock door and the door frame needs to be achieved by the provision of a compressible gasket between the door and door frame. This gasket should be regularly inspected and maintained in a serviceable condition.

134 All airlocks need to be fitted with an observation window at least 75 mm in diameter so that the lock attendant can observe the interior of the lock.
All airlocks need to be lit so that the level of illumination is sufficient to allow observation of those inside the airlock.

**Manlocks - general requirements**

Manlocks need to be situated as high above the tunnel invert as possible. If the tunnel gradient and diameter permit, partial bulkheads or curtains need, where appropriate, to be constructed across the upper part of the tunnel cross-section to form air pockets in which workers may seek refuge in the event of flooding of the tunnel.

When tunnelling under an area of surface water, the inner door of a tunnel boring machine manlock needs to be capable of being latched shut to prevent air loss in the event of a blow-out in the tunnel face. Alternatively, a second door hinged on the inside of the lock can be provided. Any locking device on the manlock door will need to be operable from either side of the door. Manlock doors need to be large enough to allow the passage of a casualty on a stretcher and never less than 600 mm minimum cross-sectional dimension.

All manlocks need to meet the general requirements for airlocks. Where appropriate they need to be protected from the extremes of weather by a fire-resistant structure.

In addition, a pressure gauge indicating the pressure in the manlock and a clock capable of being read to the nearest five seconds and in working order need to be visible to people in the manlock. A copy of the decompression tables should be available inside the manlock.

Electricity cables passing through manlocks into the working chamber need to be ducted through the manlock in fire-resistant ducts.

In situations where the people in the manlock cannot be directly observed by the lock attendant, an indirect means of enabling the attendant to observe these people will be necessary, for example, closed circuit television.

The number of people who can be accommodated in a manlock under normal circumstances needs to be clearly marked on it.

In an emergency, any manlock needs to be sufficiently large to accommodate all the people likely to be in the working chamber at any time.

**Requirements for oxygen decompression**

Manlocks should not contain any electrical equipment including any motor, switchgear or transformer other than any electrical equipment essential for the safe operation of the manlock itself. Such equipment should normally be operated from extra low voltage supplies.

Likewise, manlocks should not contain any hydraulic oil tank, pump or motor or other hydraulic equipment or pipework.
In selecting materials for the manlock, particular attention should be paid to minimising the quantity of flammable material. Manlocks should be kept thoroughly clean at all times and free of any mineral oil or grease. In general, all materials, fixtures and fittings in the lock should be chosen to be of as low flammability as is reasonably practicable and to minimise the risk of static electrical discharge.

The interior of the manlock should be painted with a low flame spread paint.

All manlock fixtures and fittings including any electrical equipment should be capable of being thoroughly washed down by a pressure washer without being adversely affected. Where appropriate, there should be a drain in the invert of the manlock to assist in the removal of excess water.

Manlock doors should be thoroughly cleaned of mineral oil and grease and only where absolutely necessary should an appropriate oxygen compatible lubricant be applied to the manlock door hinges.

**Horizontal locks**

In determining the size of manlocks, it is recommended that all horizontal manlocks need to be at least 1.5 metres internal diameter if circular or 1.35 metres minimum cross-sectional dimension if non-circular and have a minimum volume of 3.0 m$^3$ with space for two people sitting and one lying on a stretcher. For lock capacities above three people, the volume needs to be increased by at least 1.0 m$^3$ per person. A manlock consisting of two compartments in series may have an entrance compartment with a minimum volume of 2.0 m$^3$. Alternatively, the requirements of BS EN 12110 apply.

Oxygen and carbon dioxide monitoring devices should be fitted in the manlock and should be capable of providing a digital readout and alarm at the lock attendant’s control station.

The manlock should be fitted with equipment to monitor the partial pressure of carbon dioxide in the manlock. The equipment should alarm when the partial pressure of carbon dioxide exceeds 5 millibars. (Partial pressure of a gas in a mixture is the absolute pressure x volume proportion of the mixture accounted for by that gas, e.g. assume air = 80% nitrogen + 20% oxygen at atmospheric pressure, then partial pressure oxygen = 1 x 0.2 = 0.2 bar.)

The oxygen monitoring equipment should be of a type suitable for operation in a hyperbaric chamber. It should be pressure compensated to at least 3.5 bar and should be capable of determining the volume concentration of oxygen, between 0 and at least 25% oxygen, to an accuracy of +/- 1.0%. The response time of the system should be less than one minute. Further information can be obtained in report FM/00/03 *Hyperbaric tests on atmospheric oxygen and oxides of nitrogen monitors* available from the HSE website. The calibration of monitoring equipment should be checked monthly or at such lesser intervals as the instrument manufacturer specifies. The upper and lower alarm levels for oxygen concentration in the manlock should be set at 23% and 19% respectively. In addition, there should be a bleed pipe from the manlock to a sampling point at the lock attendant’s station.
Manlocks should contain seating for people being decompressed from pressures over 1.0 bar. Seat dimensions should comply with the current version of BS EN 12110. Back support is necessary to maintain a gap between the person sitting and the surface of the manlock wall. The layout of the manlock seating should allow each person being decompressed to sit with legs relaxed.

**Combined locks**

Combined locks may be used for the compression and decompression of people where it is not reasonably practicable to have separate manlocks and materials locks. People and materials may occupy a combined lock simultaneously for compression only, provided free movement of people is not restricted. When it is to be used for oxygen decompression, all materials should be taken out from the lock prior to decompression starting and any spills or surface contamination by oil or grease removed. Combined locks need to meet all the requirements for manlocks.

**Vertical locks**

Vertical locks may be used for compression of people to all permissible pressures but should only be used for the decompression of people from pressures of less than 0.7 bar because the comparatively restricted space in a vertical lock would necessitate standing for too long in the event of decompression from pressures of 0.7 bar or over.

Vertical manlocks need to have a volume of not less than 0.75 m³ and a floor area of 0.4 m² per person.

Where practical, all lock doors of a vertical lock need to be hinged to open in the direction of higher pressure. Where this is not possible, e.g. on a materials lock, both doors need to be fitted with a pressure activated mechanical interlock to prevent the outer door from being opened when the lock is pressurised or the inner door is open.

**Airdecks**

The structural design of an airdeck needs to take account of live and dead loading on the airdeck with and without air pressure in the working chamber.

When an airdeck is not built into a shaft but is set on top of it, the combined weight of the airdeck, airlock and kentledge needs to exceed the upthrust on the airdeck from compressed air at the maximum working pressure by 20%. When an airdeck is built into a shaft, skin friction between the shaft and the ground should be ignored when calculating the ballast requirement. If the weight of the shaft lining is included as part of the balancing weight, the connection of the airdeck to its support in the shaft needs to be designed for a safe working load of at least 1.5 times the weight of the shaft lining.
Valves, controls and gauges – compressed air supply

161 Valves for controlling the flow of air into or out of a manlock are required to enable the lock attendant to control the flow with sufficient accuracy so that the compression/decompression rules can be adhered to.

162 Lock attendants need to be able to simultaneously supply air to and exhaust air from a manlock so that the lock can be ventilated without varying the pressure of air in it. The use of a single 3-way valve to control both supply and exhaust airflow does not permit this.

163 Servo-operated valves should only be used if they can be manually operated in the event of a failure of the servo-mechanism. They need to be of a type, which in the event of failure, fail to the closed position.

164 The layout of pipework and valves in a manlock needs to be such that, in an emergency, pressure can be reduced from within by the occupants.

165 The valves, controls and gauges which allow lock attendants to operate and monitor the airlock(s) under their control need to be situated at the lock attendants’ stations, which need to be situated in free air as close as possible to the airlock(s) under their control.

166 The layout of valves, controls and gauges needs to take account of good ergonomic principles. In addition, lock attendants need to be able to observe easily from the valve operating position the interior of the locks under their control. All valves, controls and gauges need to be clearly marked with their function and direction of operation.

167 Gauges used by lock attendants or medical lock attendants in controlling the decompression of people need to be calibrated before work in compressed air begins and at intervals of not more than six months thereafter. It is recommended that the certificate of calibration be maintained on site.

168 Analogue gauges should comply with the requirements for industrial gauges in BS EN 837-1:1998 or equivalent and have an indicating scale of not less than 150 mm diameter, and, if possible, the full scale deflection needs to be such that at normal working pressure the gauge is operating in the upper half of its range. Digital gauges can be used and should have an accuracy equal to or better than an equivalent analogue gauge. It is recommended that digital gauges have a display on which the digits are at least 15 mm high.

169 Pressure gauges complying with BS EN 837-1:1998 are manufactured to be accurate within a tolerance of 1% over most of their working range. Two gauges attached to a single chamber may, therefore, not always register exactly the same pressure. Frequently, decompression is controlled using an analogue or digital gauge at the lock attendant's station, but it is the recording pressure gauge trace which is kept in the compressed air contractor’s records. It is important, therefore, for the lock attendant to check frequently that both gauges give consistently similar readings over their full working range. Where the readings differ by more than 0.05
bar, the gauges need to be recalibrated or replaced as required. One gauge, known to be accurate, should consistently be used as the reference gauge to control all compressions and decompressions. A test gauge complying with the requirements of BS EN 837-1:1998 may usefully be provided in the compressor attendant’s station on site to facilitate calibration checks.

170 When the pressure in the working chamber is 0.7 bar or more, suitable recording pressure gauges need to be located at lock attendants’ stations for each compartment of the manlock under their control. To be suitable, recording gauges will need to produce a paper record and operate at a rate of not less than one revolution every four hours for circular charts and not less than 120 mm per hour for linear charts. Maximum accuracy in reading circular charts can be achieved with a ‘perimeter zero’ design.

171 Suitable recording pressure gauge charts are those which cover a pressure range of 0.0 to 4.5 bar, are calibrated in 0.1 bar increments and are capable of being read to 0.05 bar.

172 Recording pressure gauges need to be checked for calibration upon installation and at 6-monthly intervals thereafter. It is recommended that certificates of calibration be available on site.

173 Electronic data capture and storage techniques can be used in place of paper records provided that at least the equivalent amount of information is recorded.

**Pipework and fittings – gas supply**

174 Gas delivery systems should only be designed and installed under the supervision of a competent person.

175 Where gas is supplied from the surface the supply should be through rigid pipework properly supported from the tunnel lining. Flexible hose may only be used where vibration or movement, which would be detrimental to rigid pipework, has to be accommodated. The pipework should be located and protected as necessary, to minimise the risk of mechanical damage.

176 Where gas is supplied from a portable supply in the tunnel, the use of long flexible hoses should be minimised. On a tunnel boring machine the supply should be by means of rigid pipework fixed to the gantries where possible. Flexible hose should be used to span all joints between gantries to accommodate movement and vibration.

177 Rigid pipework should normally be of a cupro-nickel alloy or seamless drawn copper tube of suitable pressure rating. Fittings should be of a suitable pressure rating and made from an oxygen compatible material such as brass, copper, cupro-nickel alloy, austenitic stainless steel, tungam or gunmetal. Joints may be welded, brazed or utilise compression fittings. Carbon steel tubing or fittings should not be used where a fitting in a preferred metal is available. Low pressure rigid pipework may be of copper to BS EN 1057.
178 All flexible hoses carrying oxygen should be externally stainless steel braided. Hoses for pressures above 10 bar should be fitted with heat sink and restraining cable. They should be lined with a material compatible with the gas they contain, and which does not give off any harmful gas when in service. Hoses carrying helium should be fit for purpose.

179 All valves and gauges should be oxygen compatible. Gauges should comply with BS EN 562 and be 63 mm diameter or more. Valves should be needle or gate slow acting valves. Ball valves should only be used for pressures of 10 bar or less and where appropriate.

180 Regulators should be fit for oxygen service and meet the ignition test criteria in BS EN ISO 7291:2001. They should have appropriate flow/pressure characteristics for the duty intended.

181 A flow-limiting device should be incorporated in the rigid supply line to cut off the supply in the event of rupture of the line.

182 Exhaust pipework should be of a material that is compatible with oxygen at exhaust discharge pressure.

183 PTFE tape should be to BS 7786. It should be used sparingly and in a manner which ensures that ‘tails’ of tape cannot enter the gas flow.

184 All oxygen pipework should be clearly marked at regular intervals with the legend ‘High pressure oxygen’ or for low pressure supply ‘oxygen’ as appropriate. The direction of flow should also be indicated. Pipework for the supply of breathing mixtures should also be appropriately marked with the contents.

185 At the lock attendant's station, there should be a shut-off valve to allow the lock attendant to control the flow of oxygen to the lock. There should be pressure gauges indicating to the lock attendant the pressure in both the high pressure supply and in the low pressure supply to the manlock. There should be similar valves and gauges at the lock attendant's station for the breathing mixture supply to the working chamber.

186 Between the lock attendant's station and the manlock, there should be a quarter turn emergency shut-off valve that must only be operated in an emergency. There should be a similar emergency shut-off valve inside any compartment of the manlock to which oxygen is supplied. All emergency shut-off valves should be clearly marked to this effect. There should be similar valves for shutting off the breathing mixture supply.

187 It should be possible to release gas pressure from any section of pipework before disconnections are made by venting it to atmosphere.

188 The use of flexible pipework should be minimised so far as is reasonably practicable. Irrespective of working pressure, all flexible pipework in the lock should be externally stainless steel braided.
189 The built in breathing system in the manlock should have individual control units for each mask or a separate supply and discharge manifold to which a number of masks are connected. Connection should be by means of a self-sealing connector. The supply of breathing mixture in the working chamber should be similarly achieved. In all cases, the supply and discharge connections should be clearly distinguishable and non-interchangeable however, a common discharge manifold may be used.

190 All lubrication should be kept to a minimum and only oxygen compatible lubricants should be used. Under no circumstances should any mineral oil or grease be used.

Oxygen cleanliness

191 All gas pipework, hoses, valves, regulators, gauges etc should be oxygen cleaned before use to BS IEC 60877:1999 or equivalent. In the event of any suspected ingress of dirt or foreign bodies to the gas system, it should again be oxygen cleaned as a precaution, or replaced. Foreign bodies include oil, grease or other organic material, metallic particles or grit. All connections should be blown out before being made.

192 When not in use, all open-ended pipes in the gas supply system should be capped and bagged or otherwise secured to prevent the ingress of dirt.

Lock attendant’s station

193 Where appropriate, lock attendants’ stations need to be protected from extremes of weather by fire-resistant shelters.

194 There should be a clock in working order at lock attendants’ stations capable of being read to the nearest five seconds.

195 Lock attendants need a pressure gauge indicating the pressure in each compartment of the lock(s) under their control and in the working chambers to which these locks give access.

Emergency lighting

196 Arrangements should be made for emergency lighting in case the normal tunnel lighting system fails. Depending on the circumstances, a backup power supply from a different source or surface standby generator, independent battery-powered lights of at least one hour’s duration, personal cap lamps, hand lamps or air lamps could be provided. A failure of the main power supply, or fire affecting it, should not adversely affect the emergency supply.

197 Equipment kept for emergency use needs to be well maintained to ensure it is always usable taking into account the adverse conditions to which it is likely to be exposed.
Communications systems

198 At least one system of voice communications needs to be provided linking: the office of the person in charge; the compressor attendant’s station; the top of any shaft giving access to an airlock; each lock attendant’s station; each compartment of a manlock; the working chamber adjacent to each manlock; the gas storage area on the surface; the location at which gas cylinders are attached to the fixed pipework on the tunnel boring machine and, at intervals not exceeding 500 metres from the manlock, each face being worked; the medical lock attendant’s station; and the medical lock.

199 The compressor attendant and the lock attendant should be able to communicate effectively throughout the time the compressor attendant may be required to assist with gas supply procedures.

200 A telephone connected to the public telephone network should be available in the office of the person in charge and the medical lock attendant’s station. These telephones need to be available whenever people are working in compressed air or are in the medical lock. Cellular phones may be used but their reliable operation from the site location needs to be confirmed.

201 In general, voice communications equipment needs to be robust and reliable. A ‘fire hardened’ system may be required to maintain communication with a manlock on a tunnel boring machine.

202 In addition, there needs to be a means of non-verbal communication, such as a tapping system using a metal object being struck against the bulkhead door and based on a pre-arranged code of signals, between lock attendants and people in manlocks under their control.

Masks

203 Oxygen breathing should be by means of a built in breathing system (BIBS). Oxygen should normally be administered through demand masks which should be of a full face type. Hoods with flexible neck seal may be used at the discretion of the contract medical adviser and person in charge. In either case, the mask or hood should be of a good fit. They should be made from materials that are fully compatible with pure oxygen. Performance including breathing resistance should conform to diving industry standards.

204 Breathing mixture should be supplied through line fed masks. Full face masks are to be preferred to minimise leakage both inwards and outwards.

205 Only closed circuit masks should be used and when in use should be connected to both the supply and discharge pipework.

206 Masks should be regularly inspected and maintained in accordance with the manufacturer’s instructions.
207 Masks should be cleaned using warm soapy water and disinfected in accordance with the manufacturer’s instructions after each use.

208 Masks which become contaminated with oil or grease, including cosmetics, should be deep cleaned using an ultrasonic bath.

209 Maintenance records should be kept for each mask.

210 Masks should be bagged or otherwise protected when not in use.

**Exhaust gas discharge**

211 All manlocks in which oxygen breathing is carried out should be fitted with an overboard dump system.

212 Exhaled oxygen should be dumped directly to free air on the surface outside the tunnel or into the tunnel ventilation system.

