

A guide to the Work in Compressed Air Regulations 1996

Guidance on regulations



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This guide looks at the Work in Compressed Air Regulations 1996 and addresses such issues as safe systems of work, medical surveillance, compression and decompression procedures, medical treatment, emergency procedures, fire precautions and instructions and training.

It provides a framework for the management of health and safety by those undertaking tunnelling and other construction work in compressed air.

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This Code has been approved by the Health and Safety Executive, with the consent of the Secretary of State. It gives practical advice on how to comply with the law. If you follow the advice you will be doing enough to comply with the law in respect of those specific matters on which the Code gives advice. You may use alternative methods to those set out in the Code in order to comply with the law.

However, the Code has a special legal status. If you are prosecuted for breach of health and safety law, and it is proved that you did not follow the relevant provisions of the Code, you will need to show that you have complied with the law in some other way or a Court will find you at fault.

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Introduction

1 The Work in Compressed Air Regulations 1996 (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 essentially update the Work in Compressed Air Special Regulations 1958. They also amplify general duties under the Health and Safety at Work etc Act 1974 and the Management of Health and Safety at Work Regulations 1992.

2 The Work in Compressed Air Regulations 1996 address such issues as: safe systems of work; medical surveillance; compression and decompression procedures (including HSE approval of procedures); 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.

3 The coverage 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) and clean rooms. The lower limiting pressure of 0.15 bar has been set to exclude work at very low pressures where the risk of decompression illness is negligible.

4 Wherever work is carried out in compressed air, the provisions of the Construction (Design and Management) Regulations 1994 will apply because the number of people required to carry out and manage such work will bring it within the applications of those Regulations. For most, but not necessarily all, compressed air projects the compressed air contractor will be the principal contractor under the Construction (Design and Management) Regulations.

5 The Construction (Health, Safety and Welfare) Regulations 1996 also apply to compressed air projects, with the Work in Compressed Air Regulations providing additional standards because of the particular risks and conditions involved in work in compressed air. The additional requirements relate to emergencies, fire precautions and welfare.

Health risks associated with work in compressed air

6 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.

Guidance

7 Methods of complying with the Work in Compressed Air Regulations are, in some cases, prescribed by the Regulations. This guidance gives further advice on how to comply with the law 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 by HSE after widespread consultation with employers, trade unions, professional bodies and medical organisations.

Regulation

1

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

Regulation 2 Interpretation

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

“the 1996 Regulations” means the Construction (Health, Safety and Welfare) Regulations 1996^(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.*

(a) SI 1996/1592.

Regulation

2

- (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.

Regulation

3

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 1994^(a) and which is not excluded by regulation 3(2) of those Regulations.*

(2) *These Regulations shall not apply to any diving operation as construed in accordance with regulation 2(2)(a) of the Diving Operations at Work Regulations 1981.^(b)*

(a) *SI 1994/3140, as amended by SI 1996/1592.*

(b) *SI 1981/399; to which there are amendments not relevant to these Regulations.*

Guidance

3

Scope of the Regulations

8 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.

9 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.

10 Work in an air-pressurised underwater habitat as part of a diving operation is not covered by these Regulations. If there is any doubt whether the Work in Compressed Air Regulations 1996 or Diving Regulations apply to work in a pressurised chamber or environment, eg in an air-pressurised habitat associated with work on underwater pipelines or marine structures, the test to be applied is that construction work is subject to the Work in Compressed Air Regulations if the primary purpose of the compressed air is to control the ingress of groundwater and/or to stabilise the ground, while the Diving Regulations apply if the primary purpose of the compressed air is to provide a breathing medium.

11 Hyperbaric oxygen treatment carried out other than in the 'adequate facilities' required by regulation 12 of these Regulations is not covered by these Regulations.

Regulation

4

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.*

Regulation

4

(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

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 1994.

Guidance

5

12 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.

13 Because of the key role of the compressed air contractor it is recommended that all employers on a site whose employees work in compressed air ascertain who has been appointed as the compressed air contractor.

Regulation

6

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.

Regulation 6

(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.

Regulation

6

(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

6

Who to notify

14 Where work in compressed air is about to be carried out, it is required that the following be informed by the compressed air contractor:

- 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;
- local ambulance service;
- local fire service;
- local establishments operating hyperbaric facilities. Lists of emergency hyperbaric facilities are maintained by HSE, the British Hyperbaric Association and the British Medical Association.

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

16 Where the escape of air from the workings may 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 supply company that work in compressed air is taking place.

Hospitals

17 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.

18 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 there unwell. 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.

19 The contract medical adviser may need to consider whether it is practical also to advise hospitals with A & E departments in the areas where compressed air workers live or to which they regularly travel at weekends.

Suspension and completion of work

20 Suspension of the work 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

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.*

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Guidance

21 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. This statement should be added to or may form the health and safety plan developed by the principal contractor under regulation 15 of the Construction (Design and Management) Regulations 1994. 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 incorporated in the health and safety plan. Sub-contractors bringing potential risk to the site need to inform the principal contractor/compressed air contractor.

22 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 and sudden loss of pressure in the working chamber and airlocks. A safer alternative may be to pressurise a length of the tunnel when entry to the cutter head is required.

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

24 A safe system of work needs to 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.

Competent persons

25 The compressed air contractor's appointment of competent persons does not detract from the compressed air contractor's responsibilities under these Regulations. Whenever people are working in compressed air, the sufficient number of competent persons required to be immediately available on site are:

- (a) a person in charge (or deputies to allow for shift working) so designated by the compressed air contractor to be in overall charge of the work in compressed air;
- (b) a compressor attendant;
- (c) a lock attendant for every lock in which people are being compressed or decompressed;

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

- (d) a medical lock attendant.

7

Guidance

26 The compressor attendant and medical lock attendant are required additionally to be available for a period of 24 hours after the last person has been decompressed.

27 It is not sufficient to provide night shift and weekend cover by means of day shift staff sleeping on site. The necessary staff are required to be at work.

28 When no work is taking place but the working chamber remains pressurised (eg over weekends and holiday periods), a compressor attendant needs to be available on site.

Person in charge

29 Persons 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 in order to be able to discharge their duties. Also, they should have previous experience of work in compressed air, or otherwise be advised by people who have had relevant experience.

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

- (a) development and implementation of the relevant parts of the health and safety plan;
- (b) emergency procedures including planning and implementation;
- (c) liaison with emergency services during an emergency;
- (d) procedures to implement the prohibition of smoking materials, alcoholic drinks and drugs;
- (e) arranging for the maintenance of health and exposure records;
- (f) delegation of duties to lock attendants and compressor attendants;
- (g) ensuring the provision of information, instruction and training;
- (h) designation of persons to be responsible for determining the pressure of air in the working chambers; and
- (i) liaison with contract medical adviser.