213 The point of discharge should be clearly marked and appropriately signed. It should be remote from the intake to any compressors and protected from adverse weather. It should be high enough above ground level to be safe from tampering.

214 The air flow in the tunnel ventilation system should be at least 100 times greater than the rate of discharge of oxygen to it. As exhaust air from the manlock can be oxygen rich, it should be dumped to the same system.

215 Exhaled breathing mixture should similarly be discharged outside the working chamber either to an overboard dump as above or to a gas reclaim system.

216 Where the flow in the tunnel ventilation system is insufficient to meet the above requirements, the exhaled oxygen or breathing mixture should be discharged into an exhaust ventilation system which extracts to the surface. Alternatively, exhaled breathing mixture may be collected in a gas reclaim system.

217 In the event of the tunnel ventilation system or any exhaust ventilation system into which exhaled gas is discharged not operating, no further routine entry into compressed air should take place. Oxygen decompression or the use of breathing mixture should be suspended and decompression should continue in accordance with emergency decompression procedures using air. Those in the working chamber should return to the manlock for decompression.

218 The manlock should be flushed through with air after every oxygen decompression.

**Atmospheric monitoring and ventilation**

219 Additional atmospheric monitoring will be required in the tunnel to detect any increase in oxygen concentration. The system should utilise fixed detector heads. Instrumentation for monitoring oxygen concentration at atmospheric pressure should comply with BS EN 50104:2002. There should be a digital readout, from the detectors in the tunnel, on the surface and at the lock attendant’s station. Where the
airlock or working chamber is an integral part of a tunnel boring machine, the display should also be at the tunnel boring machine operator's control panel for detector heads on the tunnel boring machine. Alarms should be set at an oxygen concentration of 23% by volume. The alarm should be both audible and visible and should indicate in the tunnel and on the surface. The atmospheric monitoring system should be intrinsically safe.

220 Detector heads should be located at regular intervals along the tunnel, in the vicinity of any gas cylinders on the tunnel boring machine and close to the point of any discharge from the overboard dump into the tunnel ventilation system.

221 Any increase in oxygen concentration in the general body of air in the tunnel, above that in natural air, should be investigated.

222 The tunnel ventilation system should be capable of maintaining a minimum air supply in the vicinity of the airlock and any gas cylinders in the tunnel, of 100 m$^3$ per minute.

223 Fans should be mounted adjacent to where gas cylinders are located on the tunnel boring machine, which should be capable of creating turbulence in the atmosphere to limit oxygen concentration increase in the event of a leak. The fans should be capable of being operated manually or automatically when the atmospheric monitoring system detects an increase in oxygen concentration in the vicinity of the cylinders above 23% by volume. The direction of flow of air from the fans should be towards the pit bottom and away from any electrical or hydraulic equipment on the tunnel boring machine. The fans should provide a total airflow of at least 100 m$^3$ per minute.

**Electrical requirements**

224 There should be no electrical equipment in a manlock except what is required for the safe operation of the manlock itself. Such equipment should normally be powered from an extra low voltage system but should not exceed 60 v to earth.

225 All electrical equipment for use in the manlock should be capable of operating safely in an oxygen enriched atmosphere and under fluctuating atmospheric pressure up to the working pressure of the manlock.

226 Electrical equipment in the manlock should be to a high level of ingress protection to prevent water ingress during cleaning of the manlock. Below chamber axis level it should be protected to level IP67 so that it is not adversely affected by washing the chamber, above axis level electrical equipment should be to at least level IP65.

227 Although oxygen is not a potentially explosive gas, elevated levels of oxygen reduce the ignition energy required to ignite other materials. Consequently, all electrical equipment in the manlock should be explosion protected as this gives a high degree of mechanical protection to the equipment and reduces the risk of sparks or hot particles being ejected.
228 All electrical equipment should be suitable for use in Zone 1 hazardous areas with gas group 2b as defined in BS EN 60079-14 or an equivalent standard.

229 All manlocks operating at pressures in excess of 1.0 bar need to be provided with a non-radiant form of heating, where necessary, to prevent chilling of those undergoing decompression. Heating can be by a hot water system fed from outside the manlock or by explosion-protected fixed heaters with thermostatic control, in the manlock. Radiant or open convection heaters should not be used. Electric heaters should be fully enclosed and be appropriately guarded. Guard surface temperature should not exceed 100°C. Heaters should be mounted in a position to avoid the accumulation of debris where possible and the excessive build up of heat beneath seating. There should be a switch for isolating power to the heater located outside the manlock.

230 Lighting of the manlock should preferably be from outside. Where adequate levels of lighting in the manlock cannot be achieved from outside, light fittings may be provided in the manlock. Switches for lighting circuits should be located outside the manlock. 'Cold' LED lighting should be considered.

231 Electric cables in the manlock should be selected to give maximum mechanical protection and should be sheathed in an LSF/LSOH material. Glanding should be appropriate to the protection classification of the equipment and the cabling used.

232 All electrical circuits in the manlock should be earthed and protected by suitable miniature circuit breakers and a 30 mA residual current device where appropriate.

233 Communications equipment in the manlock should be chosen for good speech quality and should preferably be explosion protected to standard E Ex ib 'intrinsic safety' or specifically manufactured for use in hyperbaric chambers. It should operate from an extra low voltage supply.

234 Electrical installation work on the manlock should be supervised and carried out by those with experience of explosion protected electrical installations.

Other plant and equipment

235 Plant and equipment not associated with the compressed air installation, but which will be used in compressed air as part of the tunnelling operation, should be capable of withstanding the maximum air pressure envisaged and also any reversal of load resulting from decompression.

Regulation 9 Appointment of contract medical adviser

Regulation

(1) The compressed air contractor shall appoint a contract medical adviser to give advice to him on all aspects of health relevant to the work in compressed air undertaken.
(2) Nothing in paragraph (1) shall prevent the appointment of an appointed doctor to be the contract medical adviser.

Guidance

236 The hyperbaric environment is one in which there is potential for serious harm to health arising from the effects of pressure or from contaminants in that environment. Construction work also poses hazards to health which can result, for example, in dermatitis, noise-induced hearing loss, low back pain or vibration white finger. The hyperbaric environment can exacerbate or in some other way change the response to exposure to construction-related occupational health hazards. Prevention requires a high standard of occupational health practice and it is for this reason that the compressed air contractor is required to appoint a contract medical adviser.

Contract medical adviser

237 The contract medical adviser is responsible to the compressed air contractor for advising on all aspects of occupational health relating to the work in compressed air. In addition, the contract medical adviser should liaise with the person in charge, the hyperbaric supervisor and the hyperbaric plant supervisor to provide professional occupational health input to the organisation of the work in compressed air, the development and implementation of the management plan and the health and safety plan, and the planning and implementation of emergency procedures. Also, the contract medical adviser should advise the compressed air contractor on:

(a) compression and decompression procedures;
(b) exposure periods and multiple exposure;
(c) familiarisation procedures;
(d) hyperbaric treatment facilities and procedures;
(e) incidence of decompression illness;
(f) emergency procedures covering hyperbaric emergencies and emergencies in the compressed air environment;
(g) first aid and welfare;
(h) the provision of information, instruction and training;
(i) maintenance of records;
(j) general occupational health topics in the context of hyperbaric exposure.

238 The term ‘medical surveillance’ refers to the assessment of fitness for work in compressed air required by regulation 10. This is the responsibility of an appointed doctor. ‘Health surveillance’ is used to refer to all other activities related to the
identification of occupational diseases and is the responsibility of the contract medical adviser.

239 The contract medical adviser is also responsible for the professional control and supervision of all medical services on site, and for professional liaison with off-site medical services including notified hospitals and the ambulance service. The contract medical adviser will oversee the work of the hyperbaric supervisor and medical lock attendants and also be responsible for supervising the treatment of all acute cases of decompression illness arising from the contract. The contract medical adviser is responsible for determining the treatment regimes to be used for the treatment of decompression illness and is also responsible for ensuring that all cases of decompression illness are medically examined as soon as practicable after they are notified to the site. The contract medical adviser must be able to provide the compressed air contractor with advice on current best practice in the identification of risk to the health of those being exposed to compressed air and in the prevention of decompression illness.

240 The contract medical adviser should supervise the collation of records of both normal and therapeutic compressions and decompressions, including manlock registers and recording pressure gauge records; prepare end-of-contract summaries and liaise with the compressed air contractor regarding the preservation of original records for a period of 40 years. The contract medical adviser should ensure that written diagnoses of all cases of hyperbaric illness which are reportable to HSE are provided to the relevant employers.

241 The contract medical adviser needs to consider what other physical, chemical or biological hazards may exist for those involved in the contract and provide appropriate advice to the contractor regarding the prevention of ill health from these causes. The contract medical adviser can also act as a focus for liaison between the site and the Employment Medical Advisory Service of HSE.

242 Work in compressed air may continue on a 24-hour basis using several shifts. The contract medical advisor must ensure that they, or a competent deputy, are available for consultation at all times when work is done under pressure and in the 24-hour period following its cessation.

243 All people who work in compressed air are required to be subject to medical surveillance (see regulation 10) provided by an appointed doctor or employment medical adviser. It is not intended that there should be a duplication of medical practitioners involved in providing services on any one contract. The particular designations indicate differing roles and responsibilities and it will usually be the case that the duties of the contract medical adviser and the appointed doctor will be carried out by the same individual.

244 Statutory medical surveillance, as required by regulation 10, should usually be undertaken by doctors appointed by HSE as described in regulation 10, but alternatively can be done by the medical staff of HSE (employment medical advisers). The formal appointment allows HSE to set standards and monitor performance and quality as well as to collect statistics. An appointed doctor has a contractual responsibility to the employer of the person who is examined but also
has responsibilities to HSE. See Appendix 19 for information on the appointment process.

245 The role of the contract medical adviser differs from that of the appointed doctor in that the contract medical adviser is responsible to the compressed air contractor for advising on all aspects of occupational health relating to the work in compressed air and as such has a remit which is wider than medical surveillance. Although it is open to employers to propose any suitably qualified doctor for appointment to undertake the medical surveillance of their employees, it is strongly recommended that, to provide medical continuity, the contract medical adviser should normally always be selected for this role, resulting in one practitioner having both responsibilities. A contract medical adviser should be an appointed doctor (see paragraph 261 and 262) but in addition, would be expected to have practical experience of work in compressed air and of occupational health in the construction industry.

246 In most cases, one doctor will act both as the contract medical adviser on behalf of the compressed air contractor and the appointed doctor on behalf of the employers represented on a contract. A possible exception is for an employer whose geographical base is distant from the site of the work and who may involve a local appointed doctor to make pre-exposure examinations. Where more than one appointed doctor is involved in a contract, the contract medical adviser will need to co-ordinate their activities.

247 The contract medical adviser should actively monitor the incidence of decompression illness during the course of a contract and should review the risk of decompression illness along with the adequacy of preventive measures to decide whether the incidence is being kept as low as might reasonably be achieved and advise the compressed air contractor accordingly. If there is any doubt that the incidence is not being kept as low as might reasonably be achieved, the contract medical adviser should make recommendations to the compressed air contractor and review the situation again. Active monitoring of the health of workers in this way will be one of the main responsibilities of the contract medical adviser (see Appendix 4). Small numbers of exposures do not allow traditional statistical analysis to be undertaken (see Appendix 9 paragraph 22), so alternative techniques for assessing the effectiveness of decompression, such as physiological monitoring of individuals post decompression, should be adopted. Individual cases of decompression illness need to be evaluated for predisposing factors. Additional and less formal means of monitoring the health of the workforce such as anonymous reporting of symptoms can also be considered.

248 The contract medical adviser has clinical responsibility for all treatments for decompression illness. Using the terminology of the Code of good working practice for the operation and staffing of hyperbaric chambers for therapeutic purposes published by the Faculty of Occupational Medicine, the contract medical adviser will act as the medical director of the facilities and may also double as the hyperbaric duty doctor. The contract medical adviser or a competent deputy needs to be available during all periods when treatments may be needed. The initial treatment of decompression illness is recompression and this should not be delayed. It is important that cases are adequately assessed as soon as possible after initial
presentation. Treatment will normally be initiated after an assessment by the medical lock attendant and discussion with the contract medical adviser. It is recommended that the contract medical adviser is familiar with the workplace and aware of the work being undertaken. The contract medical adviser should have a deputy if the site is geographically remote or for when the contract medical adviser is unavailable. Similar consideration should be given to the deputy being an appointed doctor as for the contract medical adviser.

249 Contract medical advisers act as professional advisers to the hyperbaric supervisor and their medical lock attendants. In this capacity, they should maintain an overview of the collation and maintenance of exposure records and the completion of the compressed air worker's health and exposure record. The contract medical adviser should liaise with the appointed doctor when both roles are not being undertaken by the same person.

250 Contract medical advisers need to advise compressed air contractors about the risks which might arise from other health hazards arising from the work activity and about any health surveillance which may be necessary for those exposed to these hazards. They should also advise the compressed air contractor on how to deal with accidental injury or non-occupational ill health occurring in the workings. Contract medical advisers will need to have a broad understanding of occupational health hazards and this will usually be demonstrated by the possession of a formal qualification in occupational medicine equivalent to specialist GMC registration such as membership of the Faculty of Occupational Medicine. Contract medical advisers will require the knowledge of hyperbaric medicine and casualty handling techniques necessary to undertake the duties described in Appendix 4. In practice, experience of the health care of compressed air workers is limited to a small number of practitioners. Those who come new to the field may wish to make arrangements to consult an experienced practitioner on an occasional basis.

251 Where the contract medical adviser is not the sole occupational health professional involved in the project, e.g. general occupational health surveillance of the workforce is undertaken by others, the contract medical adviser shall have primacy in all matters relating to occupational health in compressed air. It is a responsibility of the compressed air contractor to ensure that the contract medical adviser has access to all the relevant health records in order to discharge his responsibilities towards people exposed to compressed air. The contract medical adviser is expected to liaise, where relevant, with the other occupational health professionals over general occupational health issues arising from the work in compressed air.

**Regulation 10 Medical surveillance**

(1) Every employer shall ensure that each of his employees who works in compressed air is under adequate medical surveillance by an appointed doctor or employment medical adviser; and where an employee is to be assigned to work in compressed air, the medical surveillance shall be commenced before he is so assigned.
(2) The medical surveillance required by paragraph (1) shall include examinations at such suitable intervals as the appointed doctor or employment medical adviser may require having regard to the pressure to which the employee has been or will be subjected in the course of work in compressed air and, in any event, at intervals of not more than 12 months.

(3) The employer shall ensure that -

(a) a health record, containing particulars approved by the Executive, is made and maintained in respect of each of his employees who is engaged in work in compressed air; and

(b) the record or a copy thereof is kept in a suitable form for at least 40 years from the date of the last entry made in it; and

(c) as soon as is reasonably practicable after an employee of his has ceased to work on any project, a copy of the relevant part or parts of the record made under sub-paragraph (a) of this regulation is provided to that employee.

(4) Where an appointed doctor or employment medical adviser has certified in the health record of any employee that, in the professional opinion of the appointed doctor or employment medical adviser, the employee should not be engaged in work in compressed air or that he should only be so engaged under conditions specified in the record, the employer shall not permit the employee to be engaged in work in compressed air except in accordance with the conditions, if any, specified in the health record unless that entry has been cancelled by an appointed doctor or employment medical adviser.

(5) Where an employee is subject to medical surveillance in accordance with paragraph (1) and an appointed doctor or employment medical adviser has certified by an entry in his health record that medical surveillance should be continued after his work in compressed air has ceased, the employer shall ensure that the medical surveillance of that employee is continued in accordance with that entry while he is employed by the employer unless that entry has been cancelled by an appointed doctor or employment medical adviser.

(6) Every employee who is or who has been engaged in or who is to be assigned to work in compressed air shall -

(a) when required by his employer and at the cost of his employer, present himself during his working hours (or such other time as may be agreed by that employee) for such medical surveillance procedures as may be required for the purposes of this regulation; and

(b) furnish the appointed doctor or employment medical adviser with such information concerning his health as the appointed doctor or employment medical adviser may reasonably require.
Guidance

252 One of the measures which limits the risk to health is the proper medical surveillance of workers who are, or who will be, exposed to compressed air. Medical surveillance is intended to limit risks to health by ensuring that only individuals who are considered fit to work in compressed air do so. Only people whose presence is essential should enter compressed air workings. This need can be challenged at the time of medical surveillance to discourage casual visitors from entering pressurised workings.

Health risks

253 At pressures below 0.7 bar, work in compressed air is comparatively free from harm. Decompression illness is extremely rare and bone necrosis (osteonecrosis) is not thought to occur, although barotrauma can arise from compression to even low pressures. The risks to health increase as the working pressure increases, so that at higher pressures decompression illness and osteonecrosis are the potentially serious complications.

254 Barotrauma can arise in any air-containing cavity in the body which is in direct connection with the surrounding atmosphere, principally the ears, sinuses and lungs. Failure to equalise pressure across a bodily structure can result in physical damage to that structure; for example, a burst eardrum could arise from a too rapid compression, particularly in the presence of an infection of the nose, throat or chest. Medical surveillance, reporting of temporary unfitness (see regulation 16) and adherence to the correct compression procedures all have a role to play in preventing this form of harm.

255 Acute decompression illness is a disease which occurs during or within the 24 hours following the decompression process. Research has shown that in tunnelling it predominantly occurs as ‘pain only’ decompression sickness (formerly known as Type 1 or by descriptive terms such as ‘bends’ or ‘niggles’). It usually involves pain around the joints, or in a small minority of cases, as serious decompression sickness (formerly known as Type 2 decompression sickness or descriptive terms such as ‘chokes’ or ‘staggers’). This is potentially a life threatening condition which may affect the central nervous system, including the vestibular system in the ear (which is responsible for balance), the heart or the lungs. Medical surveillance can help identify individuals who may be at greater than normal risk of decompression illness.

256 Those who work in compressed air at pressures of 1.0 bar or over, run the risk of developing a chronic condition of the bones known as dysbaric (or aseptic) osteonecrosis. When this occurs part of the normal bone structure is replaced by new, weaker bone. Most bone necrosis is situated in parts of the long bones where it is symptomless and causes no disability. Less commonly, the site of bone damage is close to a joint surface in the shoulder or hip where there is a danger that the joint surface will collapse (juxta-articular lesions) as a result of wear and tear. This creates a painful joint with only limited movement for which surgical joint replacement is the only treatment. Medical surveillance for those who will work at pressures of 1.0 bar or over includes screening of the long bones to identify any pre-existing disease or development of new lesions (see Appendix 7).
Decompression illness, barotrauma and osteonecrosis are all conditions which are reportable under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (see Appendix 4).

Dysbarism is a prescribed industrial disease (A3) for which statutory compensation may be paid. In this context, dysbarism includes decompression illness, barotrauma and osteonecrosis.

General duty on employers to make arrangements for medical surveillance

All employers whose employees will work in compressed air have a duty to ensure that all employees who work in compressed air are under adequate medical surveillance. Surveillance will, in all cases, include a pre-exposure medical examination. Thereafter, a full medical examination is required to be repeated at least once in every period of 12 months during which a person is employed to work in compressed air.

Medical surveillance will not be considered adequate unless further assessments are also made:

- at a frequency related to the working pressure (see paragraph 268); following illness or incapacity causing an inability to work for three or more days; or

- following any episode of ill health related to work in compressed air.

Medical surveillance of compressed air workers has to be undertaken by appointed doctors (or employment medical advisers), see paragraph 263. The statutory function of the appointed doctor in a compressed air contract is limited to the certification of continuing medical fitness. Employers normally seek to have the contract medical adviser appointed to undertake medical surveillance of their staff to ensure continuity between the roles of health surveillance and the provision of treatment. The procedure to be followed to have a doctor appointed under these Regulations is set out at Appendix 19.

A doctor who wishes to become an appointed doctor to carry out medical surveillance of compressed air workers needs to be competent in occupational medicine and also to have specialist knowledge of hyperbaric medicine. Possession of a higher qualification such as the Diploma in Occupational Medicine or Membership of the Faculty of Occupational Medicine is likely to be a minimum requirement. Knowledge of hyperbaric medicine can be gained from appropriate courses in diving medicine or from relevant courses specific to compressed air work which may be organised in the future. An outline syllabus for such a training course is given at Appendix 5.

Duties of the appointed doctor

The duties of the appointed doctor comprise:

(a) examination of all people proposed for work in compressed air and certifying medical fitness before each individual is initially exposed to increased
pressure. With the individual’s consent the general practitioner may be informed that examination for work in compressed air has taken place, and of the resulting assessment of fitness;

(b) assessment and certification of continuing fitness of all people at suitable frequency and as advised in this guidance (see paragraphs 260 and 268); and

(c) maintenance of accurate and comprehensive clinical records and ensuring their safe retention for 40 years after the last exposure to compressed air on the contract.

264 Medical examination is the responsibility of the appointed doctor. The contract medical adviser may be the only appointed doctor for a contract in which case, this person should be responsible for the statutory examination of all people who intend to work in compressed air, before and during the course of work, including arrangements for imaging examinations of the joints; deciding on fitness for work following any illness or injury; arranging any special examinations which may be considered advisable; and maintenance of clinical records by the appointed doctor for a minimum period of 40 years after the last known exposure to compressed air of the individual. If more than one appointed doctor is involved in a contract, the contract medical adviser will need to provide information about the nature of the contract and the intended work to the other appointed doctors, and advise the other doctors regarding the fitness standards which will be accepted.

Content of medical examinations


Assessment of continuing fitness for work

266 A thorough annual medical examination and the reporting of minor illnesses which may affect fitness for work will help to ensure that individuals are not at risk of hyperbaric illnesses as a result of underlying medical conditions. However, it is considered advisable that the continuing fitness of individuals for work in compressed air should be monitored by the appointed doctor during the course of a contract.

267 The monitoring needs to comprise a review of the health of the individual based on sickness absence records, compressed air work history and any reported discomfort or ill health arising from exposure to compressed air. The review needs to take place at the compressed air site where detailed records of exposure are available and where information can be obtained from lock attendants, people in charge and individual workers. The review may include an examination of the ears, nose and throat, or other systems, at the discretion of the doctor.

268 Appropriate intervals for such assessments of fitness are: once every three months for work taking place at pressures up to but not including 1.0 bar; and
monthly when pressures are 1.0 bar or over. More frequent assessments may be required at the appointed doctor’s discretion when the work involves arduous physical activity or mixed gas applications.

**Other medical examinations**

269 Examination should also be made of any worker whose continuing fitness for work in compressed air is called into question. No one should be further exposed to compressed air following an episode of decompression illness without having a medical assessment by the appointed doctor.

270 For workers who have been exposed to a pressure of 1.0 bar or over it is good practice to have a repeat of the screening of the long bones up to one year after exposure to compressed air ceases. This is particularly relevant for workers who intend to continue a career working in compressed air or who have experienced episodes of decompression illness during the course of work. Where an appointed doctor considers that it is necessary that the status of the long bones should be checked after exposure to work in compressed air has finished, an entry to this effect can be made in the health record. If the person concerned continues to be with the same employer on the date when the follow-up examination is recommended to take place, the employer can arrange for this to be done by the appointed doctor. The appointed doctor may also, with the worker’s consent, notify the general practitioner of the need for follow-up screening via the National Health Service.

271 It is recommended that the appointed doctor ensures all workers certified fit for work in compressed air are made aware of the special risks of respiratory disorders and that they have received written advice on work in compressed air. Such advice is contained in the *Compressed air worker’s health and exposure record* which is available from HSE Books (see Appendix 14).

**Health record**

272 The results of medical surveillance are required to be recorded in a health record which is maintained by the employer for each worker. The health record will contain personal details of the worker and space to record the date, type and result of each medical assessment. The result may be that a person is fit to work in compressed air, or fit to work subject to certain restrictions or is unfit to work either temporarily or permanently in compressed air. The health record will need to contain information on the items listed at sub-paragraphs (a) to (d) of paragraph 277.

273 The health record is the employer’s statutory record of the results of medical surveillance and will be retained by the employer at the end of a contract for a period of 40 years. The appointed doctor will retain the detailed clinical records. Individual employees should be given a personal health and exposure record which summarises the results of their health surveillance, their hyperbaric experience and also the training which they have received. The health section in the individual health and exposure record will duplicate the employer’s health record. Personal copies of the health record describe part of an individual’s medical history and workers may find it useful to bring the record to the attention of their general practitioner. Under
regulation 10(3)(a) the Health and Safety Executive has approved the particulars to be contained in a health record and can approve future changes.

**Work restrictions specified in the health record**

274 Restrictions which may be placed include those on: the maximum pressure to which a person should be exposed; the maximum duration of exposure per shift; the number of entries to be made per day or date of next assessment. Employers are required to ensure that any such restriction is brought to the attention of the compressed air contractor so that lock attendants can be notified. Any list of those fit to enter compressed air needs to be clearly marked to indicate that a restriction applies to the person concerned, and a note of the nature of the restriction retained.

**Availability of medical records**

275 The findings of an earlier medical examination by another appointed doctor within the immediately preceding four weeks may be accepted as proof of fitness if no restriction has been made. For work at pressures below 1.0 bar this period can be extended to 13 weeks. Where longer periods have elapsed, an examination needs to be made, the content of which will depend on the intended working pressure and the availability of information from the previous medical examination. Appointed doctors will need to co-operate to make the results of previous medical surveillance available to minimise unnecessary examinations. Records should be held on site to facilitate this.

**Maintenance of compressed air worker’s health and exposure record**

276 Employees have a personal responsibility to safeguard their health and exposure record and to present it to their employer so that it can be updated and checks made prior to entry into compressed air. All lists of personnel fit to enter the workings need to be kept up to date.

277 The compressed air worker’s health and exposure record needs to contain the following information:

(a) personal details of the employee;

- name
- national insurance number
- date of birth
- address (permanent)

(b) details of the employer;

- name and address
- contracts at which employee exposed to compressed air
(c) details of appointed doctor;

- name, address and telephone number, and the name and address of the contract medical adviser, if different

(d) details of medical surveillance;

- date, type and result of each assessment, including any restriction imposed on the exposure of the employee

(e) details of exposure;

- date, shift, maximum working pressure and working period for each exposure

(f) details of training;

- date of the instruction and training required by regulation 15

278 The health and exposure record should be retained by the compressed air contractor until work in compressed air is completed or the person leaves employment. During that time it needs to be readily available to the person named on it or his or her employer.

279 At the end of a contract or when workers leave employment, their compressed air worker’s health and exposure records are required to be returned to them updated to include:

(a) name and details of the appointed doctor or employment medical adviser;

(b) details of all medical surveillance;

(c) details of exposures, decompressions and any decompression illness.

280 The compressed air contractor may wish to obtain a signed receipt from the individual acknowledging that this has been done.

**Duty to submit to medical surveillance**

281 As the medical examination has an important role in the prevention of hyperbaric illness, no person can be exposed to compressed air without first having been medically examined. All people who intend to work in compressed air will, therefore, have to submit to medical examination by an appointed doctor (or employment medical adviser) and to co-operate fully, particularly in the provision of information about any relevant medical condition, or past history of illness arising from exposure to compressed air.
Regulation 11 Compression and decompression procedures

(1) The compressed air contractor shall ensure that compression or decompression of any person engaged in work in compressed air is carried out in accordance with any procedures approved by the Executive.

(2) The compressed air contractor shall ensure that no person shall be subjected to a pressure exceeding 3.5 bar except in an unforeseen emergency.

(3) The compressed air contractor shall ensure that no person shall be subjected to the procedure of decanting except in an emergency.

(4) The compressed air contractor shall ensure that an adequate record of exposure is made and maintained in respect of the times and pressures at which work in compressed air is undertaken and that the record or a copy thereof is kept in a suitable form for at least 40 years from the date of the last entry made in it.

(5) The compressed air contractor shall ensure that an individual record of exposure containing the information specified in paragraph (6) is made and maintained in respect of each person who undertakes work in compressed air and that the record or a copy thereof is kept in a suitable form for at least 40 years from the date of the last entry made in it.

(6) The record referred to in paragraph (5) shall contain the date, time of entry, duration and maximum pressure of each exposure and decompression details of each exposure to which the person to whom the record relates is subjected.

(7) The compressed air contractor shall ensure that, as soon as is reasonably practicable after a person has ceased to work on any project -

(a) the employer of that person is provided with a copy of such part or parts of the record made pursuant to paragraph (4) as relate to that person; and

(b) that person is provided with a copy of such part or parts of the record made pursuant to paragraph (5) as relate to him.

(8) An employer who is provided with a copy of a record pursuant to paragraph (7) shall ensure that the record or a copy thereof is kept in a suitable form for at least 40 years from the date of the last entry made in it.

Guidance

282 The procedures for compression and decompression can be considered in three classes: general procedures to be followed during all compressions and decompressions; specific procedures for decompression from a given duration of exposure to a particular pressure; and any site-specific arrangements instituted by the compressed air contractor. The following guidance (paragraphs 283–322) relates
to the general procedures which need to be followed during all compressions and decompressions.

283 Regulation 11 requires that compression and decompression procedures approved by HSE be followed. Appendix 8 sets out the procedures, including specific decompression tables, which HSE has approved under this regulation. These approved procedures do not cover every aspect of compression and decompression, but for those aspects which they do cover, they must be followed. The guidance in paragraphs 282–322 is based on the approved procedures set out at Appendix 8. If it is intended to use decompression tables or other compression or decompression procedures which are different from those which are approved, then formal approval by HSE of the new tables or procedures will need to be obtained before they are put into use. Guidance on the approval procedure is given in Appendix 18.

284 The compression and decompression of people should only take place in a manlock under the control of a competent lock attendant in accordance with the compressed air contractor’s procedures. All people entering compressed air need to be made aware of the responsibilities of the lock attendant.

285 Any person who chooses to ignore any of the procedures for compression and decompression, or to flout the authority of the compressed air contractor should be disciplined appropriately.

286 All workers new to compressed air need to have a ‘lock test’ in which they experience the compressed air environment as part of their assessment for suitability for this type of work. This will be overseen by the hyperbaric supervisor or contract medical adviser.

287 During compression and decompression to working pressures, new starters need to be accompanied in the manlock by a colleague competent to advise them on procedures to be followed.

**Compression**

288 The lock attendant should ensure that the procedure for compression described in Appendix 8 is followed.

289 All pressures need to be read to the nearest 0.05 bar above the reading shown on the gauge, e.g. 0.96 bar becomes 1.0 bar.

290 No one who, due to illness, is unfit for work in compressed air should be compressed.

291 Exceptionally there are people who have episodes of ‘pain only’ decompression illness (e.g. ‘niggles’) and suppress it by getting back into compressed air each day. Whenever such behaviour is suspected, the person needs to be excluded from work in compressed air and referred to the compressed air contractor immediately.
For record-keeping purposes, it is recommended that the starting time of all 24-hour periods be defined on the first day of compressed air working on the contract, e.g. 07.00 hours.

**Limits of exposure, including multiple exposures**

People exposed to compressed air need to spend at least 12 consecutive hours at atmospheric pressure in any 24-hour period.

Except in an emergency, no worker should be exposed to compressed air at pressures up to 0.7 bar for periods of time longer than 8.5 hours in any 12-hour period.

Except in an emergency, no worker should work at pressures of 0.7 bar and over for an exposure period of longer than 8 hours. If necessary, to ensure the safety of the tunnel, this period may be extended by 10 minutes to allow shift change-over at the face.

Multiple exposure to compressed air at pressures of 0.7 bar or over in any working shift should, where possible, be avoided. However, people such as the clients’ representatives, engineers and maintenance staff, do undergo multiple exposures but should be limited to three periods in the working chamber in any 12-hour period. Thereafter, they will need to spend at least 12 hours at normal atmospheric pressure. The total exposure to compressed air in the 12-hour period should not exceed the maximum permissible exposure for that pressure, were it to be experienced in a single exposure. The appropriate decompression regime after multiple exposures is:

(a) the first exposure period - a normal decompression;

(b) subsequent exposure periods - normal decompression for which the exposure period is the total exposure period for that working shift excluding any time spent earlier in that shift on decompression;

(c) when deriving decompression times for multiple exposures, the maximum pressure of any of the up-to-three exposure periods will determine the pressure component of the table to be used.

On a site where there is more than one point of entry to, or egress from, work in compressed air, the compressed air contractor will need to operate a system of record-keeping and information transfer to ensure that each lock attendant is fully aware of the pressure and duration of any previous exposure(s) to compressed air during the current shift.

**Decompression**

The compressed air contractor should ascertain both the oxygen decompression regime and emergency air decompression regime currently approved by HSE before commencement of the work in compressed air. Decompression should be carried out by the lock attendant strictly in accordance
with the approved decompression regime and in the event of any interruption to the oxygen decompression procedure the lock attendant should continue the decompression in accordance with the approved emergency air decompression regime.

299 The procedures at Appendix 8 have been formally approved by HSE for use in accordance with the Regulations. They include use of the Blackpool Tables modified to include oxygen decompression.

300 Prior to decompression commencing, the lock attendant should check that the volume of oxygen immediately available for use is sufficient for the decompression, any subsequent therapeutic treatment and the decompression of any tender accompanying the casualty. The lock attendant should also carry out a functional test on the BIBS system and flush the chamber with air on completion.

301 All sources of supply should be connected but their valves should be shut until required for use.

302 Immediately prior to the commencement of oxygen breathing, the appropriate cylinder valves should be slowly and carefully opened under the direct control of the lock attendant.

303 At the start of the first oxygen breathing period, the lock attendant should instruct people being decompressed to put on masks. Oxygen breathing should continue on a 20 minute oxygen, 5 minute air cycle or as required by the approved decompression regime.

304 The lock attendant should regularly monitor the oxygen pressure in both the high pressure and low pressure pipework. The lock attendant should change over cylinders as required and this should be done at times of zero flow in the system.

305 In the event of the manlock atmosphere becoming enriched above 23% oxygen by volume, the lock attendant should advise the hyperbaric supervisor and ventilate the chamber until the oxygen concentration returns to below 22%.

306 In the event of any fire in the tunnel, airlocks or working chamber, the lock attendant should immediately advise the hyperbaric supervisor, shut off the flow of oxygen to the manlock and initiate the appropriate emergency procedures. The oxygen supply should also be shut off at the surface.