31 Where responsibilities have been delegated to 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.

Compressor attendant

32 Compressor attendants need to be competent to operate and routinely maintain the electrical equipment and mechanical plant in their charge. They may need access to professional electrical and mechanical engineering advice and supervision.

33 Compressor attendants need to:

- (a) inspect daily the compressed air plant on the surface;
- (b) operate and undertake routine maintenance of the compressed air plant within their charge;
- (c) vary the air supply pressure in response to instructions from people so designated by the person in charge;
- (d) maintain records of air pressure and quality of air being supplied to the tunnel;
- (e) respond to high/low pressure alarms; and
- (f) operate the medical lock under instruction from the medical lock attendant in an emergency.

Guidance

34 Where work in compressed air is being undertaken at more than one location on site, each with separate compressed air plant, a separate compressor attendant will be necessary for each location.

Lock attendant

35 Lock attendants need to be competent to operate the locks in their charge. In addition they should be competent to operate (pressurise and depressurise) the medical lock under instruction in an emergency.

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

37 Lock attendants will need to receive 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.

38 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.

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

Medical lock attendant

40 Medical lock attendants need to have some medical training and also practical experience relevant to hyperbaric work. They are required to be employed specifically as medical lock attendants and not have such duties on a secondary basis. They might be registered general nurses (RGN), hold HSE 'Diver Medic' certificates, or have similar equivalent qualifications. Unless already satisfying other requirements as 'suitable persons' under the Health and Safety (First Aid) Regulations 1981, medical lock attendants should hold a current First Aid at Work Certificate.

Guidance

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41 Medical lock attendants need to be able 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; and
- (e) understand the need to assess regularly the progress of individuals under treatment.

42 Medical lock attendants need to be trained to operate the medical locks available on site. In addition to the training required for manlock attendants, medical lock attendants need to understand the principles of, and be able to implement the procedures for, the treatment of acute decompression illness, including the use of oxygen. A worker under treatment may need to be accompanied in the compression chamber by an attendant and medical lock attendants may undertake this role. Whether medical lock attendants go into the chamber or remain outside, they need to 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.

43 Medical lock attendants need to:

- (a) be medically fit and willing to go into compressed air;
- (b) be under the supervision of the contract medical adviser;
- (c) have immediate access to all records of pressures and other relevant information regarding conditions in the working chambers and manlocks;
- (d) maintain and regularly update the records required by the Regulations; and
- (e) be available to assist the appointed doctor with routine medical assessments and accompany new starters in the airlock during lock tests.

Regulation

8

Regulation 8 Plant and equipment

(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

44 Compressed air contractors have duties under this regulation for all the plant and ancillary equipment required to carry out the work in compressed air in a safe manner.

45 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.

46 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, 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.

47 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 1992.

48 In some situations the requirements of the Pressure Systems and Transportable Gas Containers Regulations 1989 will apply to the compressed air plant and guidance on this is given in Appendix 1.

49 The pressure equipment needs to have a design pressure of 1.1 x maximum working pressure. This factor of 1.1 is additional to the load factor required by limit state design codes. Pressure equipment needs to be capable of withstanding a hydraulic pressure test at 1.5 x maximum working pressure. Bulkheads which cannot be tested need to have a factor of 1.1 increased to 1.5 to give a design pressure of 1.5 x maximum working pressure. Airlocks, bulkheads, airdecks and their anchoring systems need to be designed by a competent engineer. The installation of these items needs to be supervised.

50 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 and Transportable Gas Containers Regulations 1989 (*Safety of pressure systems* HSE Books ISBN 0 11 885514 X).

51 The pressure equipment needs to be tested to the working pressure 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 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.

52 The plant and ancillary equipment should be regularly maintained by, or under the supervision of, a compressor attendant.

Guidance

Power supply

53 The main supply of electrical energy may be from the public electricity supply or from independent generating plant. In both cases there needs to be a standby power supply available. It should be possible to resume air supply within not more than 5 minutes of a failure of the main power supply. The capacity of the standby power supply needs to be sufficient to power all the duty compressors and their ancillary equipment.

Air supply, plant etc

54 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. If diesel compressors are used, care needs to be taken to ensure that the air entering the intakes cannot be contaminated by exhaust emissions.

55 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.

56 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.

57 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, eg 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.

58 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.

59 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.

60 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

61 The supply of compressed air to the working chamber should be sufficient to maintain an atmosphere in the working chamber such that, when measured at normal atmospheric pressure, the level of any contaminant (other than oil content) does not exceed 10% of the short-term exposure limit for that contaminant in the current edition of *Occupational exposure limits* (EH40). Ventilation is also required

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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.

62 The air needs to be odourless with an oil content not exceeding 0.5 mg/m³ at normal atmospheric pressure.

63 It is recommended that air quality be checked at least once a day and the results recorded (see Appendix 2).

64 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.

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

Air pipelines

66 Any pipeline supplying compressed air to the workings needs to be duplicated between the compressed air plant and the lock attendant's station. 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.

67 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 if the noise from the air pipeline discharge exceeds an instantaneous sound level of 80 decibels.

68 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.

69 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.

70 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.

71 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.

72 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.

73 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.

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Temperature in the working chamber

74 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.)

Airlocks - general requirements

75 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.

76 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.

77 All airlocks need to be fitted with a glass observation window at least 75 mm in diameter so that the lock attendant can observe the interior of the lock.

78 All airlocks need to be lit so that the level of illumination is adequate.

Manlocks - general requirements

79 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.

80 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 openable 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.

81 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.

82 In addition, a pressure gauge indicating the pressure in the manlock and a clock capable of being read to the nearest 5 seconds and in working order need to be visible to people in the manlock. A copy of the decompression tables should

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be available inside the manlock. All manlocks operating at pressures in excess of 1.0 bar need to be provided with a non-radiant form of heating. Electricity cables passing through manlocks into the working chamber need to be ducted through the manlock in fire-resistant ducts.

83 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.

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

85 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.

Horizontal locks

86 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 m³ 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 m³ per person. A manlock consisting of two compartments in series may have an entrance compartment with a minimum volume of 2.0 m³. However, a CEN standard currently in draft will, when adopted, set appropriate standards relating to manlock size, where the manlock is an integral part of a small diameter tunnel boring machine, with which operators will have to comply.

87 Horizontal manlocks which are an integral part of a tunnel boring machine need to be fitted with equipment to monitor the partial pressures of oxygen and carbon dioxide in the manlock. The equipment should give an alarm at the lock attendant's station when the partial pressure of oxygen is less than 200 millibars or 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, eg assume air = 80% nitrogen + 20% oxygen at atmospheric pressure, then partial pressure oxygen = 1 x 0.2 = 0.2 bar.)

88 Manlocks should contain seating for people being decompressed from pressures over 1.0 bar. The normally accepted size of seating, recommended by HSE, is 400 mm wide with at least 500 mm length of seating for each person in the manlock. 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 fully outstretched.

Combined locks

89 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, provided free movement of people is not restricted. Combined locks need to meet all the requirements for manlocks.

Vertical locks

90 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 1.0 bar because the comparatively restricted space in a vertical lock

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would necessitate standing for too long in the event of decompression from pressures of 1.0 bar or over.

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

92 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, eg 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

93 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.

94 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

95 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.

96 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 air flow does not permit this.

97 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 that, in the event of failure, fail to the closed position.

98 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.

99 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.

100 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.

101 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 6 months thereafter. It is recommended that the certificate of calibration be maintained on site.

102 Analogue gauges should comply with the requirements for industrial gauges in BS 1780:1985 or equivalent and have an indicating scale of not less than

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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. It is recommended that digital gauges have a display on which the digits are at least 15 mm high.

103 Pressure gauges complying with BS 1780:1985 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 1780:1985 may usefully be provided in the compressor attendant's station on site to facilitate calibration checks.

104 When the pressure in the working chamber is 1.0 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 1 revolution every 4 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.

105 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.

106 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.

107 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.

Lock attendant's station

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

109 There should be a clock in working order at lock attendants' stations capable of being read to the nearest 5 seconds.

110 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

111 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 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.

112 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.

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Communications systems

113 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; and, at intervals not exceeding 500 metres from the manlock, each face being worked; the medical lock attendant's station; and the medical lock.

114 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.

115 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.

116 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.

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Regulation

Regulation 9 Appointment of contract medical adviser

(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.*

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117 The hyperbaric environment is one in which there is potential for serious harm to health to arise from the effects of pressure or of dissolved gases. 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. 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. The advice which is given should cover aspects of health and medical surveillance, medical treatment of cases of decompression illness, maintenance of records and general occupational health topics. Appendix 4 outlines these aspects. In this context the term medical surveillance refers to the assessment of fitness for work in compressed air required by regulation 10. Health surveillance is used to refer to all other activities related to the identification of occupational diseases.

118 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 advisor. 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.

119 Statutory medical surveillance, as required by regulation 10, should be undertaken either by the medical staff of the Health and Safety Executive (employment medical advisers), or, more usually, by doctors with a formal relationship with HSE by means of an 'appointment' to enable them to do this type of work. The formal appointment allows HSE to monitor standards and to collect

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statistics. An appointed doctor has a contractual responsibility to the employer of the person who is examined and the above responsibilities to HSE.

120 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 and has a remit which is wider than medical surveillance. Although it is open to employers to choose 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. As a minimum a contract medical adviser should have the level of knowledge and experience of hyperbaric work of an appointed doctor (see paragraph 136).

121 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.

122 The contract medical adviser needs to be able to provide the compressed air contractor with advice on the latest knowledge and understanding with regard to the prevention of decompression illness, and to do so will need to be familiar with the current literature. The contract medical adviser needs to monitor actively the incidence of decompression illness during the course of a contract to assess whether this is being kept as low as might reasonably be achieved. If there is any doubt that this is not being 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).

123 The contract medical adviser is responsible for the supervision of 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. The contract medical adviser may need to enter the medical lock to make a clinical examination and is required to be medically fit for exposure to compressed air.

124 Contract medical advisers act as professional advisers to their medical lock attendants. In particular, they need to supervise the collation and maintenance of exposure records and the completion of the compressed air worker's health and exposure record.

125 Contract medical advisers need to advise compressed air contractors about the risks which might arise from other health hazards present in the working environment and about any health surveillance which may be necessary for those exposed to these hazards. 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 such as membership of the Faculty of Occupational Medicine. Contract medical advisers will require the knowledge of

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hyperbaric medicine 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 and those who come new to the field may wish to make arrangements to consult such an experienced practitioner on an occasional basis.

Regulation

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*

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- (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.*

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126 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 pressure.

Health risks

127 At low pressures, below 1.0 bar, work in compressed air is comparatively free from harm. Decompression illness is 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 neurological decompression illness and osteonecrosis are the more serious complications.

128 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 ear drum 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.

129 Decompression illness is a disease which occurs during or following the decompression process. It predominantly occurs as a relatively simple condition, usually involving pain around the joints, the bends, or as a serious potentially 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 may identify individuals who are at greater than normal risk of decompression illness.

130 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 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 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 radiology of the long bones to identify any pre-existing disease.

131 Decompression illness, barotrauma and osteonecrosis are all conditions which are reportable under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (see Appendix 5).

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

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General duty on employers to make arrangements for medical surveillance

133 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.

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

- at a frequency related to the working pressure (see paragraph 141);
- following illness or incapacity causing an inability to work for 3 or more days; or
- following any episode of ill health related to work in compressed air.

135 Medical surveillance of compressed air workers has to be undertaken by appointed doctors (or employment medical advisers), see paragraph 119. 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. Applications to have a doctor appointed under these Regulations should be submitted to the local HSE office.

136 A doctor who wishes to become an appointed doctor to carry out medical surveillance of compressed air workers needs to have training and experience in occupational medicine and also specialist knowledge of hyperbaric medicine. Possession of a higher qualification such as the Associateship of the Faculty of Occupational Medicine is likely to be a minimum requirement. Knowledge of hyperbaric medicine can be gained from training courses in diving medicine or from any courses specific to compressed air work which may be organised. An outline syllabus for such a training course is given at Appendix 6.

Role of the appointed doctor

137 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 134 and 141); 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.

Content of medical examinations

138 The detailed requirements of the medical examinations are given in Appendix 7 and those relating to radiology of the long bones are in Appendix 8.

Assessment of continuing fitness for work

139 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

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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.

140 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.

141 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.

Other medical examinations

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

143 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 radiology of the long bones 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 radiology.

144 It is recommended that the appointed doctor ensures that 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 16).

Health record

145 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 150.

146 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

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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.

Work restrictions specified in the health record

147 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; or the number of entries to be made per day. 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

148 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.

Maintenance of compressed air worker's health and exposure record

149 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.

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

- (a) personal details of the employer
 - 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

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151 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.

152 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.

153 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

154 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.

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Regulation

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 -*

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- (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

155 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 156-83) relates to the general procedures which need to be followed during all compressions and decompressions.

156 Regulation 11 requires that compression and decompression procedures approved by the Health and Safety Executive be followed. Appendix 9 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 156-83 is based on the approved procedures set out at Appendix 9. 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.

157 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.

158 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.