307 In the event of failure of the atmospheric monitoring or ventilation system, the lock attendant should immediately advise the hyperbaric supervisor, shut off the flow of oxygen to the manlock and complete the decompression on the emergency air table until the relevant system has again become operative.

308 In the event that the oxygen concentration in the general body of air in the tunnel should rise above 23%, the oxygen supply to the manlock should be turned off at the point of high pressure supply and the decompression completed as an emergency air decompression. The hyperbaric supervisor should be advised of the incident.
309 On completion of the decompression, the lock attendant should ensure all valves on the oxygen supply system are shut off and that appropriate cleaning and maintenance of the manlock including the BIBS is carried out.

**Decompression following use of breathing mixture**

310 The compressed air contractor should ascertain the appropriate decompression regime and emergency decompression regime approved by HSE for use with the relevant breathing mixture(s) before commencement of the work in compressed air.

311 Decompression should be carried out strictly in accordance with the approved decompression regime. In the event of any interruption to the approved decompression procedure, the lock attendant should advise the hyperbaric supervisor and continue the decompression in accordance with the approved emergency decompression regime.

312 Procedures by which a contractor can seek approval for an alternative decompression regime are set out in Appendix 18.

**Decompression – general precautions**

313 If automatic apparatus is used to control the decompression, the lock attendant will still need to ensure that the decompression procedure is accurate. In the event of failure of the automatic apparatus, it will be necessary for the lock attendant to control the decompression manually and ensure that the hyperbaric supervisor is informed.

314 The hyperbaric supervisor and the contract medical adviser need to be informed in the event of someone collapsing or being taken ill during decompression.

315 If ear block occurs during decompression, a small increase of pressure of 0.1 bar may be sufficient to relieve the problem.

**Familiarisation**

316 The advice of the contract medical adviser on matters of familiarisation should be sought and followed.

317 At pressures of 1.0 bar and over, familiarisation shifts should be worked by all people new to work in compressed air on that site.

318 It is normal practice for familiarisation shifts to be timed so that decompression occurs with other members of the shift.

319 In determining the familiarisation procedures, the contract medical adviser should consider the working pressure and the nature of the work to be done in compressed air. The contract medical adviser should also consider whether additional familiarisation is required to accommodate increases in working pressure or changes in temperature and whether a re-familiarisation procedure is required for workers following a period of absence from work in compressed air.
Inadequate physical fitness is thought to contribute to the occurrence of decompression illness. If the work to be done on any particular contract involves a change in work patterns, e.g. from machine to manual digging, it is advisable to make provision for familiarisation to the change to more arduous physical labour.

**Emergency decanting**

In some emergency situations it is preferable to remain under pressure in the manlock or working chamber and this should be assessed as part of the tunnel emergency procedures. Decanting should only be carried out as a means of evacuating the tunnel in an emergency, e.g. following fire or inundation of the workings. In such an event the people should return to the manlock immediately and be decompressed to atmospheric pressure as rapidly as the situation demands.

Thereafter they should be immediately transfer to the medical lock and be recompressed to the working pressure; held at this pressure for ten minutes; and then be decompressed to atmospheric pressure in accordance with a therapeutic treatment table.

The contract medical adviser and hyperbaric supervisor should be informed immediately the decision to decant is made. The hyperbaric supervisor should ensure that the appropriate emergency procedures are implemented.

**Keeping of decompression records**

The compressed air contractor is required to keep all decompression records on site for the duration of the work in compressed air. Thereafter, compressed air contractors are required to arrange for the records to be kept, for example, at their registered offices or that of any successor company for a further 40 years. During that time the records need to be accessible to HSE. Individuals, or their agents, whose names appear in the records should have access to their own records. A copy of the decompression tables used should be kept with the records. The records should be kept in a non-paper form such as microfiche or electronic storage medium. In addition, each employer is required to keep a copy, provided by the compressed air contractor, of the records relating to their employees and retain them in a similar manner.

Where the compressed air contractor does not have a UK office, a copy of the records should be deposited with “Constructing Better Health” (see Appendix 14 and www.cbhscheme.com). Records from contracts run by a joint venture formed from a number of UK and/or non-UK based companies need to be kept by all members of the joint venture.

Before individuals’ health and exposure records are returned to them on completion of work in compressed air, the record of their personal exposure to compressed air is required to be completed (see paragraph 277). Employees should keep their health and exposure records safely as they will need to present them to their employer when they next apply to work in compressed air. The employer will pass them to the compressed air contractor before such work is started. Visitors to compressed air projects will need to give their ‘Compressed air worker’s health and
exposure record directly to the compressed air contractor prior to entering compressed air.

**Regulation 12 Medical treatment**

**Regulation**

(1) Every compressed air contractor shall ensure that adequate facilities are provided and maintained for the treatment of persons working in compressed air and for the treatment of persons who have worked in compressed air within the preceding 24 hours.

(2) In the case of work undertaken at a pressure of 0.7 bar or above, the facilities referred to in paragraph (1) shall include -

(a) a medical lock;

(b) a person competent to operate that lock; and

(c) a person (whether the same or in addition to the person referred to in sub-paragraph (b) above) competent to provide medical assistance in respect of any condition arising from such work.

(3) In the case of work undertaken at a pressure of 1.0 bar or above, the facilities referred to in paragraph (1) shall include -

(a) a medical lock; and

(b) the presence of a person competent both to operate that lock and to provide medical assistance in respect of any condition arising from such work, which person shall be employed specifically for such purposes.

**Guidance**

**Medical locks**

326 Regulation 12 relates to the need to make preparations for the treatment of any cases of decompression illness which might arise from work in compressed air. This is separate from the need for the provision of first-aid arrangements in the pressurised workings. The incidence of decompression illness varies with the pressure at which work is undertaken and the facilities required are determined by the maximum working pressure. Useful advice on the general operation and staffing of hyperbaric treatment facilities is contained in the *Code of good working practice for the operation and staffing of hyperbaric chambers for therapeutic purposes* published by the Faculty of Occupational Medicine. Appendix 10 gives information on the diagnosis, recording and evaluation of decompression illness.

327 Up to 0.7 bar, the risk of decompression illness arising is extremely low. Only very rarely has decompression illness been reported below 0.7 bar. For work below 0.7 bar, it is not necessary to provide facilities for treatment of decompression illness.
on site. However, the hyperbaric supervisor needs to be aware of the location and operational status of the nearest suitable facility for the treatment of decompression illness and how to contact the chamber operators. The person in charge, lock attendants and the contract medical adviser also need access to this information.

328 Where the pressure in a working chamber is 0.7 bar or above, a medical lock will need to be provided and maintained. The medical lock is best selected by the compressed air contractor in conjunction with the contract medical adviser. It needs to be of an appropriate size and consist of an inner (treatment) chamber and an outer (entrance) chamber and normally be at least 1.8 m in diameter with a maximum working pressure of at least 1.0 bar above the maximum pressure anticipated in the working chamber. If considered appropriate by the contract medical adviser, a surface compression chamber complying with the requirements of the Diving at Work Regulations 1997 may be used. The medical lock will normally be located on the surface near to the top of the shaft giving access to the compressed air workings.

329 As a minimum, the medical lock should meet the requirements for, and be equipped to, the standard for manlocks. In addition, it should be equipped with a facility for supplying food, drink and medical supplies to people undergoing therapeutic treatment.

330 The medical lock will need to be fitted out with suitable equipment, of fire-resistant materials, including a couch not less than 1.85 m long, mattresses, blankets and dry garments. There needs to be a means of verbal communication between each compartment of the lock and the person operating the lock.

331 The medical lock should be adequately ventilated, and heated by means of a thermostatically controlled non-radiant heating system. The medical lock needs to be adequately lit by means of an external lighting system or by an internal explosion-protected system. The recommended level of illumination is not less than 350 lux at the couch surface.

332 The medical lock should be fitted with equipment to allow the administration of oxygen, by built-in breathing system (BIBS), to people being treated in the lock, and with a suitable supply of oxygen. Fittings and oxygen for three masks to be in operation simultaneously in the medical lock should be sufficient for most contracts.

333 At least one medical lock needs to be provided for every 100 people working in compressed air per 24 hours.

334 The medical lock must be kept ready for immediate use while people are working in compressed air and for 24 hours thereafter.

335 The administration of hyperbaric oxygen in the medical lock should be in accordance with the principles of the guidance in this document and under the clinical supervision of the contract medical adviser.

336 Although there is a possibility of ‘pain only’ decompression illness occurring between 0.7 bar and 1.0 bar, a medical lock attendant as defined in paragraphs 71-
72 is not required to be present as the frequency of cases of decompression illness will be low. However, the hyperbaric supervisor must ensure that someone is available on site who is able to competently perform the duties which would otherwise be undertaken by a dedicated medical lock attendant and who is able to initiate and manage recompression therapy under the direction of the hyperbaric supervisor or contract medical adviser.

337 Such a person could be a site engineer or a supernumerary lock attendant. He or she will have to have received some basic medical training, more than just first aid, and have knowledge of the presentation and treatment of decompression illnesses. He or she will need to be able to elicit and document basic symptoms and signs and record these and their response to treatment. The contract medical adviser will remain responsible for the management of the medical condition of the worker.

338 At pressures of 1.0 bar or over, the risk of a case of decompression illness occurring increases and there is the possibility of this being the serious form of the illness. For this reason it is necessary for the lock to be continuously manned by a medical lock attendant, both during the course of the work and for 24 hours after the last person has left the workings. The requirements for a medical lock attendant are given in paragraphs 71–72.

339 The hyperbaric supervisor should ensure there is a person available who can act as tender and enter the medical lock with the casualty if required to provide basic care and monitor their condition. The tender does not need to be a dedicated role but could be the medical lock attendant provided another person is available to operate the medical lock.

340 Sufficient medical equipment needs to be available for use in the medical lock to enable a full clinical examination of an individual to be made. For work at pressure of 1.0 bar and above, suitable medical equipment needs to be available to facilitate the resuscitation of a shocked casualty. The detailed list of equipment will need to be decided by the contract medical adviser, taking account of the recommendations in the report by the Faculty of Occupational Medicine.

341 Clinical responsibility for all treatment rests with the contract medical adviser (acting as the hyperbaric duty doctor in the terms of the Faculty Report). Treatment will usually begin on the initiative of the hyperbaric supervisor or medical lock attendant, after discussion with the contract medical adviser. The casualty needs to be medically examined as soon as this is practicable.

342 Full clinical records need to be kept of the examination and treatment of all cases of decompression illness. A suitable checklist for the initial examination of the neurological system is given in Appendix 10. It is important to document the state of the nervous system after all episodes of illness to ensure that any minor damage is detected. A suitable case sheet for summarising the features of a case of decompression illness is given in Appendix 9.
Use of the medical lock

343 Except for the lock testing of new starters and in emergencies, the medical lock should only be used for therapeutic recompression. When the medical lock is full or is being used to treat a patient for whom, in the opinion of the medical lock attendant, hyperbaric supervisor or the contract medical adviser, any unnecessary increase in medical lock pressure would have an adverse effect, then work in compressed air should cease until the medical lock is capable of accepting further patients.

Recompression therapy

344 Anyone reporting symptoms after decompression should be thoroughly assessed by the medical lock attendant in conjunction with the contract medical adviser.

345 The initial treatment of all forms of decompression illness is recompression therapy. In all cases, persons suffering from symptoms, however slight, which could be due to work in compressed air, should be encouraged to return for treatment. They should not try to treat themselves by taking alcohol and analgesics or waiting until the next shift in compressed air when some temporary relief of symptoms may occur. Where there is doubt about the origin of symptoms, then, after discussion with the contract medical adviser, and provided that there are no contra-indications, a single recompression may be informative.

346 Any recompression therapy should take into account the oxygen exposure already experienced by the person, including the effects of exposure to breathing mixtures during the working shift and any subsequent decompression.

347 Recompression therapy should be carried out in accordance with procedures set out by the contract medical adviser. Treatment regimes need to be based on the best available protocols. These could involve the use of recognised therapeutic oxygen tables such as US Navy Tables 6 or 6A or Royal Navy Tables or use of heliox treatment tables such as Comex 30.

348 Because the treatment of a serious case is more difficult than that of a ‘pain only’ case, it is important to decide which type of decompression illness is being dealt with. It should always be remembered that ‘pain only’ and serious decompression illness may occur together. If there is any doubt, the patient will need to be treated as suffering from the more serious illness.

349 If a person faints or becomes ill during decompression in the manlock, everyone in the lock needs to be recompressed at once to the working chamber pressure. The hyperbaric supervisor, or in his absence the duty medical lock attendant, should be informed immediately. The casualty, accompanied by a responsible colleague, needs to be removed to the working chamber while a medical lock tender is locked in to attend to the casualty. Meanwhile, the others are decompressed in the usual way allowing for the now extended exposure period. The casualty needs to remain in the working chamber until the contract medical adviser is satisfied that he or she is symptom free. The casualty, his colleague and the tender
should then be decompressed slowly in accordance with the advice of the contract medical adviser.

350 A patient should not be transferred to hospital, where treatment can only be symptomatic, until it is certain that the residual symptoms can no longer be improved by recompression or are not caused by decompression illness.

351 If information is received that a compressed air worker is suffering from decompression illness at a place remote from the site, it may be more expedient for recompression treatment to be given elsewhere. In such cases, it may be helpful for the contract medical adviser to discuss the treatment of decompression illness arising from work in compressed air with the staff operating the remote recompression chamber.

352 Information about therapeutic recompression procedures is given in Appendix 11. In case of difficulty, the contract medical adviser can seek assistance from the duty diving medical officer, Ministry of Defence (Navy).

**Regulation 13 Emergencies**

(1) The compressed air contractor shall ensure that no person works in compressed air unless there are suitable and sufficient arrangements for action to be taken in the event of an emergency.

(2) Without prejudice to the generality of paragraph (1), the arrangements required by that paragraph shall extend to -

(a) arrangements for ensuring that the requirements of regulations 39, 40 and 44(3) of the 2007 Regulations are complied with;

(b) the provision and maintenance of a sufficient number of suitable means of access;

(c) the provision and maintenance of suitable means of raising the alarm; and

(d) (where an airlock is required for the purpose of putting into operation an evacuation pursuant to regulation 39(1) of the 2007 Regulations) the maintenance of that airlock in such a condition as to be fit to receive persons in the event of an emergency having regard, in particular, to the air supply to and the temperature of that airlock.

**Guidance**

**Access and egress**

353 Any working chamber, including one which consists of the cutterhead or plenum chamber of a tunnel boring machine, needs to be accessible by at least two single compartment manlocks or a manlock of two or more compartments. With the exception of when the manlocks (or compartments) are in use, it is necessary always
to have one manlock (or compartment) readily available for people to gain access to the working chamber and another manlock (or compartment) available for the rapid escape of people from the working chamber, (typical layouts which meet the minimum requirements of this regulation are illustrated in Appendix 12).

**Emergency procedures in the health and safety plan**

354 The compressed air contractor should include in the construction phase plan (see paragraph 34) the detailed procedures to be followed in the event of an emergency. Likely emergency scenarios which need to be considered include fire, atmospheric contamination, leakage of oxygen or breathing mixture, transport accidents (including derailment, breakdown or collision, damage to oxygen cylinders), non-availability of normal means of access/egress in a shaft, personal injury or illness, loss of power, threat to the life support system for the airlock, blow-out or inundation.

355 The plan will need to include the site management structure, means of implementing the emergency procedures, liaison with the emergency services, removal of casualties from the pressurised workings and procedures for evacuation of the working chamber and airlocks (including emergency decompression and medical procedures). The planning arrangements will need to include the provision of a rescue team and any equipment necessary for use in an emergency. Target response times should be stated and need to be similar to those of the emergency services.

356 Practice drills to test the full range of emergency procedures must be held and the plans reviewed in the light of the outcome of the exercises.

357 Suitable intervals for such drills would be within 21 days of work in compressed air commencing and at least once in every period of six months thereafter for all shifts.

**Emergency team fitness**

358 Rescue work in an emergency as part of the emergency response team can be extremely physically and mentally demanding. The employer will have to consult with the contract medical adviser about the risk assessment for this kind of work. It may be necessary to require a substantially higher degree of fitness than is required for planned compressed air work. It should, in particular, assess the cardio-pulmonary demands of wearing breathing apparatus and carry out potentially very strenuous work. In deciding what that standard should be, employers and contract medical advisers should consider the fitness standards for similar occupational groups such as mines rescue team members or firefighters.

**Fire**

359 The use of airlocks which are part of a tunnel boring machine could result in people in the airlock or working chamber being prevented from escaping from a fire in the tunnel by virtue of the need for decompression. While people are working in such circumstances and particularly when oxygen decompression is being
undertaken, all non-essential power systems on the machine need to be shut down and no maintenance or hot work undertaken.

360 An extensive fire detection and suppression system will also be required. Such systems need to have a power supply which is independent of the machine power supply and be capable of operating even in the event of a fire affecting the machine. During such an emergency, the power, communications and air supply to the airlocks need to be maintained, as well as means to maintain the airlock at a safe temperature.

361 The means of raising the alarm in case of fire need to be ‘fire hardened’ so as to remain operable at all times.

**Injury – evacuation of casualties**

362 The contract medical adviser and hyperbaric supervisor should be involved in planning the extrication of a casualty from the working chamber to the point of reception of the casualty by the public emergency services. This will include the provision of appropriate equipment and planning for the decompression of the casualty and the provision of appropriate first aid treatment under pressure.