159 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 conducted by the medical lock attendant or contract medical adviser. 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

160 The lock attendant should ensure that the procedure for compression described in Appendix 9 is followed.

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

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

163 Exceptionally there are people who have frequent 'niggles' ('pain only' decompression illness) and suppress it by getting back into compressed air each

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day. Whenever such behaviour is suspected, the person needs to be excluded from work in compressed air and referred to the contract medical adviser immediately.

164 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, eg 07.00 hours.

Acclimatisation

165 Insufficient acclimatisation appears to be a significant cause of decompression illness. The advice of the contract medical adviser on matters of acclimatisation needs to be sought and followed.

166 At pressures of 1.0 bar and over, acclimatisation shifts need to be worked by all people new to work in compressed air on that site. When the working pressure is between 1.0 bar and 2.0 bar, acclimatisation needs to be carried out over at least two shifts, the first of which is not longer than 4 hours.

167 When the working pressure is 2.0 bar or over, it is necessary that acclimatisation be carried out over a period of at least four working shifts.

168 Acclimatisation shifts need to be timed so that decompression occurs with other members of the shift.

169 At pressures of 1.0 bar or more and on the advice of the contract medical adviser, an acclimatisation procedure will also need to apply to any workers who may have lost their acclimatisation following a period of absence from work in compressed air.

170 At pressures in excess of 1.0 bar, when the maximum pressure to which a person is likely to be exposed during a shift exceeds that during the previous shift by more than 0.3 bar, any people so affected need to be appropriately acclimatised on the advice of the contract medical adviser.

171 Inadequate physical fitness can contribute to the occurrence of decompression illness. If the work to be done on any particular contract involves a change in work patterns, eg from machine to manual digging, it is advisable to make provision for acclimatisation to the change to more arduous physical labour.

Limits of exposure, including multiple exposures

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

173 Except in an emergency, no worker should be exposed to compressed air at pressures up to 1.0 bar for periods of time longer than 10 hours in any 12-hour period.

174 When the working pressure is 1.0 bar or over, each worker should be limited to three periods in the working chamber in any 12-hour period. Except in an emergency, no worker should work at pressures in this range 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.

175 Multiple exposure to compressed air at pressures of 1.0 bar or over in any working shift should, where possible, be avoided. However, people such as the clients' representatives, engineers and maintenance staff do occasionally undergo multiple exposures, and where they do, the maximum that should normally be

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allowed is three entries to compressed air 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.

176 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

177 The lock attendant should ensure that the procedures for decompression described in Appendix 9 are followed.

178 The procedures at Appendix 9 have been formally approved by HSE for use under the Regulations. They include use of the Blackpool Tables, which were published by the Construction Industry Research and Information Association in their report 44 (third edition 1982).

179 If a contractor wishes to seek approval for alternative procedures, it will be necessary to provide full supporting justification for these, including the theoretical derivation, any laboratory evaluation, and reference to experience which may exist of the use of the procedures outside the United Kingdom. To be acceptable, the likely risks of decompression illness and osteonecrosis using the proposed procedures should be less than those occurring with the use of the existing tables.

180 If decompression tables using oxygen breathing are proposed, an analysis of the comparative risks and benefits of oxygen breathing will need to be included in the supporting material.

181 If automatic apparatus is used to control the decompression, the lock attendant will 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 person in charge is informed.

182 The person in charge and the contract medical adviser need to be informed in the event of someone collapsing or being taken ill during decompression.

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

Emergency decanting

184 Decanting should only be carried out as a means of evacuating the tunnel in an emergency, eg following fire or inundation of the workings. In such an event the procedure to be followed by people in the workings is:

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- (a) return to the manlock immediately and be rapidly decompressed to atmospheric pressure;
- (b) immediately transfer to the medical lock and be recompressed to the working pressure;
- (c) be held at this pressure for 10 minutes; and
- (d) be decompressed to atmospheric pressure following a therapeutic treatment table.

185 The contract medical adviser will need to be informed immediately decanting has been initiated.

Keeping of decompression records

186 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. Where the compressed air contractor does not have a UK office, it would be helpful if a copy of the records were offered to HSE. Records from contracts run by a joint venture formed from a number of UK and/or non-UK based companies need be kept by all members of the joint venture. During that time the records need to be accessible to HSE. People, or their agents, whose names appear in the records are required to have access to their own records. The records may be kept in a non-paper form such as microfiche or computer disc. A copy of the decompression tables used will need to be kept with the records. In addition, each employer is required to keep a copy, provided by the compressed air contractor, of the records appertaining to their employees and retain them in a similar manner.

187 Before individuals' health and exposure records are returned to them, the record of their personal exposure to compressed air is required to be completed. 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 records directly to the compressed air contractor prior to entering compressed air.

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Regulation

Regulation 12 Medical treatment

(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*

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- (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.*

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Medical locks

188 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 Operations at Work Regulations 1981 may be used. The medical lock will normally be located near to the top of the shaft giving access to the compressed air workings.

189 A medical lock will generally need to meet the requirements for, and be equipped to, at least the standard for manlocks. In addition it should be equipped with a facility for supplying food, drink and medical supplies to people undergoing therapeutic recompression treatment.

190 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.

191 The medical lock needs to 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.

192 If work is to take place at a pressure of 1.0 bar or over, the medical lock needs to 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. Guidance on the safe use of high pressure oxygen is contained in Appendix 13.

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

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

Use of the medical lock

195 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 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.

Provision of adequate facilities

196 This requirement relates to the need to make preparations for the treatment of any cases of decompression illness which might arise from work in compressed

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air. It does not relate to the need for the normal provision of first-aid arrangements. The incidence of decompression illness is related to 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.

197 At or above 0.15 bar and below 0.7 bar the likelihood of decompression illness arising is very low. Only very rarely has decompression illness been reported below 0.7 bar. In these cases it is not necessary to provide facilities for treatment of decompression illness on site. The compressed air contractor needs, however, 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.

198 At or above 0.7 bar and below 1.0 bar there is a possibility of 'pain only' decompression illness occurring and a medical lock has to be provided. A medical lock attendant as defined in paragraphs 40-43 is not required to be present as the frequency of cases of decompression illness will be low. However, someone has to be available on site who is able to perform the duties which would be undertaken by a dedicated medical lock attendant and who is able to initiate and manage recompression therapy under the direction of the contract medical adviser.

199 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.

200 At pressures of 1.0 bar or over, the likelihood 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 both to provide a medical lock for treatment and for the lock to be continuously manned by a medical lock attendant, during the course of the work and for 24 hours after the last person has left the workings. The requirements of a competent medical lock attendant are given in paragraphs 40-43. It is advisable also to have available a person who can enter the medical lock with workers to provide basic care and monitor their condition, although it will not always be necessary for the person to enter the lock. This could be the medical lock attendant if another suitable person is available to operate the medical lock.

201 There needs to be available for use in the medical lock sufficient medical equipment 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.

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

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203 Full clinical records need to be kept of the examination of all cases of decompression illness. A suitable checklist for the initial examination of the neurological system is given in Appendix 11. It is important to document the state of the nervous system after all episodes of illness, in order 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 10.

Recompression therapy

204 The initial treatment of all forms of decompression illness is recompression therapy. In all cases, any people 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.

205 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. The decision whether or not to use oxygen will rest with the contract medical adviser.

206 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.

207 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 casualty, accompanied by a responsible colleague, needs to be removed to the working chamber while the others are decompressed in the usual way. 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 and colleague should then be decompressed slowly in accordance with the advice of the contract medical adviser.

208 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.

209 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 recompression chamber.

210 Information about therapeutic recompression procedures is given in Appendix 12. In case of difficulty, the contract medical adviser can seek assistance from the duty diving medical officer, Ministry of Defence (Navy).

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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 19, 20 and 25(3) of the 1996 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 20(1) of the 1996 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.*

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Access and egress

211 Any working chamber, including one which consists of the cutterhead 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 14).

Emergency procedures in the health and safety plan

212 The compressed air contractor should detail in the health and safety plan the procedures to be followed in the event of an emergency. Likely emergency scenarios which need to be considered include fire, atmospheric contamination, transport accidents (including derailment, breakdown or collision), 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.

213 The health and safety plan will need to include details of the site management structure, means of implementing the emergency procedures, liaison with the emergency services 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.

214 Practice drills to test the emergency procedures set out in the health and safety plan will need to be held. Suitable intervals for such drills would be within 21 days of work in compressed air commencing and at least once in every period of 6 months thereafter for all shifts.

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Fire

215 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, all non-essential power systems on the machine need to be shut down and no maintenance or hot work undertaken.

216 An extensive fire detection and suppression system will also be required. Such systems need to be 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.

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

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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 21 of the 1996 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).*

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218 Equipment for fighting fire should include a fire main throughout the airlocks and working chamber. There needs to be a sprinkler system in the manlocks which can be operated from both inside the lock and from the lock attendant's station. The fire main and sprinkler system need to be charged to a high enough pressure to give an adequate flow in the workings. Fire hoses should be located at regular intervals. It is strongly recommended that hoses and attachments be compatible with the local fire service's equipment.

219 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.

220 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, may require specialised fire-fighting equipment due to the nature of the hazard presented by them. Fire-fighting techniques which could result in atmospheric contamination such as dry powder or gas extinguishers should preferably not be used in enclosures. Portable extinguishers, if provided, need to be suitable for use in hyperbaric environments.

221 Wherever practicable, combustible material should not be taken into compressed air. All materials burn more fiercely in compressed air and material which is not combustible at atmospheric pressure may become combustible with increasing pressure.

222 Airlocks and the working chamber need to be kept clean and free from combustible rubbish such as waste timber, mineral oil and grease, paper, plastic,

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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.

223 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.

224 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.

225 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.

226 If reasonably practicable, 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 foam or dry powder 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.

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

228 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.

229 The provision of flame-retardant overalls for all people working in compressed air and the exclusion of nylon and similar garments from the workings needs to be considered.

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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.

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230 The provision of information, instruction and training for all people working in compressed air may be undertaken by anyone competent to do so, but 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.

231 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 workers, 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,

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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.

232 Details of the instruction and training received can be entered in the compressed air worker's health and exposure record, which also contains information relating to safe working practices.

233 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;
- (b) risks to safety - eg fire, flood/inundation, blow-out;
- (c) site emergency procedures including use of emergency equipment - eg fire extinguishers, rescue equipment and use of self-rescuers;
- (d) risks to health - decompression illness ('niggles', 'bends', 'chokes', 'staggers'), barotrauma, 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), 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) acclimatisation;
- (i) good working practice and postures - eg need to avoid constricting limbs such as by prolonged kneeling;
- (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) 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 or labels.

234 Practical training should include the use of self-rescuers (see Appendix 15) and a trial compression and ear clearing, ie the 'lock test'.

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Regulation

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.*

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(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

16

235 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, 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.

236 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 communication 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).

237 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.

238 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.

239 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 medical lock attendant regarding the possible need for therapeutic recompression.

Regulation

17

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

17

240 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 will need to have the authority of the compressed air contractor to refuse to compress any person who they have reasonable grounds to believe is so affected.

Guidance

241 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.

Prohibition of alcohol

242 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.

243 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 242.

Prohibition of drugs

244 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.

245 The lock attendant may need to obtain advice on such drugs from the contract medical adviser either directly or through the 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.

246 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.

17

Regulation

18

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 -

Regulation

18

- (a) *such facilities as are required by regulation 22 of the 1996 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

18

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

Sanitary conveniences and washing facilities

248 Sanitary conveniences should be provided both on the surface (eg 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. The washing facilities and sanitary conveniences on the surface should be provided in accordance with the requirements of the Construction (Health, Safety and Welfare) Regulations 1996.

249 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

250 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, eg record-keeping or minor maintenance tasks.

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

Food and drinks during recompression therapy

252 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

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

19

253 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.

254 The badge, label or device needs to be made of a durable material and worn next to the body. It will need 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.

255 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

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

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.

Regulation

22

Regulation 22 Revocations and modification

(1) *The instruments specified in column 1 of Part I 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

Schedule 1 Information to be contained in a notice given pursuant to regulation 6(1), 6(2) or 6(3)

Regulation 6(4)

- 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.*

1

Schedule

Schedule 2 Revocations and modification

Regulation 22

Part I Revocations

<i>(1)</i> <i>Title of instrument</i>	<i>(2)</i> <i>Reference</i>	<i>(3)</i> <i>Extent of revocation</i>
The Work in Compressed Air Special Regulations 1958	SI 1958/61	The whole Regulations
The Work in Compressed Air (Amendment) Regulations 1960	SI 1960/1307	The whole Regulations
The Work in Compressed Air (Prescribed Leaflet) Order 1967	SI 1967/112	The whole Order
The Work in Compressed Air (Health Register) Order 1973	SI 1973/5	The whole Order
The Employment Medical Advisory Service (Factories Act Orders etc. Amendment) Order 1973	SI 1973/36	In Part II of the Schedule, the entry in respect of - The Work in Compressed Air Special Regulations 1958
The Construction (Metrication) Regulations 1984	SI 1984/1593	Regulation 3, and in the list in regulation 1(2) and in Schedule 1, the entries in respect of - The Work in Compressed Air Special Regulations 1958

Part II Modification

<i>(1)</i> <i>Title of instrument</i>	<i>(2)</i> <i>Reference</i>	<i>(3)</i> <i>Extent of modification</i>
The Pressure Systems and Transportable Gas Containers Regulations 1989	SI 1989/2169	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)"

Appendix 1 Application of the Pressure Systems and Transportable Gas Containers Regulations 1989

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 and Transportable Gas Containers Regulations (PSTGCR), will exist and the requirements in PSTGCR will apply.