**Regulation 14 Precautions against fire**

(1) The compressed air contractor shall ensure that there is provided in respect of work in compressed air any means for fighting fire required pursuant to regulation 41 of the 2007 Regulations and that any airlock or working chamber is operated and maintained in such a manner as to minimise the risk of fire.

(2) No person shall smoke or have with him any materials for the purpose of smoking when in compressed air.

(3) The compressed air contractor shall ensure compliance with paragraph (2).

**Guidance**

363 The ignition energy required to start a fire is less in compressed air, materials burn more vigorously and with much greater radiant heat output. Material that is not combustible at atmospheric pressure may become combustible but not spontaneously combustible, with increasing pressure.

364 Because of the potentially devastating effect of fire in an airlock, wherever practicable, combustible material should not be taken into compressed air.

365 It is essential that airlocks and the working chamber are kept clean and free from combustible rubbish such as waste timber, mineral oil and grease, paper, plastic, cloth and straw. Where necessary, however, a set of timber face boards and
a small amount of straw in a closed metal container may be kept in the working chamber for face support.

366 Equipment for fighting fire should include a fire main throughout the airlocks and working chamber. The occupants of the manlock should be protected against fire by the provision of a water spray system capable of covering the entire floor area of the lock. The system should be permanently charged and should be capable of immediate operation. It should be capable of being turned on from either inside or outside the manlock. Water spray heads should be open and not be fitted with any heat actuated mechanism. The pressure of water in the system should be sufficient to provide a water spray at all pressures in the manlock. The capacity of the water spray should be sufficient to extinguish any foreseeable fire in the manlock. Unless the manlock is on a tunnel boring machine, fire hoses should be located at regular intervals in the working chamber and in the manlock. It is strongly recommended that hoses and attachments be compatible with the local fire service’s equipment.

367 Tunnel boring machines operating in compressed air need to be fitted with a water spray curtain at their outbye end. Once activated, the spray should be capable of operating unattended.

368 Items of plant and equipment for compressed air supply above ground and in the compressed air workings, such as compressors, electrical motors and switchgear or hydraulic pumps should be covered by fire extinguishing systems. Equipment located in hyperbaric environments may require specialised firefighting equipment due to the nature of the hazard presented by them. Firefighting techniques which could result in atmospheric contamination such as dry powder or gas extinguishers should only be used in enclosures. Portable extinguishers, if provided, need to be suitable for use in hyperbaric environments.

369 The use of burning or welding equipment needs to be strictly limited and carried out in a safe manner under a permit-to-work procedure.

370 Electrical switchgear needs to be of a type that does not contain oil. All electrical enclosures should be fitted with inert gas or dry powder fire-extinguishing equipment which discharges directly into the enclosure and which, once activated, is capable of operating unattended.

371 Electrical cabling needs to be insulated with materials having low flame propagation and low smoke and fume generation properties when subjected to fire. The insulating sheath of such cables may have limited resistance to oil or water and needs to be regularly inspected to ensure its integrity.

372 Low flammability and non-toxic hydraulic fluids should be used in the hydraulic systems of tunnelling machinery. The choice of fluid will also be influenced by how little smoke is generated on combustion. Pumps and motors need, where possible, to be enclosed to contain any high pressure discharge of oil, and fluid leaks should not be allowed to accumulate. Rigid hydraulic pipework is to be preferred where practicable. Fixed fire-extinguishing equipment of sufficient capacity for the amount of fluid on the tunnel boring machine should protect the hydraulic installation.
Once activated it needs to be capable of operating unattended. Other lubricants and greases should also be of low flammability types.

373 Conveyor belting needs to be of a type whose fire and smoke generating properties make it suitable for use in coal mines.

374 Flexible ventilation ducting should be of a fire retardant material.

375 The compressed air contractor is required to ensure that all people at work in compressed air are made fully aware of the prohibition on smoking materials and the reasons for it, and to enforce strictly the prohibition.

376 Flame-retardant high visibility overalls should be worn by all people working in compressed air. Relevant standards for protective clothing include BS EN 471+A1: 2007 and BS EN 571:1995. Nomex overalls should be worn by those burning or welding. Nylon and similar garments should be excluded from the workings.

377 There should be a water drench system covering the location of the gas cylinders on the tunnel boring machine. This system should be capable of either manual or automatic operation in the event of a fire in the vicinity of the cylinders. The capacity of the water drench should be sufficient to cool the gas cylinders for at least 15 minutes to prevent gas release due to over-pressurisation of the cylinders.

378 All personnel should clean oil, grease and similar substances including cosmetic substances, from their skin and should change into clean flame retardant clothing before entering the manlock.

379 Dirty clothing should be bagged and taken through the materials lock for laundering prior to reuse.

380 There should be a sterile area around the surface gas storage areas from which the presence of flammable materials or activities likely to give rise to an ignition source, are prohibited.

Regulation 15 Information, instruction and training

The compressed air contractor shall ensure that adequate information, instruction and training has been given to any person who works in compressed air so that he is aware of the risks arising from such work and the precautions which should be observed.

Guidance

381 It is essential that the person in charge, the contract medical adviser and hyperbaric supervisor liaise with representatives of the workforce to ensure that the training carried out adequately addresses the risks on the project and encourages a positive attitude towards health and safety in compressed air working.

382 The provision of information, instruction and training for all people working in compressed air should be undertaken by the hyperbaric supervisor in conjunction
with the contract medical adviser. The compressed air contractor is responsible for ensuring that it is carried out to a standard which is appropriate for the circumstances of the project.

383 For a person who has not previously worked in compressed air it is anticipated that instruction and training will take between a half and one day to complete. Experienced compressed air contractors, who can provide proof of instruction and training by means of an entry in a compressed air worker’s health and exposure record, may only require a refresher course and/or training in site-specific topics such as emergency procedures, rescue equipment and self-rescuers. Information, instruction and training need to be provided for new starters once the work in compressed air is under way. Refresher instruction and training need to be given periodically.

384 Details of the instruction and training received can be entered in the compressed air worker’s health and exposure record (see paragraph 277), which also contains information relating to safe working practices.

385 Suitable topics to be covered by the information provided and in the instruction and training given include:

(a) reasons for the use of compressed air; the medical reasons for the use of oxygen. Persons using breathing mixtures should similarly be instructed in their use;

(b) risks to safety - e.g. fire, flood/inundation, blow-out; the dangers of oxygen, in particular the enhanced fire risk, and the need for high standards of cleanliness both personally and in the manlock and its equipment. The use of the HSE DVD *The heat within: The effects of fires in tunnels* (ISBN 978 0 7176 6411 5) should be part of this training;

(c) site emergency procedures including use of emergency equipment - e.g. fire extinguishers, rescue equipment and use of self-rescuers;

(d) risks to health - decompression illness (‘niggles’, ‘bends’, ‘chokes’, ‘staggers’), barotrauma, medical complications including over exposure to hyperbaric oxygen, osteonecrosis and their symptoms; the purpose of medical surveillance and the need to co-operate with this; heat illnesses and their recognition; the effects of cold;

(e) need for decompression - decompression tables (including details of the tables being used on the contract), oxygen breathing techniques, working pressure and shift length, problems of omitted decompression; the fact that bone damage can occur as the result of a single inadequate decompression and that it is essential to observe all the correct procedures carefully;

(f) rules for compression and decompression including repeat compression and the need to remain on site after decompression, to take only gentle exercise, have tepid rather than hot showers, avoid diving or flying after decompression (see regulation 18);
(g) procedures for return to site out of hours, or if feeling unwell in lock;

(h) familiarisation;

(i) good working practice and postures - e.g. need to avoid constricting limbs such as by prolonged kneeling; the correct use of masks or hoods to ensure proper fit, the need to minimise leakage of gas from the masks and the need to inform the lock attendant immediately in the event of free flow of gas. (It may be necessary to have an attendant in the manlock for the first few decompressions to ensure that masks are properly fitted and used);

(j) authority and duties of compressed air contractor, person in charge, lock attendant, medical lock attendant, compressor attendant, appointed doctor and contract medical adviser;

(k) strong emphasis on reasons for prohibition on drugs, alcohol, smoking;

(l) reasons for unfitness for work in compressed air including colds, influenza, ear/nose/throat infection, pregnancy and illnesses that need to be brought to the attention of the employer;

(m) importance of the health and exposure record; and

(n) wearing of badges, labels or devices.

386 Practical training should include the use of self-rescuers (see Appendix 13), a trial compression and ear clearing, i.e. the 'lock test'.

**Regulation 16 Fitness for work**

(1) The compressed air contractor shall ensure, so far as is reasonably practicable, that every person who works in compressed air is under adequate medical surveillance and works only in accordance with the conditions, if any, specified in his health record.

(2) Notwithstanding paragraph (1), the compressed air contractor shall ensure that no person works in compressed air where the compressed air contractor has reason to believe that person to be subject to any medical or physical condition which is likely to render that person unfit or unsuitable for such work.

(3) A person engaged in work in compressed air shall report forthwith any medical or physical condition which he has reason to believe is likely to render him unfit or unsuitable for such work to the compressed air contractor and, in the case of an employee, to the employer.

**Guidance**

387 All people engaged in work in compressed air have a duty under this regulation to report both to their employer and to the compressed air contractor any illness or medical condition which may render them unfit for work in compressed air. Normally the report will be made to the compressed air contractor through the
person in charge, hyperbaric supervisor, or to the lock or medical lock attendant. The list of those fit to enter the workings will need to be amended in the light of the report of unfitness.

388 The training which is given to all people working in compressed air will need to include an explanation of the types of illness which may render a person temporarily unfit. These include:

- any systemic illness - including common respiratory or gastro-intestinal upsets;
- any disease of the nose, sinuses, throat or ears which may prevent free passage of air;
- any new medical treatment initiated by a registered medical practitioner;
- any condition which results in self-medication;
- decompression illness (from work or sport diving); and
- pregnancy (which is not compatible with work in compressed air).

389 Procedures for compression referred to in regulation 11(1) do not permit the compression of people who have indicated that they may be temporarily unfit.

390 Once a person has reported an illness likely to prevent entry to compressed air working, fitness to resume work in compressed air will need to be confirmed by an appointed doctor or an employment medical adviser.

391 People suffering from any ill effects which may have arisen as a result of exposure to compressed air should, as soon as practicable, seek advice from the hyperbaric supervisor or medical lock attendant regarding the possible need for therapeutic recompression.

Regulation 17 Intoxicating liquor and drugs

(1) The compressed air contractor shall ensure that no person works in compressed air where the compressed air contractor has reason to believe that person to be under the influence of drink or a drug to such an extent that his capacity to carry out any task for which he is responsible is impaired.

(2) No person shall consume alcohol or have with him any alcoholic drink when in compressed air.

(3) The compressed air contractor shall ensure compliance with paragraph (2).

Guidance

392 The compressed air contractor needs to establish appropriate management procedures, supported by site supervisors and lock attendants, to prevent access to
compressed air working of anyone considered to be under the influence of drink or drugs, and to prevent the taking of alcohol into compressed air. Lock attendants should have the authority of the compressed air contractor to refuse to compress any person whom they have reasonable grounds to believe is so affected.

393 The procedures approved for compression prohibit compression of any person who is under the influence of drink or a drug to an extent liable to cause incapacity to work. The reason for this prohibition will need to be made clear to employees in the information, instruction and training provided. Site management is expected to use judgement and experience in looking for any indication that this regulation may have been breached.

394 Many employers now operate policies to deal with the misuse of drugs and alcohol by employees. Work in compressed air is no exception.

Prohibition of alcohol

395 The effects of alcohol are a danger while working in compressed air for three reasons:

(a) unsafe behaviour may result, jeopardising the health and safety of the worker or others;

(b) alcohol increases the risk of decompression illness; and

(c) the effects of alcohol may mimic those of decompression illness, thus interfering with the diagnosis of this condition.

396 A number of studies have noted that the incidence of decompression illness is elevated on the ‘back’ shift. It is thought that this may be a result of the consumption of alcohol in the period prior to work commencing. All who may work in compressed air should be discouraged from consuming alcohol prior to working in compressed air for a period sufficient to avoid the problems described in paragraph 395.

Prohibition of drugs

397 Prescribed or proprietary medication may also affect fitness for work in compressed air, and regulation 16(3) is also relevant. An individual’s capacity may be impaired either by the condition for which the medication has been taken or by the medication itself. Often little advice is given to the public about the possible effects of over-the-counter medication and for this reason it is important that workers should report temporary illness which results in self-medication or the need for prescribed drugs.

398 The lock attendant may need to obtain advice on such drugs from the contract medical adviser either directly or through the hyperbaric supervisor or medical lock attendant. In cases of doubt, an individual should not be compressed. It is important that workers seek advice as early as possible about the potential effects of any medication which is prescribed for them or purchased.
The recreational use of prohibited drugs may also have effects which cause unsafe behaviour. Lock attendants and site managers will need to use their experience and judgement in deciding whether a person may be under the influence of such drugs. Again, in cases of doubt, a person should not be compressed and the advice of the contract medical adviser obtained. It is not proposed that drug screening programmes be routinely introduced. This may be appropriate on some occasions after a considered review of all the circumstances and necessary consultation with employees and should follow accepted professional guidance.

**Regulation 18 Welfare**

*The compressed air contractor shall ensure that there are provided and maintained for the use of any person engaged in work in compressed air -*

(a) *such facilities as are required by Schedule 2 of the 2007 Regulations;*

(b) *suitable drinks for consumption during or after decompression;*

(c) *suitable food and drinks for consumption by any person receiving therapeutic recompression or decompression; and*

(d) *adequate and suitable facilities for remaining on the site after decompression.*

**Guidance**

400 The compressed air contractor is required to ensure that adequate welfare facilities are provided and maintained.

**Sanitary conveniences and washing facilities**

401 Sanitary conveniences should be provided both on the surface (e.g. in the welfare accommodation) and, unless clearly not practicable, in the manlock and working chamber. Suitable screening, for privacy of people using sanitary conveniences underground, should be provided.

402 It is essential to provide washing or other hand cleaning facilities in the workings. This is particularly important when working at higher pressures as it is normal practice for meal breaks to be taken underground.

403 The washing facilities and sanitary conveniences on the surface should be provided in accordance with the requirements of regulations 9(1)(b), 13(7) and 22(1)(c) and Schedule 2 of the CDM Regulations.

404 Because of the nature of the work, suitable and adequate shower and drying facilities will be necessary. Water supplied to the showers should be tepid as a hot shower could increase the risk of a person developing decompression illness.
Facilities for remaining on site etc

405 The purpose of remaining on site needs to be made clear to all those engaged in work in compressed air. After decompression from a maximum working pressure of 1.0 bar or over, people need to remain on site for at least 1 hour. If the maximum working pressure was over 2.8 bar, people need to remain on site for 1.5 hours. During this period people should not engage in any arduous physical activity. The time can be used for showering and changing and for light duties only, e.g. record-keeping or minor maintenance tasks.

406 All washing and welfare accommodation above ground should be heated, kept clean and be provided with seats.

Food and drinks during recompression therapy

407 Hot or cold drinks should be available in all cases. The need to provide food will depend upon when recompression therapy takes place in relation to the end of the shift, and the duration of the therapy. The preferences of the worker undergoing recompression therapy should also be taken into account.

Regulation 19 Badge, label or other device

(1) Every compressed air contractor shall ensure that any person who works in compressed air at a pressure of 0.7 bar or above is supplied with a suitable and suitably worded badge, label or other similar device for the guidance of others should that employee be taken ill after leaving work and that the badge, label or device, as the case may be, contains such particulars as may be approved by the Executive.

(2) Every person to whom a badge, label or other device has been supplied in accordance with paragraph (1) shall wear that badge, label or device for 24 hours after leaving work in compressed air.

Guidance

408 The badge, label or device is required to be worn in case the person collapses and is unable to indicate his or her history of work in compressed air. This should be explained to all people engaged in work in compressed air in the course of information, instruction and training.

409 The badge, label or device needs to be made of a durable material and worn next to the body. Currently HSE requires it to state clearly that the wearer is a person who has been exposed to work in compressed air, and give the location and telephone number of the site medical lock to which a worker suffering from decompression illness should be referred. The contact telephone number of the contract medical adviser can also be given for use in emergencies.

410 Decompression illness is unlikely to occur more than 24 hours after leaving compressed air workings, but this is not an absolute cut-off point.
Regulation 20 Defence in proceedings

In any proceedings for an offence consisting of a contravention of regulation 14(3) or 17(3) it shall be a defence for any person to prove that he took all reasonable precautions and exercised all due diligence to avoid the commission of that offence.

Regulation 21 Power to grant exemption

(1) Subject to paragraph (2), the Executive may, by a certificate in writing, exempt any person or class of persons from all or any of the requirements or prohibitions imposed by these Regulations, and any such exemption may be granted subject to conditions and to a time limit, and may be revoked by a certificate in writing at any time.

(2) The Executive shall not grant any such exemption unless, having regard to the circumstances and in particular to -

(a) the conditions, if any, which it proposes to attach to the exemption; and

(b) any other requirements imposed by or under any enactment which apply to the case,

it is satisfied that the health and safety of persons who are likely to be affected by the exemption will not be prejudiced in consequence of it.

Guidance

411 A request for exemption from the requirements of a particular regulation (as opposed to approval of a decompression regime) should be made in writing and sent along with supporting evidence to HSE’s Head Office in Redgrave Court, Merton Road, Bootle, Merseyside L20 7HS - see Appendix 18.

412 While the maximum exposure pressure permissible under regulation 11(2) is 3.5 bar, work in compressed air at higher pressures has been successfully undertaken elsewhere in Europe. Should there be a requirement for such work in the UK the procedure would be to seek an exemption from regulation 11(2). Such an exemption, were it to be granted, would most likely require the use of non-air breathing mixtures in the working chamber and decompression in accordance with tables used in commercial diving. A corresponding request for approval of an alternative decompression regime would also be required in these circumstances – see Appendix 18. Before granting an exemption, HSE is required to consider not only compressed air issues but also other relevant statutory requirements which could reasonably include; fire, emergency procedures, stability of the ground etc.
Regulation 22 Revocations and modification

(1) The instruments specified in column 1 of Part 1 of Schedule 2 to these Regulations are hereby revoked to the extent specified in the corresponding entry in column 3 of that Schedule.

(2) The instrument specified in column 1 of Part II of Schedule 2 to these Regulations is hereby modified to the extent specified in column 3 of that Schedule.
Schedule 1 Information to be contained in a notice given pursuant to regulation 6(1), 6(2) or 6(3)

Regulation 6(4)

Schedule

1. The fact that work in compressed air is being undertaken.
2. The location of the site of the work in compressed air.
3. The date of the commencement and the planned date of completion of the work in compressed air.
4. The name of the compressed air contractor and a 24-hour contact telephone number (or numbers) of that contractor.
5. The name, address and telephone number of the contract medical adviser.
6. The intended maximum pressure at which the work in compressed air is to be undertaken.
7. The planned pattern of the work in compressed air to be undertaken including details, where applicable, of shift and weekend working.
8. The number of workers likely to be working in compressed air in each shift.
Schedule 2 Revocations and modification

Regulation 22

Part I: Revocations

Schedule

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<td><strong>Title of instrument</strong></td>
<td><strong>Reference</strong></td>
<td><strong>Extent of revocation</strong></td>
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<td>The Work in Compressed Air Special Regulations 1958</td>
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<td>The Work in Compressed Air (Amendment) Regulations 1960</td>
<td>SI 1960/1307</td>
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<td>SI 1967/112</td>
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<td>The Work in Compressed Air (Health Register) Order 1973</td>
<td>SI 1973/5</td>
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<td>The Employment Medical Advisory Service (Factories Act Orders etc. Amendment) Order 1973</td>
<td>SI 1973/36</td>
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<td>The Construction (Metrication) Regulations 1984</td>
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Part II: Modification

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<tr>
<td>The Pressure Systems and Transportable Gas Containers Regulations 1989</td>
<td>SI 1989/2169</td>
<td>In paragraph 8 of Part I of Schedule 2 for the words “the Work in Compressed Air (Special) Regulations 1958” substitute “the Work in Compressed Air Regulations 1996 (SI 1996/1656)”</td>
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Appendix 1 Application of the Pressure Systems Safety Regulations 2000

1 Where there is a pressure vessel and associated pipework (which includes pipes, hoses, bellows, filters and other pressure-containing components) and overpressure protective devices at a pressure above 0.5 bar, a pressure system, as defined in the Pressure Systems Safety Regulations 2000 (PSSR), will exist and the requirements in PSSR will apply.

2 A pressure system, as defined in PSSR, is a system comprising one or more rigid pressure vessels (air receivers, surge vessels), associated pipework and protective devices. If there is no pressure vessel, then there is no pressure system and PSSR will not apply. It will similarly not apply when the air pressure in the system is less than 0.5 bar.

3 Occasionally, hired mobile compressor units are used and tied in to existing pipework. A mobile compressor unit (above 0.5 bar), which usually consists of compressor, coolers, air receiver and protective devices, is covered by PSSR as a mobile pressure system. It is the owner of the compressor unit who has responsibility for compliance, particularly with regulation 8 of PSSR which requires the pressure system to have a written scheme of examination certified as being suitable by a competent person (as defined in PSSR). Any further additions to the scope of this pressure system, such as existing pipework to which a mobile compressor unit may be connected on site, will also need to be considered as part of the overall pressure system and it is the user (as defined in PSSR) who has responsibility for compliance with PSSR for that part of the pressure system. The user in this case may be the compressed air contractor.

4 Normally, pipework would only require including in a written scheme of examination if:

(a) it is subject to a duty where its mechanical integrity is liable to be importantly reduced by corrosion, erosion, fatigue or other factors; and

(b) it is in such a service and location that failure, with a sudden release of stored energy, would give rise to danger.

5 Regarding site pipework, new or existing, which has to be connected to compressor units, the user should consult a competent person on what other pressure-containing parts (such as separators and driers) need to be included in a written scheme of examination.

6 Regarding the competent person, the PSSR Approved Code of Practice Safety of pressure systems gives detailed guidance (see the guidance in respect of regulation 2) on the necessary attributes of the competent body for drawing up or certifying written schemes of examination.

7 Any working chamber, tunnel, manlock or airlock in which people work in compressed air, being work to which the WCA Regulations apply, is excepted from the requirements of PSSR.
The PSSR apply to cylinders of oxygen, nitrogen or helium and to the gas supply pipework respectively.
Appendix 2 Use of portable electronic atmospheric gas monitoring equipment in compressed air workings

1 The following is a summary of the key points which need to be considered when using portable atmospheric monitoring equipment for routine monitoring in compressed air tunnels (based on the conclusions of HSE research).

- Commonly available monitors can be used accurately at pressures up to 3.5 bar.

- Monitors taken into the tunnel for the first time should be allowed to stabilise after switching on and then checked, using clean air, to ensure that the toxic and flammable gas sensors are reading zero, and the oxygen sensor is registering approximately 20.9% v/v $O_2$. If not, the toxic and flammable sensors should be re-zeroed using clean air and the oxygen sensor recalibrated at the operating pressure before use. The clean air can be provided in one of two ways:
  
  (a) a gas sample bag of clean air; or

  (b) from the manlock if it has been filled with clean air.

- Monitors used under hyperbaric conditions for the first time or which have new sensors, particularly oxygen sensors, need to be given some hours under pressure to stabilise. Stabilisation times are likely to be much shorter on subsequent use.

- Monitors which have been calibrated at atmospheric pressure should not initially need the toxic and flammable sensors span calibration (calibration at the upper end of the working range) checked at pressure. At 1.0 bar, the effects of pressure on the span calibration should be small and positive. Over a period of time the span calibration on the toxic sensors will be affected and a larger positive effect will be observed. Therefore, if toxic gas is present, a regular calibration check at the working pressure needs to be carried out.

- In clean air (i.e. no toxic gases present), only the oxygen sensor should be affected by transient pressure changes, and any sudden changes in pressure could cause the monitor to go into alarm. In the presence of toxic gases, e.g. CO, $H_2S$, NO$_2$ etc, pressure fluctuations could cause the relevant sensor in the monitor to alarm. Pressure reductions could cause the sensor to under-read. This is a particular problem when the tunnel is of small volume.

- Monitors need to be sited away from bulkheads and also points at which compressed air enters the tunnel. Control backfilling procedures for locks etc to minimise the rate of fall of pressure in the tunnel. Be aware that during the period when sensors are affected by rapid pressure fluctuations, they cannot provide accurate measurements.
• Condensation resulting from the effects of pressure changes on the humid atmosphere in most compressed air tunnels could cause the monitor to malfunction.

• The Control of Substances Hazardous to Health Regulations 2002 (COSHH) are applicable at both normal atmospheric pressure and in hyperbaric conditions. Occupational exposure limits under COSHH are set with respect to normal atmospheric pressure and strictly do not apply to pressurised workings. Hyperbaric Exposure limits are given in HSE publication EH75/2 *Occupational exposure limits for hyperbaric conditions: Hazard assessment document*. Assessment of the effects of exposure to atmospheric contaminants in hyperbaric atmospheres depends on whether it is the mass or the concentration of a contaminant which is the cause of harm.

2 Instrument manufacturers need to be consulted about the use of their instruments in compressed air and their instructions should be followed.

3 Further information on the behaviour of atmospheric monitoring instruments in compressed air can be found in Research Reports available on the HSE website.
Appendix 3 Types of airlock

Schematic illustrations of different configurations of airlocks are given below.

Figure 1: Lock formed by bulkheads in tunnel lining

Figure 2: Self-contained pressure vessel (boiler) lock

Figure 3: TBM lock
Figure 4: T-lock

Figure 5: Two-compartment vertical lock
Appendix 4 Reporting of hyperbaric illnesses under RIDDOR

1 Schedule 3 of the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR) lists three diseases arising from work involving breathing gases at increased pressure that are reportable to the enforcing authority. These are:

- disease 5 decompression illness
- disease 6 barotrauma resulting in lung or other organ damage
- disease 7 dysbaric osteonecrosis

2 The duty to report rests on the responsible person who, in the case of employees, is their employer. A report is required to be submitted on receipt of written confirmation by a registered medical practitioner that the disease has been diagnosed.

3 The contract medical adviser should ensure that each employer on a project is given such written notice for any case of reportable disease which occurs amongst his or her employees. For self-employed people the report can be submitted by someone other than the affected individual. It could be agreed that the contract medical adviser submits the necessary report on behalf of any self-employed people.

4 Guidance has been prepared on the criteria for diagnosis of certain reportable diseases. Decompression illness has been defined as ‘any signs or symptoms arising from the presence of gas within tissues or vessels of the body following a reduction in ambient pressure’.

5 In addition, regulation 19(2)(d) of the CDM Regulations requires that every contractor should promptly provide the principal contractor with information relating to any death, injury, condition or dangerous occurrence reportable under RIDDOR.
Appendix 5 Outline syllabus for a course in hyperbaric medicine relevant to work in compressed air

1. A contract medical adviser should have practical experience of work in the tunnel environment and be fit to enter compressed air, however, an appointed doctor does not require such experience.

2. At present, no courses in hyperbaric medicine with specific reference to compressed air are available. Some of the content of courses in diving medicine will be relevant to the medical surveillance of compressed air workers. The Faculty of Occupational Medicine has identified a need for courses to be established for those intending to provide treatment in hyperbaric facilities.

3. Until specific courses are available, medical practitioners providing services to compressed air contracts will need to obtain knowledge by personal study and by attending relevant courses in diving medicine. Experience of hyperbaric medicine should be obtained by working under supervision on a compressed air contract and at an established hyperbaric treatment facility or by work in diving medicine.

4. Any course which is arranged should include practical exposure to the tunnel environment and also to a pressurised environment (although not necessarily in a compressed air tunnel). Candidates should ideally be certified fit for work in a pressurised environment.

Introduction to work in compressed air

- Reasons for use of compressed air in civil engineering
- Physiological effects of raised atmospheric pressure
- Acute and chronic health effects from exposure to high pressure
- Decompression illness, classification, current understanding of aetiology including risk factors and the role of acclimatisation
- Osteonecrosis, pathophysiology and known risk factors
- Role of controlled decompression in prevention of decompression illness
- Safety aspects of hyperbaric oxygen decompression

Statutory control of work in compressed air

- Health and Safety at Work etc Act 1974
- Management of Health and Safety at Work Regulations 1999
- Construction (Design and Management) Regulations 2007
- Work in Compressed Air Regulations 1996
• Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
• Control of Substances Hazardous to Health Regulations 2002 as amended
• Control of Noise at Work Regulations 2005
• Control of Vibration at Work Regulations 2005
• Health and Safety (First Aid) Regulations 1981
• Social Security (Industrial Injuries)(Prescribed Diseases) Regulations 1985 as amended.

Role of contract medical adviser

• Duties
  • Liaison with compressed air contractor, hyperbaric supervisor, lock attendants, medical lock attendants, medical lock tender, appointed doctors and employees’ general practitioners
  • Understanding of the practical control of a working site
  • Role in prevention and treatment of decompression illness including investigation of individual cases and monitoring of the overall incidence of disease during a contract
  • Responsibility for supervising the medical management of all cases of decompression illness from a contract
  • Provision of general occupational health advice

Fitness for compressed air work

• Medical examinations, frequency in relation to pressure
• General aspects including possible restrictions on exposure
• Special examinations, including MRI and/or radiology
• Special considerations regarding women of reproductive capacity
• Effects of alcohol, medication and prohibited drugs and ethics of drug screening programmes

Decompression tables, principles and use

• Decompression tables, their derivation and use
• Compression chambers; their construction and operation, including a visit to site/chambers and demonstration of their use and experience of exposure

• Comfort of individuals in locks including heating, ventilation and atmospheric monitoring

Treatment

• Diagnosis of decompression illness

• Principles and procedures for treatment including the use of oxygen

Records

• Maintenance of clinical records

• Individual air records

• Records of cases of decompression illness

References


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• Slocombe R, Buchanan J, Lamont D Engineering and Health in Compressed Air Work Thomas Telford Ltd 2003 ISBN 978 0 7277 3254 5

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• Lamont DR Decompression illness and its regulation in contemporary UK tunnelling: An engineering perspective PhD thesis, Aston University, Birmingham.

• A code of good working practice for the operation and staffing of hyperbaric chambers for therapeutic purposes Royal College of Physicians Faculty of Occupational Medicine 1994 ISBN 1 873240 99 6

• Hyperbaric medical facilities in the UK A Report of the British Medical Association 1993 ISBN 0 7279 0819 7

• Guidelines on testing for drugs of abuse in the workplace Royal College of Physicians Faculty of Occupational Medicine 1994 ISBN 978 1 87324086 1
Appendix 6 Medical examinations

Appendix 7 Screening for Osteonecrosis

1 Recommendations for radiological skeletal surveys for the detection of osteonecrosis were originally published by the Medical Research Council Decompression Sickness Panel in Radiography June 1981, pp 141-43. The Medical Research Council Decompression Sickness Panel was eventually disbanded and its role taken over by the BTS Compressed Air Working Group.

Appendix 8 Compression and decompression procedures currently approved by HSE

Compression

1 The procedure to be followed during compression is:

a) increase the pressure in the manlock gradually to not more than 0.3 bar in the first minute after starting compression;

b) maintain the pressure of 0.3 bar until the lock attendant has checked that no person in the lock complains of discomfort;

c) thereafter, increase the pressure at a uniform rate not faster than 0.6 bar per minute and such that no one suffers discomfort.

2 If a person complains of discomfort at any time during compression, the compression should be stopped immediately. If the discomfort does not quickly cease, the pressure should be gradually decreased. If the discomfort does not cease during decompression, the person concerned should be released from the lock when atmospheric pressure is reached and referred to the contract medical adviser.

3 If a person appears to be suffering from deafness and vertigo during compression, the person concerned should be carefully decompressed as soon as possible, released from the manlock and referred to the contract medical adviser.

Decompression

4 The procedure for decompression following work in compressed air is a staged decompression, normally including the breathing of pure oxygen for part of the decompression.

5 Decompression from pressures of 0.7 bar and over is required to be in accordance with the decompression tables ‘Work in Compressed Air Regulations 1996 - Approved decompression tables - August 2001’ in Appendix 8. Decompression from pressures of less than 0.7 bar should be at a rate of 0.4 bar per minute.

6 Decompression from pressures between 0.7 and 0.95 bar shall be carried out in accordance with Part 1 of the Tables. The compressed air contractor may use air or oxygen breathing at his discretion but shall follow the relevant table from Part 1.

7 Decompression from pressures of 1.0 bar and above shall be carried out in accordance with Part 2 of the Tables.

8 If, for any reason oxygen breathing has to be aborted, the emergency air tables to be used shall be the ‘Work in Compressed Air Regulations 1996 – Approved decompression tables – August 2001 without the use of oxygen’. For pressures below 1.0 bar the emergency air table to be used shall be Table 1 of the ‘Blackpool tables’.
9 Decompression procedures should include:

(a) checking that the recording pressure gauge is functioning correctly;

(b) ascertaining the period during which workers have been exposed to compressed air, i.e. the period from the start of compression to the start of decompression, and the maximum working pressure to which they have been exposed. When two or more workers are being decompressed in the manlock and their exposure periods or their maximum working pressure do not fall within the same range, the decompression procedure should be based upon the longest exposure period experienced by any one of the workers concerned and the maximum working pressure during that period.

(c) determining the decompression table to be used, on the basis that pressures shall be in increments of 0.05 bar with actual pressures being rounded up to the next 0.05 bar increment above the actual pressure; i.e. 0.66 bar becomes 0.7 bar, 0.96 bar becomes 1.0 bar etc;

(d) determining the appropriate stage pressures, times at stage pressures and periods of oxygen breathing from the decompression tables;

(e) noting the starting time and starting the stop-clock where provided;

(f) reducing the pressure at a rate of 0.4 bar per minute to, but not lower than, the first stage according to the decompression tables being used;

(g) retaining that pressure for the number of minutes prescribed in the table, then reducing the pressure at the same rate as before to the next stage, and so on;

(h) oxygen breathing at stops of 0.6 bar and below as indicated in the tables;

(i) routinely ventilating the manlock at intervals of no more than 15 minutes unless more frequent ventilation is required such as a result of an increase in oxygen or carbon dioxide concentration. The routine ventilation should be carried out at a convenient stage pressure by first opening the inlet valve, then the outlet valve, the latter being adjusted to maintain the stage pressure. Close both valves before reducing the pressure to the next stage. Pressure fluctuation due to ventilation should not exceed 0.05 bar.