2 A pressure system, as defined in PSTGCR, 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 PSTGCR 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 PSTGCR as a mobile pressure system. It is the owner of the compressor unit who has responsibility for compliance, particularly with regulation 8 of PSTGCR which requires the pressure system to have a written scheme of examination certified as being suitable by a competent person (as defined in PSTGCR). 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 PSTGCR) who has responsibility for compliance with PSTGCR 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 PSTGCR 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. Further advice regarding the competent person is also given in *A guide to the Pressure Systems and Transportable Gas Containers Regulations 1989* (HSE Books ISBN 0 7176 0489 6).

7 Any working chamber, tunnel, manlock or airlock in which people work in compressed air, being work to which the Work in Compressed Air Regulations 1996 apply, is excepted from the requirements of PSTGCR.

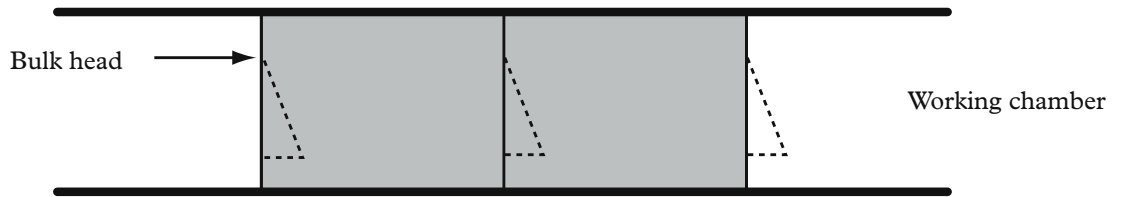
Appendix 2 Use of portable electronic atmospheric gas monitoring equipment in compressed air workings

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 an HSE study).

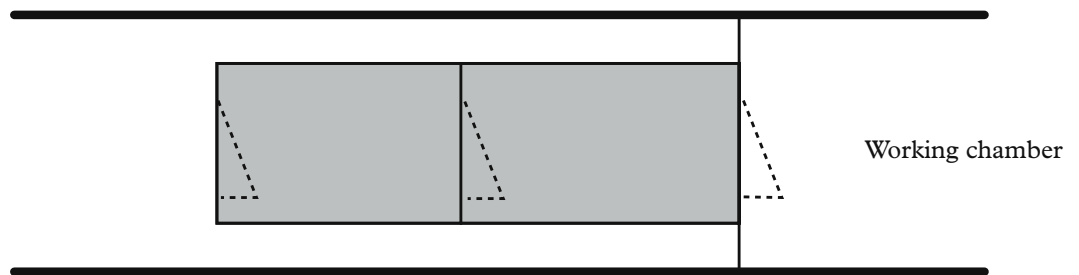
- Commonly available monitors could be used accurately at pressures up to 3.5 bar.
- Monitors taken into the tunnel for the first time should be allowed to stabilise after switching on and then checked, using clean air, to ensure that the toxic and flammable gas sensors are reading zero, and the oxygen sensor is registering approximately 20.9% v/v O₂. 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 (ie 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, eg CO, H₂S, NO₂ etc, pressure fluctuations could cause the relevant sensor in the monitor to alarm. Pressure reductions could cause the sensor to underread. 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 1994 (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. 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.

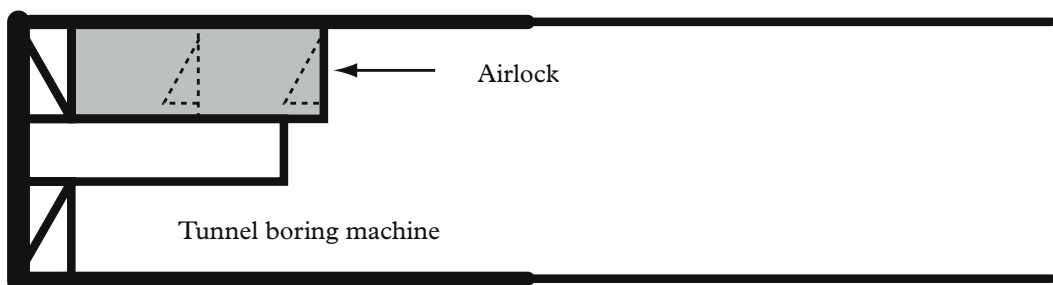
Appendix 3 Types of airlock



Lock formed by bulkheads in tunnel lining



Self-contained pressure vessel (boiler) lock



TBM lock

Appendix 4 The role of the contract medical adviser

1 The contract medical adviser needs to be able to provide advice on all aspects of occupational health relevant to the project. If the employer appoints the contract medical adviser to undertake the statutory medical examinations, one doctor can fulfil the roles of both contract medical adviser and appointed doctor. Contract medical advisers need themselves to be fit to enter compressed air at the pressure to be used in the course of the contract and hold a compressed air worker's health and exposure record.

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

3 The role of the contract medical adviser can be summarised under four main headings:

- (a) prevention and medical examination;
- (b) monitoring and treatment of decompression illness;
- (c) maintenance of records;
- (d) general occupational health advice.

Prevention and medical examination

4 The contract medical adviser will need to be involved in the planning and preparation of a compressed air contract to ensure that the possible general health effects and any specific implications for the incidence of decompression illness are considered at an early stage. He or she may be asked to advise on shift durations for the proposed work and also any necessary specific preventive measures.

5 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 he or she 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 radiological examination; deciding on fitness for work following any illness or injury; arranging any special examinations which may be considered advisable; and maintenance of clinical records for a 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.

Monitoring and treatment of decompression illness

6 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 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.

7 The contract medical adviser should monitor the incidence of decompression illness in the course of a contract, and review the adequacy of preventive measures and advise the compressed air contractor accordingly. Individual cases of decompression illness need to be evaluated for predisposing factors and the overall incidence of the disease monitored as described in Appendix 10. Other means of monitoring the health of the workforce such as anonymous reporting of symptoms can also be considered.

Maintenance of records

8 The contract medical adviser needs to:

- (a) supervise the collation of records of both normal and therapeutic compressions and decompressions, including manlock registers and recording pressure gauge records;
- (b) prepare end-of-contract summaries; and
- (c) 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.

General occupational health advice

9 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.

Appendix 5 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 which 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 of the 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(1)(e) of the Construction (Design and Management) Regulations 1994 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 6 Outline syllabus for a course in hyperbaric medicine relevant to work in compressed air

1 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.