10 If a person in the manlock collapses or is taken ill during the decompression, the lock attendant needs to raise the pressure in the lock to the pressure in the working chamber and ensure that the hyperbaric supervisor is informed immediately.
Work in Compressed Air Regulations 1996

Approved decompression tables - August 2001

Part 1 Decompression from pressures of 0.7 - 0.95 bar.

1 The compressed air contractor may use either the oxygen or air decompression table. Where an 'Exposure Period' appears on two lines, the longer duration of 'Total decompression period (min)' should be used.

Oxygen decompression table

2 Oxygen should be breathed at stage pressures of 0.6 bar and below (columns shaded and with bold type in tables). There should be an air break of five minutes after every 20 minutes of oxygen breathing. The rate of change of pressure should be 0.4 bar/minute.

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Air decompression table - Air only decompression: No oxygen breathing

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Part 2 Oxygen decompression from pressures of 1.0 bar and over

3. Oxygen should be breathed at stage pressures of 0.6 bar and below (columns shaded and with bold type in tables). There should be an air break of five minutes after every 20 minutes of oxygen breathing. The rate of change of pressure should be 0.4 bar/minute.

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</tr>
<tr>
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<td></td>
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<td></td>
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<td>5 15 15 25 30 45 55 100</td>
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<td>3.2-3.45</td>
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<td>40 50 80</td>
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<td>1.0-1.5</td>
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<td></td>
<td>1.5-2.0</td>
<td>5 15 25 30 35 45</td>
<td>164</td>
<td>4</td>
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<td></td>
<td>2.0-2.5</td>
<td>5 10 20 25 30 40 45</td>
<td>184</td>
<td>5</td>
</tr>
<tr>
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<td></td>
<td>2.5-3.0</td>
<td>5 5 15 25 25 30 40 45</td>
<td>199</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0-4.0</td>
<td>5 15 20 25 30 30 40 45</td>
<td>219</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0-4.25</td>
<td>5 10 15 20 25 35 45 60 120</td>
<td>344</td>
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</tr>
</tbody>
</table>
Appendix 9 Diagnosis, recording and evaluation of decompression illness

1 Decompression illness is a term which covers the range of medical complications which can arise as a result of exposure to hyperbaric environments. As such it includes the condition previously described as decompression sickness and the conditions of arterial gas embolism and barotrauma. As it is often difficult to make a diagnosis based on an accurate knowledge of the pathological mechanism of the presenting symptoms, a new classification of decompression illness based on the features of the illness has been introduced (reference - Francis T J R and Smith D (Eds) Describing dysbarism Bethesda, Md.: Undersea and Hyperbaric Medical Society 1991. This classification is based on the evolution of the presenting symptoms, the nature of the manifestations, the time of onset of the condition, the gas burden and any evidence of barotrauma.

A reclassification describing decompression illness

The presentation of acute decompression illness

Evolution

progressive
static
spontaneously improving
relapsing

Manifestation

pain
– limb pain
– girdle pain
cutaneous
neurological (including audiovestibular)
pulmonary
lymphatic
constitutional (malaise, anorexia, fatigue)

hypotension

Time of onset

Gas burden (e.g. depth-time profile)

Evidence of barotrauma (lung, sinus, ear, dental)

2 Under this classification, the conditions previously known as decompression sickness are described as decompression illness and qualified by the nature of the manifestation. Those cases presenting with predominant features of limb pain would previously have been classified as Type I decompression sickness.

Symptoms of ‘pain only’ decompression illness (previously Type I)

3 Workers have pain in one or more limbs. While not feeling or looking ill, they usually appear to be in pain. The pain may commence at any time from the later stages of decompression up to 24 hours after decompression, although occasional cases start later. Whatever the intensity of the pain, agonising (the ‘bends’) or slight (the ‘niggles’), all cases should be treated. The severity of the pain may mask evidence of serious decompression illness.

Symptoms of serious decompression illness (previously Type II)

4 In compressed air work, the most common serious manifestation of decompression illness is with neurological symptoms, including those from the audiovestibular system. In this publication the term ‘serious decompression illness’ is almost synonymous with neurological decompression illness, although other possible effects are included in the description in paragraphs 5-8 which follow.

5 Workers usually feel and appear ill. Characteristically, the cardiovascular, neurological, respiratory or gastro-intestinal systems are affected. Occasionally they also complain of pains in the limbs.

6 The symptoms sometimes commence during the later stages of decompression, although generally within 45 minutes after decompression. The symptoms may be delayed for some hours, but this is uncommon.

7 A patient with serious decompression illness may present as follows:

d) loss of consciousness. This may occur during the later stages of manlock decompression or soon after its completion;

e) collapse, with signs and symptoms of shock;

f) giddiness (the ‘staggers’);

g) difficult breathing (tightness of the chest or ‘chokes’);
h) visual symptoms (flashes of light, spots before the eyes or tunnel vision);
i) headache;
j) abdominal pains, with or without vomiting;
k) weakness or paralysis of limbs;
l) tingling or numbness of limbs.

8. The signs and symptoms of serious decompression illness are so varied that making a correct diagnosis might prove difficult. It is essential, therefore, that all workers with abnormal signs or symptoms who have been exposed to compressed air during the previous 24 hours should be urgently recompressed. If adequate recompression does not relieve some of the symptoms almost immediately, the diagnosis needs then to be reconsidered.

Other signs and symptoms

9. In addition to the signs and symptoms already mentioned, certain other complications of decompression may be encountered:

(a) a bluish mottling of the skin of the trunk. Sometimes called ‘bruising’, this may be associated with any of the symptoms already mentioned or it may occur alone;

(b) irritation of the skin over the chest, neck or face. This may precede and accompany mottling; early cases respond to treatment by recompression;

(c) localised swelling, usually in the neck and shoulder area. This results from gas in the subcutaneous tissues and may be seen to disappear on recompression. It requires no treatment unless painful, at which time the worker should be recompressed;

(d) a ‘squelching’ noise on movement at the knee or shoulder joint. Clearly audible to other people, this is caused by gas in or around a joint. It appears to be of little consequence and disappears after a few hours.

10. The conditions described in paragraph 9, do not necessarily require treatment as decompression illness. They should, however, be taken into consideration when assessing a worker’s fitness to continue working in compressed air. These symptoms may be accepted as evidence that, for the worker in question, the decompression procedure may have been inadequate. They are reportable under RIDDOR as decompression illness.

11. Nose bleeding is usually associated with a head cold, but should workers cough blood, even though the origin of the blood may be considered to be post-nasal, their lungs need to be investigated.

12. Deafness associated with decompression, affecting one or both ears, may result from an obstruction in the passage between the ear and the throat causing the
ear drum to bulge outwards. This may be relieved by nasal decongestants or, if
unsuccessful, specialist ear, nose and throat advice may be sought.

Recording and evaluating decompression illness

13 The occurrence of a case of decompression illness shall be recorded in the
lock attendant’s register against the person’s exposure immediately preceding the
event.

14 Full clinical records should be kept of the presentation and treatment of all
cases of decompression illness. For the purpose of providing a summary of this
information, the case sheet that follows, devised by the former Medical Research
Council Decompression Sickness Panel, Compressed Air Working Group may be of
help.

15 Analysis of the circumstances surrounding each case of decompression
illness is important in order to determine whether there were any preventable factors.
On an individual basis these may derive from failure of familiarisation, temporary
unfitness or inadequate decompression. A check needs to be made on the adequacy
of decompression following all cases of decompression illness.

16 Where there is confidence that decompression procedures have been
properly followed, it may be necessary to limit the duration of exposure. It may, for
example, be advisable to reduce the limit on the total time spent in compressed air,
work and decompression, to a maximum of eight hours, which would have the effect
of reducing the shift length, particularly at higher pressures. This restriction could be
applied to individuals or to groups.

17 Any reduction in working time will have the effect of increasing the number of
shifts worked which in turn can increase the risk of decompression illness occurring.
Shift length and the resulting number of shifts required to complete a job have to be
carefully balanced.

18 Shift length reduction should not be seen as a substitute for proper
management and control of a contract and should only be introduced as a response
to cases of decompression illness if all other controls are operating satisfactorily.

19 One way to evaluate the experience of decompression illness on any
particular contract and to monitor the effect of interventions is to compare the
amount of decompression illness with the average experience of those contracts for
which records are held on the former Newcastle Decompression Sickness Registry.
The historical bends rate is known for a range of exposure time and pressure cells.

20 Using the number of decompressions experienced in any contract distributed
into the same time and pressure cells, it is possible to apply the historical bends
rates to obtain the number of cases which might have been expected to occur in
each cell. The totals in each of the relevant cells are then added and the ratio of the
actual number of bends cases on the contract divided by the number predicted gives
an indication of the performance of the contract in comparison with a very broadly
based national average.
The ratio thus derived has been referred to as the standardised bends ratio. A ratio of less than one indicates experience better than the national average and the reverse is true for a figure above one. The ratio is only a general guide. The data which form the basis for the average experience are now quite old. Finding a standardised bends ratio of greater than one is certainly a cause for concern but it cannot be interpreted that a figure of less than one shows that there is no room for improvement.

There are a number of measures of the incidence of decompression illness. It is important when quoting numerical values that the basis of calculation is fully understood. The measures currently preferred by HSE and their derivation were described in the Proceedings of the Institution of Civil Engineers, Paper 14384 Lamont DR and Booth R “Acute decompression illness in UK tunnelling”, November 2006. The results for air decompression to the Blackpool Tables from 1984 – 2001 are set out in Table 1. There are not yet sufficient data on oxygen decompression to allow the publication of similar results for it.

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Time</th>
<th>0 - &lt; 2</th>
<th>2 - &lt; 4</th>
<th>4 - &lt; 6</th>
<th>6 - &lt; 8</th>
<th>&gt;= 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.7</td>
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<td>0.00</td>
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<tr>
<td>0.7 – 0.95</td>
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<td>0.03</td>
<td>0.06</td>
<td>0.20</td>
<td>0.21</td>
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</tr>
<tr>
<td>1.0 – 1.25</td>
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<td>0.02</td>
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<td>0.24</td>
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<td>No data</td>
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<td>No data</td>
<td>No data</td>
<td>No data</td>
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</tr>
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</table>

Table 1 Single exposure risk factors

Note: These figures were derived from copies of records held by compressed air contractors and donated to HSE for research purposes. * insufficient exposures to be statistically valid.
Example of Compressed air worker’s decompression illness case sheet
Appendix 10 Decompression illness initial assessment checklist

1. All workers presenting symptoms of possible decompression illness should have these symptoms assessed and recorded. This should be done as soon as possible after symptoms are reported. Timing will depend on the nature and severity of symptoms. Assessment should not delay recompression therapy and may need to be done during this treatment. The checklist is based on one devised for a compressed air contract current at the time of preparation of this guidance. The checklist can be modified to suit the needs of individual contracts.

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Date</td>
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</tr>
<tr>
<td>Maximum pressure of last shift</td>
</tr>
<tr>
<td>Duration of last shift</td>
</tr>
<tr>
<td>Any other exposure to compressed air in last 24 hours</td>
</tr>
<tr>
<td>Time since decompression</td>
</tr>
<tr>
<td>Symptoms</td>
</tr>
<tr>
<td>Worker’s complaints - general</td>
</tr>
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<td>Walking and balance</td>
</tr>
<tr>
<td>Breathing</td>
</tr>
<tr>
<td>Mental function - general</td>
</tr>
<tr>
<td>Level of consciousness</td>
</tr>
<tr>
<td>Vision</td>
</tr>
<tr>
<td>Hearing</td>
</tr>
<tr>
<td>Peripheral numbness</td>
</tr>
<tr>
<td>- tingling</td>
</tr>
<tr>
<td>Pain</td>
</tr>
<tr>
<td>- limbs</td>
</tr>
<tr>
<td>- other</td>
</tr>
<tr>
<td>Skin</td>
</tr>
</tbody>
</table>

**Physical assessment**

Vital signs:  pulse rate

blood pressure

respiration rate
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<th>Right</th>
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</thead>
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<tr>
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<td></td>
</tr>
<tr>
<td>Reaction to light</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction to accommodation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye movements</td>
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<td></td>
</tr>
<tr>
<td>Nystagmus present</td>
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<td></td>
</tr>
<tr>
<td>Facial nerve, smile, clench teeth, equal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tympanic membranes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speech, quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tongue, any deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Co-ordination: finger nose test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Muscle strength</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder shrug</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grip strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raise arms to shoulder height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Push with flexed arm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pull with flexed arm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight leg raising</td>
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<td></td>
</tr>
<tr>
<td>Dorsiflexion of foot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantarflexion of foot</td>
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<tr>
<td>Reflexes:</td>
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<tr>
<td></td>
<td>arms</td>
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</tr>
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<td>legs</td>
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<tr>
<td>Sensation:</td>
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<td></td>
<td>leg</td>
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</tr>
<tr>
<td></td>
<td>pin prick</td>
<td></td>
</tr>
<tr>
<td></td>
<td>arm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>leg</td>
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</tr>
</tbody>
</table>
Appendix 11 Therapeutic recompression

1 Management of the treatment of decompression illness is the responsibility of the contract medical adviser. Contract medical advisers should decide which treatment regime to use and advise the hyperbaric supervisor accordingly. Advice on the treatment regime should extend to situations in which symptoms are not fully resolved.

2 Treatment regimes using oxygen have been published by the Royal Navy and the United States Navy in their respective diving manuals, and have been reproduced in publications such as Larn and Whistler’s Commercial diving manual (David and Charles, ISBN 978 0 7153 0100 5).

3 For many years in tunnelling, procedures for treating decompression illness developed by the Medical Research Council Decompression Sickness Panel and published by the Construction Industry Research and Information Association in their Report 44, third edition 1982, Medical code of practice for work in compressed air, were used, apparently successfully.

4 The hyperbaric supervisor should initiate therapeutic recompression immediately a case of decompression illness has been identified in accordance with procedures previously agreed with the contract medical adviser. These procedures should set out requirements for contact between the hyperbaric supervisor and contract medical adviser over diagnosis, treatment, extension of treatment etc.

5 The contract medical adviser should assess the casualty on completion of treatment.

6 In the absence of advice from the contract medical adviser to the contrary, US Navy Tables 6 and 6A should be used for treating decompression illness arising from tunnelling in compressed air.

7 Information about therapeutic recompression procedures is given above. In an emergency, assistance can be sought from the duty diving medical officer, Ministry of Defence (Navy).

Appendix 12 Access to and egress from the working chamber

Arrangements for access to and egress from the working chamber are covered in regulation 13(2)(a) and (b).

Figure 8: Two-compartment tunnel airlock

Figure 9: Two single-compartment tunnel airlocks
Figure 10: Two-compartment vertical tunnel lock
Appendix 13 Selection and use of self-rescuers and breathing apparatus in compressed air workings

1 There are three types of self-rescuer available for use underground:

(a) **filter self-rescuer**: this only provides protection against dust and carbon monoxide in the tunnel atmosphere. It does not provide protection against oxygen deficiency or other atmospheric contaminants. The duration of a filter self-rescuer is unaffected by pressure. Such equipment is suitable for use in compressed air where the only atmospheric contaminant is likely to be carbon monoxide;

(b) **oxygen self-rescuer - chemical oxygen and compressed oxygen types**: this provides protection against oxygen deficiency and all atmospheric contaminants. Its duration is not significantly affected by pressure. Because of possible adverse effects on the user due to oxygen toxicity it is not suitable for use at tunnel pressures in excess of 1.0 bar or lower pressure as advised by the contract medical adviser;

(c) **compressed air self-rescuer**: this provides protection against oxygen deficiency and all atmospheric contaminants. The duration of the equipment, however, is significantly reduced by increased pressure and it is unlikely to be suitable for use in compressed air.

Breathing apparatus - for rescue team use

2 The duration of open circuit breathing apparatus is significantly reduced in compressed air. Care should be taken in selecting breathing apparatus to ensure that it is of sufficient duration to allow for a reserve of at least five minutes on return to a place of safety. This is in addition to the capacity required to allow the user to leave the airlock, get to a casualty, carry out essential first aid and return to the lock. A dedicated rescue skip with a bulk on-board supply of compressed air may be required for rescue operations.

Breathing rates - all equipment

3 Users of all equipment are likely to suffer from stress and exertion during an underground emergency. Breathing rates are therefore likely to be high and this will need to be considered when selecting equipment.

Nitrox and heliox

4 If the use of such gases in closed circuit breathing apparatus is considered as a means of extending the duration of equipment, current limits on partial pressures and exposure times applicable to commercial diving in UK waters need to be adopted.
Hyperbaric self rescuer

5 A prototype self-rescuer capable of use at pressures up to 3.5 bar was developed under contract to HSE (Anthony, TG ‘Generic modification of compressed oxygen self-rescuers for use in compressed air tunnels at pressures of 0.0 to 3.5 bar gauge’ Proceedings of the 2nd International Conference on Engineering and Health in Compressed Air Work, Oxford 2002 Slocombe RT, Buchanan J, Lamont DR, eds, Thomas Telford 2003, London). To date it has not been produced commercially.
Appendix 14 Record-keeping

Introduction

1 The Regulations require the making and maintenance of the records described in this appendix. The records, and those responsible for them, are: clinical - appointed doctor; exposure – compressed air contractor; and health - employer. The records, or a copy of them, have to be kept in a suitable form for a period of at least 40 years from the date of the last entry in each record.