2 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.

3 As any course which is arranged should include practical exposure to a compressed air environment, candidates need to be certified fit for work in compressed air and have a compressed air worker's health and exposure record.

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

Statutory control of work in compressed air

- Health and Safety at Work etc Act 1974
- Management of Health and Safety at Work Regulations 1992 and their 1994 Amendment Regulations
- Construction (Health, Safety and Welfare) Regulations 1996
- Work in Compressed Air Regulations 1996
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
- Control of Substances Hazardous to Health Regulations 1994
- Noise at Work Regulations 1989
- Health and Safety (First Aid) Regulations 1981
- Relevant Social Security Prescribed Diseases Regulations

Role of contract medical adviser

- Duties
- Liaison with compressed air contractor, lock attendants, medical lock attendants, 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 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

Bennet P B and Elliott D H *The physiology and medicine of diving* 4th Edition 1993
W B Saunders ISBN 0 7020 1589 X

Jardine F M and McCallum R I *Engineering and health in compressed air work* E & F
N Spon 1994 ISBN 0419184600

*Results of the analysis of compressed air records in the Decompression Sickness
Central Registry* CIRIA Project Report 6 September 1992

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

Hyperbaric medical facilities in the UK A Report of the British Medical Association
1993 ISBN 0727908197

Royal College of Physicians Faculty of Occupational Medicine *Guidelines on testing
for drugs of abuse in the workplace* 1994 ISBN 1 873240 86 4

Appendix 7 Medical examinations

1 The objective of the medical examinations is to ensure so far as is possible that the worker is fit to enter and work in compressed air. The opportunity can be taken to ensure that any worker exposed to compressed air has been made aware of the risks of decompression illness.

2 The risks of working in compressed air include decompression illness (including cochlear and vestibular dysfunction), dysbaric osteonecrosis and barotrauma to the ears and sinuses. This list is not exhaustive.

3 All people working in compressed air also need to be fit for construction site and tunnel work generally.

4 The complexity of the examinations recommended in the following sections means that it is impractical for one doctor to examine large numbers of workers at short notice. The appointed doctor needs, however, to have access to any of the special examinations required, and should not base decisions on inadequate or incomplete information, no matter how urgent the apparent need. Medical examinations need generally to be arranged well in advance of the start of work and employers should not assume that any individual, particularly on the professional side, will be found fit for this type of work.

5 On any contract, some staff may be recruited several months in advance and a reserve of fit workers built up. Health changes in the intervening months may be significant.

6 The first examination for a person about to work in compressed air on any contract, and the annual full examination should include:

- a health questionnaire
- a full clinical examination
- spirometry
- pure tone audiometry for all workers

Where work is to take place at 1.0 bar or over, the following should also be added:

- at initial examination:
 - chest radiography
 - haematological examination of blood
- at initial and subsequent examinations:
 - exercise tolerance test

Questionnaire and interview

7 It is advisable to check on all points of the questionnaire used since not all workers fully understand the importance of some injuries and accidents. The actual amount of previous exposure to compression should be assessed. The interview also allows some assessment of character and understanding; the willingness of the person to undertake the proposed work needs to be ascertained. Any doubt about this should be discussed with the individual and may contribute to reaching a decision of 'unfitness'.

8 At the start of a contract, a number of workers who genuinely fear work in compressed air may appear for examination. The appointed doctor needs to identify where this is the case, perform a proper physical examination, and, if satisfied that individuals are not psychologically suited to work in compressed air, will need to certify them as 'unfit'.

9 More difficult are those who are apprehensive and if physically fit, will commence work through a sense of obligation. If they do not adapt quickly to the work, they appear to be prime candidates for real or spurious decompression illness in the acclimatisation period.

10 The worker needs to be able to read written instructions and notices and demonstrate familiarity with the underground construction industry. For some posts a good standard of written and spoken English will be required.

11 Workers should be aged 18 years or more. New starters will normally be aged 35 years or under. The only real bar on age for experienced hands should be inability to meet the medical requirements. However, susceptibility to decompression illness increases with age.

Physical examinations

12 Weight should be assessed from several aspects. Physique needs to be commensurate with weight - slim muscular workers are usually preferred. Height/weight ratios such as the Quetelet or Ponderal Index and assessment of body fat by skinfold measurements are useful.

Ears, nose and throat

- 13 (a) The nasal airways should be clear and free of infection. The sinuses also should be disease-free; any acute illness should be treated and any chronic illness carefully assessed. Nasal abnormality is associated with Eustachian dysfunction.
- (b) The mouth, tonsillar fauces and gums should be healthy, especially in those selected for emergency rescue and breathing apparatus duties. There should be no obvious dental cavities in which air may become trapped. Full dentures are permitted.
- (c) The external auditory meati need to be clean and free of excessive wax and infection. A small amount of wax may be left in situ. The tympanic membrane should be intact even though scarred from previous infection. The middle ear cleft should be patent and free of effusion and infection. A dry perforation of the eardrum should not disbar. Previous difficulty with either flying, sport or professional diving and tunnel work suggests caution is necessary in the compression test.
- (d) All persons need to have a pure tone audiogram conducted according to accepted technical standards, see HSE Guidance Note MS 26 *A guide to audiometric testing programmes*. Noise-induced hearing loss (NIHL) is common in compressed air workers, and baseline investigations are necessary. Severe NIHL may be a cause for rejection particularly if communication difficulties arise.
- (e) Hearing loss typical of auditory barotrauma is less frequently seen but can be recognised in the 6 to 8 kHz range as usually unilateral losses of 25 dB upwards. Careful enquiry and possibly electro-nystagmography and caloric studies may be needed to assess abnormalities of balance.

Lungs and respiratory function

- 14 (a) The lungs need to be clinically normal with normal chest development.
(b) A full plate chest radiograph should be normal. Old primary foci are acceptable. Bullae and evidence of old lung disease or serious chest injury are not acceptable. Chest surgery may be acceptable if the reason for the surgery would not itself disbar.
(c) Spirometry should not be less than 20% below the predicted value for age, height and sex. The FEV1/FVC ratio should not be below 70% although some men may have high FVC values permitting lower ratios after careful assessment.

Heart and circulation

- 15 (a) The pulse should be in the normal range at rest. Sitting blood pressure should be no greater than 145/90, with lower levels preferred in younger workers.
(b) The heart should be normal in size and the heart sounds should be normal. The significance of any murmurs needs to be assessed. The peripheral circulation should be normal.
(c) An ECG should be recorded if there are clinical indications. All workers should be capable of a 5-minute step-up test at a rate of 30 per minute on a 43 cm box. The pulse rate should fall satisfactorily after exercise. The tests should, ideally, be conducted in a way which allows an objective estimate of fitness based on the recovery heartbeat counts.