Clinical records

2 Appointed doctors are required to maintain accurate and comprehensive clinical records to meet normal professional standards and the terms of appointments made by HSE.

Exposure records

3 Current practice is to produce these records in electronic format. This has been shown to generate significantly more accurate records than hand recording and should be adopted by the compressed air contractor.

4 The exposure record will need to contain personal details of the worker and record information on the exposure. Exposure records should be kept in a spreadsheet or database format which is compatible with commonly available office software packages. The following data fields should be completed for each exposure:

Unique site reference number for each worker;

*NI number;

*Employer;

*Surname;

*First name;

Date of exposure (in date format);

*Occupation;

Compression start time (in time format);

Decompression start time (in time format);

Exposure period (in time format);

Max exposure pressure;

Decompression table number;
Line number;

Comments (include record of any DCI in this field);

Location on site if multiple workings (e.g. Shaft 4A, Shaft 1 etc).

Alternatively for fields marked *, a separate summary spreadsheet or database can be provided to link that information to the unique site reference number used for each worker in the main exposure spreadsheet or database.

Appropriately formatted date and time fields should be used to record all dates and times.

5 A part of the exposure record should be produced by the lock attendant each time a person is compressed and decompressed. The master copy (with appropriate secure backup) of the exposure record spreadsheet or database should be updated at least daily and kept by the hyperbaric supervisor.

6 The exposure record needs to contain each person’s name, national insurance number and employer so that an individual exposure record can be compiled in respect of each person and an exposure record can be compiled in respect of all the employees of each employer.

Health records

7 Both employers’ and personal health records will need to contain personal details of the worker and record the date, type and result of each medical assessment. Sub-paragraphs (a) to (d) of paragraph 277 in the guidance give full details of the information needed.

8 The personal health record provided under regulation 10(3)(c) is the property of the employee and should be provided to the appointed doctor for completion at the time of each assessment. It may be convenient for the appointed doctor to retain the health records during the course of a contract.

The compressed air contractor

9 The compressed air contractor has to ensure that:

(a) an adequate exposure record is made and maintained of the times and pressures at which work in compressed air is undertaken and that the record or a copy of it is kept in a suitable form;

(b) an individual exposure record is made and maintained for each person who undertakes work in compressed air;

and, as soon as is reasonably practicable, after a person has ceased to work on any project, that:

(c) the employer of that person is provided with a copy of the parts of the exposure record that relate to that person;
that person is provided with a copy of the parts of the individual exposure record that relate to him or her.

**The employer**

10 Employers have to ensure that:

(a) a health record (employers’) is made and maintained for each of their employees who is engaged in work in compressed air and that the record or a copy of it is kept in a suitable form;

(b) a copy of the relevant part of the health record is provided to the employee to whom it relates as soon as is reasonably practicable after that employee has ceased to work on any project; and

(c) the record of exposures or a copy thereof provided to the employer by the compressed air contractor is kept in a suitable form.

**The compressed air worker's health and exposure record**

11 The Regulations require that compressed air workers are provided with details of relevant parts of their health record and record of exposure which will be used to summarise the results of that worker’s medical surveillance, exposure to compressed air and training. The health section will duplicate the employer’s health record and the exposure section will duplicate the individual exposure record. This health and exposure record will be the personal property of the compressed air worker who should keep it securely between contracts.

12 The compressed air contractor should ensure that the exposure section of the compressed air worker’s health and exposure record is completed and handed to the compressed air worker as soon as is reasonably practicable after that worker has ceased to work on the project.

13 It is recommended that employers provide each of their employees with a personal health and exposure record. Copies of a logbook, *Compressed air worker’s health and exposure record*, which contains the details required by the Regulations are available from HSE Books. Other layouts could be used but the minimum details needed are stated in paragraph 277 of this guidance.

**Keeping of the records**

14 The compressed air contractor is required to keep all exposure records on site for the duration of the work in compressed air. Thereafter, the compressed air contractor and the employer should arrange for the records for which they are responsible to be kept for at least 40 years from the date of the last entry.

15 The health and exposure records can be kept in any convenient manner. They may be kept in a non-paper form such as microfiche or computer disc.

16 A copy of the decompression tables used needs to be included with the records.
17 It is recommended that the health and exposure records are kept on the computer system at the offices of Constructing Better Health, B & CE Building, Manor Royal, Crawley, West Sussex RH10 2QP. A fee will be charged for this service.

18 The records should be sent to Constructing Better Health as soon as is reasonably practicable after the work in compressed air has ceased.

19 It is recommended that the database function of a standard office software package should be used to form the database in which the records should be stored. Spreadsheets offer insufficient flexibility for data sorting and analysis.

20 The Constructing Better Health computer system can read any data from the most commonly used spreadsheet and database packages, but if in doubt check with Constructing Better Health.

21 The employee’s national insurance number needs to be included in the records which are retained by Constructing Better Health as this number is the major form of identification.

**Access to the records**

22 The records should be accessible to:

- HSE;

- individual compressed air workers, or their representatives, who can retrieve their own records by contacting their employers or Constructing Better Health, providing their personal details (including NI number) and details of the contract on which they were employed; and

- compressed air contractors and employers, who can only retrieve records for their own contracts.
## Appendix 15 Summary of principal changes in requirements with increasing pressure

<table>
<thead>
<tr>
<th>Pressure equals or exceeds (bar)</th>
<th>Requirement 6</th>
<th>Guidance paragraph number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>Work in Compressed Air Regulations apply</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Intervals between fitness assessments not to exceed three months</td>
<td>268</td>
</tr>
<tr>
<td></td>
<td>Exposure limited to 8.5 hours</td>
<td>294</td>
</tr>
<tr>
<td>0.5</td>
<td>Pressure Systems Regulations apply</td>
<td>Appendix 1</td>
</tr>
<tr>
<td>0.7</td>
<td>Decompression in vertical lock prohibited</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td>Recording pressure gauge required</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>Exposure at &lt;0.7 bar limited to 8.5 hours</td>
<td>294</td>
</tr>
<tr>
<td></td>
<td>Exposure at 0.7 bar and over limited to 8 hours</td>
<td>295</td>
</tr>
<tr>
<td></td>
<td>Multiple exposures should be avoided</td>
<td>296</td>
</tr>
<tr>
<td></td>
<td>Medical lock provided</td>
<td>328</td>
</tr>
<tr>
<td></td>
<td>Someone available on site able to perform duties of medical lock attendant</td>
<td>336</td>
</tr>
<tr>
<td></td>
<td>Resuscitation equipment required</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>Stage decompression on air or oxygen</td>
<td>Appendix 8</td>
</tr>
<tr>
<td>1.0</td>
<td>Medical lock attendant and medical lock tender required</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Compressor and medical lock attendant to be on site for 24 hrs after final decompression</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Seating and heating in lock</td>
<td>154 and 229</td>
</tr>
<tr>
<td></td>
<td>Bone imaging</td>
<td>256</td>
</tr>
<tr>
<td></td>
<td>Intervals between fitness assessments not to exceed one month</td>
<td>268</td>
</tr>
<tr>
<td>Stage</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>Familiarisation</td>
<td>317</td>
</tr>
<tr>
<td></td>
<td>Remain on site one hour after decompression</td>
<td>405</td>
</tr>
<tr>
<td></td>
<td>Stage decompression on oxygen</td>
<td>Appendix 8</td>
</tr>
<tr>
<td>2.8</td>
<td>Remain on site 1.5 hours after decompression</td>
<td>405</td>
</tr>
<tr>
<td>3.5</td>
<td>Max exposure limit</td>
<td>9</td>
</tr>
</tbody>
</table>
Appendix 16 Minimum requirements for gas delivery systems - pipework, valves, gauges etc

1 The performance criteria to be observed when designing the oxygen delivery system include:
   - flow velocity and pressure in all pipework to be kept to a minimum during use;
   - supply lines to be kept pressurised but with line valves shut, when oxygen is not being used;
   - valves to be slow opening except for emergency shut-off valve - all the above to reduce the risk of fire due to adiabatic compression;
   - pipe diameter to be minimised consistent with supplying required flow volumes;
   - flow-limiting device to be fitted downstream of pressure regulator;
   - all sections of pipework to have pressure gauges to indicate delivery line pressure and valved dumps to facilitate the discharge of oxygen when it is required to empty the line.

2 All pipework should be routinely functionally pressure tested as part of operating procedures.

3 Only the minimum number of cylinders required to supply the manlock should be open at any time.
Figure 11 Minimum requirements for oxygen supply pipework - fixed manlock

<table>
<thead>
<tr>
<th>Item ref</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Primary oxygen supply from a single oxygen cylinder, bank of cylinders or bulk liquid supply. Nature of supply depends on quantity of oxygen required</td>
</tr>
<tr>
<td>B, P</td>
<td>Pressure gauge and valve on cylinder, bank of cylinders or bulk liquid supply. Gauge to indicate pressure at point of supply</td>
</tr>
<tr>
<td>C, K, Q</td>
<td>Connection point to fixed pipework for additional primary oxygen supply (only required if individual cylinders are used). As A, B and P</td>
</tr>
<tr>
<td>D, L, R</td>
<td>Non-return valve</td>
</tr>
<tr>
<td>E, M, S</td>
<td>Shut-off valve - high pressure</td>
</tr>
<tr>
<td>N</td>
<td>Secondary or backup oxygen supply – this must be connected to the delivery pipework and available for use at all times when decompression is in progress</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>F</td>
<td>Pressure gauge - high pressure. Gauge to indicate input pressure to pressure reduction device or regulator</td>
</tr>
<tr>
<td>G</td>
<td>Pressure reduction device or regulator</td>
</tr>
<tr>
<td>H</td>
<td>Shut-off valve and flow-limiting device (see paragraph 181)</td>
</tr>
<tr>
<td>J</td>
<td>Pressure gauge - low pressure. Gauge to indicate output pressure from pressure reduction device or regulator</td>
</tr>
<tr>
<td>T</td>
<td>Emergency shut-off valve at lock attendant’s station</td>
</tr>
<tr>
<td>U</td>
<td>Control valve on oxygen supply for routine use by lock attendant during decompression</td>
</tr>
<tr>
<td>V</td>
<td>Pressure gauge - low pressure. Gauge to indicate oxygen supply pressure at lock attendant’s station</td>
</tr>
<tr>
<td>W, X</td>
<td>Emergency shut-off valve inside manlock</td>
</tr>
</tbody>
</table>

**Procedures for operation**

(a) with all valves shut, connect up all supplies;

(b) individually pressure test each high pressure connection using gauge F. Close off all valves after test. Remake and retest any connections found to be leaking;

(c) pressurise line H - U, close valve H and observe pressure in line H - U for five minutes to confirm no leaks in shaft/tunnel pipework. If any leak is detected, immediately advise person in charge and lock attendant. Emergency procedures to be initiated. Alternative air decompression to be carried out until oxygen supply re-established;

(d) advise lock attendant that oxygen is available for use if not already aware;

(e) to use oxygen slowly open valves B, P, E, H and U in that order;

(f) changeover between oxygen sources is to be carried out while zero flow in system during air breathing period. Valve E to be shut before opening valve S (or M if additional oxygen supply connected);

(g) even when not in use, the oxygen line between H and U should be kept pressurised with valves H and U shut. Oxygen pressure in the line should be monitored periodically on gauge V by lock attendant.
Figure 12 - Minimum requirements for oxygen supply pipework - manlock on tunnel boring machine

<table>
<thead>
<tr>
<th>Item ref.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Primary oxygen supply from a single oxygen cylinder or bank of cylinders. Nature of supply depends on quantity of oxygen required</td>
</tr>
<tr>
<td>B, M</td>
<td>Pressure gauge and valve on cylinder or bank of cylinders. Gauge to indicate pressure at point of supply</td>
</tr>
<tr>
<td>C, N</td>
<td>Non-return valve</td>
</tr>
<tr>
<td>D, P</td>
<td>Shut-off valve - high pressure</td>
</tr>
<tr>
<td>L</td>
<td>Secondary or backup oxygen supply – this must be connected to the delivery pipework and available for use at all times when decompression is in progress</td>
</tr>
</tbody>
</table>
### Procedures for operation

(a) on the surface with all valves shut, connect up all cylinders;

(b) individually pressure test each high pressure connection using gauge E and with valve G closed. Close off all valves after test. Remake and retest any connections found to be leaking;

(c) deliver supply to tunnel boring machine in accordance with guidance and advise lock attendant;

(d) make connection H;

(e) pressurise line J–R, close valve G and observe pressure in line G - R for five minutes to confirm no leaks in tunnel boring machine pipework. If any leak is detected, immediately advise person in charge and lock attendant. Emergency procedures to be initiated. Alternative air decompression to be carried out until oxygen supply re-established;

(f) to use oxygen, slowly open valves B, M, D, G, J and R in that order;

(g) changeover between oxygen sources is to be carried out while zero flow in system during air breathing period. Valve D to be closed before opening valve P;
even when not in use, the oxygen line between J and R should be kept pressurised with valves J and R shut. Oxygen pressure in the line should be monitored periodically on gauge S by lock attendant.
Appendix 17 Materials prohibited in manlock

1 The following materials should be prohibited from the manlock:

• adhesives - non water based;
• aerosols;
• batteries with unprotected terminals;
• cosmetics;
• cleaning fluids - organic solvents;
• electrical equipment - non-essential;
• foodstuffs - finely powered;
• materials for smoking including ignition sources;
• mineral oils, greases etc;
• textiles - not fire-retardant treated.
Appendix 18 Procedures for seeking HSE approval of an alternative decompression regime or exemption from a regulation

The text highlighted in grey below is currently under revision by HSE.

1 A written application with supporting evidence should be submitted to HSE, Redgrave Court, Merton Road, Bootle, Merseyside L20 7HS.

Approval

2 The supporting evidence for approval of an alternative decompression regime should include:

- a description of the tables to be approved;
- their theoretical derivation if they are not listed in HSE Research Report RR126;
- reports of any laboratory evaluation or hyperbaric trials of the tables, details of experience of their long-term use using HSE’s preferred measures of DCI incidence (see Lamont DR and Booth R, *Acute decompression illness in UK tunnelling* Proceedings of the Institution of Civil Engineers Paper 14384 November 2006);
- a robust technical justification of the benefits of these tables over those currently approved;
- submissions from expert advisers, if any, to the compressed air contractor supporting the application;
- a scheme for monitoring the overall effectiveness of the decompression regime throughout its use on site. Such a scheme should allow for physiological monitoring at the level of individual exposed persons.

3 To be acceptable, the likely risks of decompression illness and osteonecrosis using the proposed procedures should be no greater than those occurring from the use of the existing tables.

Exemption

4 The supporting evidence for an application for an exemption from regulations should include:

- a description of the exemption sought;
- a robust technical and medical justification of why the exemption is considered necessary;
- submissions from expert advisers, if any, to the compressed air contractor supporting the exemption.
Appendix 19 Appointment procedures for appointed doctors

The text highlighted in grey below is currently under revision by HSE.

1 Medical practitioners wishing to undertake medical examinations under the Work in Compressed Air Regulations 1996 must apply to HSE for appointment. The initial contact person in HSE will be the diving/compressed air portfolio holder within EMAS/Corporate Medical Unit who will advise on the administrative process to follow (see http://www.hse.gov.uk/doctors/information.htm for further details).

2 Doctors seeking appointment should understand the role of the appointed doctor and be competent to carry out the tasks of an appointed doctor. This will require specific knowledge and preferably practical experience relevant to working in compressed air. Given the complexities of the tunnelling environment and compressed air working in particular, a high level of occupational health knowledge relating to the construction industry is likely to be required. Therefore, HSE would give preference to applicants with a consultant/specialist qualification in occupational medicine.

3 At present, there are no training courses available in the UK that are specific to the medical aspects of compressed air working. However, many of the medical issues are common to all types of hyperbaric exposure. Hence, competence as an Approved Medical Examiner of Divers (AMED) along with competence in construction-related occupational medicine should be sufficient for a doctor to be appointed under these regulations. Possession of a higher qualification occupational medicine - the Diploma in Occupational Medicine from the Faculty of Occupational Medicine or higher - is a minimum requirement. Where compressed air work involving the use of non-air breathing mixtures is to be undertaken, the appointed doctor should also have attended relevant diving medical courses in these topics. Doctors holding qualifications in hyperbaric medicine, such as those recognised by the Diving Medical Advisory Committee or the European Diving Technology Committee, can also be considered for appointment.

4 As very few tunnelling projects in the UK require the use of compressed air, the demand for appointed doctors under these regulations is both infrequent and intermittent. This creates difficulties in maintaining competence. Therefore, every application for appointment will be judged on its own merits and may be linked and restricted to a particular compressed air working project. This does not preclude appointment for several projects at the same time.

5 If an appointment is granted, then the appointed doctor’s work may be subject to periodic review by HSE. This may include inspection of the medical files or other ways of audit of performance. Competence must be maintained through adequate and suitable refresher training. This has to be in line with similar requirements on Approved Medical Examiner of Divers and with the GMC’s general requirements for CPD and revalidation.
6 Appointed doctors who also act as contract medical advisers, and as such could personally be involved in prescribing and supervising hyperbaric treatments, must be medically fit to enter the hyperbaric chamber if required.