Abdomen

16 The abdomen should be normal to palpation. There should be no herniae. The urine should be free of abnormal constituents. Where abnormalities are found, the subject needs to be referred for investigation.

Special considerations for women of reproductive capacity

- 17 (a) There is no experience of the outcome of pregnancy in women who have worked in compressed air. However, theoretical considerations and experimental results indicate that there is reason to consider that there is risk of serious harm to the foetus from the presence of gas bubbles in the circulation. For these reasons pregnant women should be excluded from work in compressed air.
(b) At the time of medical examination the doctor should discuss with females the potential risk to a foetus from the effects of decompression and explain the need for an early declaration of pregnancy.

The nervous system

- 18 (a) Corrected distance vision should be 6/12 or better using both eyes; near vision should be N8 using both eyes. Colour vision needs to be checked where this is relevant to the work to be done.
(b) The cranial nerves should be intact.
(c) All motor function should be normal but stable abnormalities which do not interfere with safety may be acceptable.
(d) A full clinical neurological examination needs to be made and there should be no Rombergism or inco-ordination.
(e) A history of spinal or cerebral decompression illness may disbar. Epilepsy, schizophrenia or other chronic psychological disease, alcohol or drug abuse, and claustrophobia are likely to be contra-indications.

Endocrine function

19 Active thyroid disease, parathyroid disease and insulin-controlled diabetes are not acceptable. Any disease, the presentation of which may mimic one or more aspects of decompression illness, such as coma, should disbar. Maturity onset diabetes, controlled by diet, may be acceptable for some work which does not involve heavy physical exercise.

The skeleton

- 20 (a) Old injuries and arthritic changes should be carefully assessed for their effects on safety, and liability to cause pain which can be confused with decompression illness.
- (b) The back should be examined and any history of back injury obtained. Surgery to backs needs to be carefully assessed. Severe persisting pain or evidence of a prolapsed intervertebral disc should disbar, the latter at least temporarily.
- (c) For work at 1.0 bar or over, the major joints should be radiologically examined for evidence of dysbaric osteonecrosis in all workers with previous experience (unless it is certain that no work has been done at pressures of 1.0 bar or over). Access to the results of recent films may avoid the need for re-examination. Where lesions are present, the worker needs to be informed and disbarred if the lesions are juxta-articular. Further details are given in Appendix 8.

Haematology

- 21 (a) Haematological changes have been reported in divers but not in tunnel workers. Nevertheless a full haematological screen is recommended for all new starts.
- (b) It is not essential to record blood group.
- (c) Haemoglobin electrophoresis is advised for sickling and B thalassaemia in individuals of appropriate ethnic origin.

Application of findings

22 As a result of medical examination an individual may be found to be fit or unfit for work in compressed air or fit subject to limitations such as to the pressure or duration of exposure. The findings of the examination need to be recorded in the statutory health record and in the person's health and exposure record.

23 All people exposed to compressed air must be able to clear the ears and should be free of relevant ear and sinus disease. Susceptibility to decompression illness is generally thought to be related to body fat content and increasing age and body fat content are both associated with an increased incidence of osteonecrosis. These associations are not, however, clear-cut. As well as the clinical findings, both age and body fat content should be considered in judging fitness for work in compressed air.

24 Also important are an individual's general physical fitness in relation to the work to be done and past experience of work in compressed air. An overall judgement has to be made as to whether the individual concerned is thought likely to be fit for the intended work and exposure to compressed air.

25 Casual visitors to compressed air should be discouraged. Medical standards should not be lowered for 'VIPs', including those with professional involvement in the contract.

Appendix 8 Radiology

1 The only practical and cost-effective technique which is available to detect the presence of aseptic necrosis of bone, after the initial damage has occurred, is radiology of the long bones. Although exposure to X-rays carries some risk, the serious nature of the damage caused by osteonecrosis justifies the use of radiology to detect this.

2 Radiological skeletal surveys for the detection of osteonecrosis should be conducted according to the guidance prepared by the Medical Research Council Decompression Sickness Panel and published in *Radiography* June 1981, pp 141-43 (reproduced from paragraph 11 to the end of this appendix). The films should be reported on by a doctor with a knowledge of the characteristic features of osteonecrosis.

3 Radiation carries with it risks of cancer and of hereditary defects. The fatal cancer risk from one skeletal survey of the type recommended for compressed air workers has been estimated to be about 1 in 65 000. Although this risk is low, it is cumulative. Six-monthly radiology between ages 18 and 46 years would entail a fatal cancer risk of the order of 1 in 1200.

4 The frequency at which the bones are examined should be related to the pressure to which an individual is exposed during the course of a contract.

5 For pressures below 1.0 bar there is no risk of osteonecrosis and no need for radiology.

6 For pressures of 1.0 bar or over it is recommended that a skeletal survey be undertaken within 3 months of initial exposure to compressed air, to act as a baseline for reference.

7 Thereafter, radiology may be repeated on an annual basis during the course of work and repeated 1 year after exposure to compressed air has ceased. Some work patterns at pressures in excess of 2.0 bar may require more frequent examinations.

8 At any working pressure a repeat examination may be necessary if there are clinical indications of bone or joint disease.

9 The need for a follow-up skeletal survey can be entered on the health record by an examining doctor under the provision of regulation 10(5). Where a worker remains with the same employer after completion of a period of work in compressed air, the employer should arrange for any such follow-up examination to be made.

10 The original radiographic plates need to be retained by the appointed doctor or the contract medical adviser for the same period as other clinical records, ie 40 years.

Radiological skeletal survey for aseptic necrosis of bone in compressed air workers

11 The basic skeletal survey should include antero-posterior projections of the heads and proximal shafts of both humeri and both femora together with antero-posterior and lateral projections of the distal two-thirds of both femora and proximal third of both tibiae, including the knee joints.

12 The radiological diagnosis of early lesions of aseptic bone necrosis requires high quality radiographs which demonstrate the bone trabeculae clearly. The optimum screen-film combination (using rare-earth intensifying screens, if available) and good screen-film contact is required, together with a grid of adequate ratio and a focal spot of 0.6 to 1.2 mm. A tube with a high speed rotating anode and 0.6 mm target, if available, is ideal.

13 Exposures should always be adequate. Probably the greatest fault lies in underpenetration of the bone tissue. Increased penetration by as much as 5 to 10 kV above normal is recommended.

14 The recommendations in the *Guidance notes for the protection of persons against ionizing radiations arising from medical and dental use* (NRPB et al, 1988, HMSO) should be followed. **Gonads must always be protected by a lead shield when radiographing the hips.**

Recommended procedure

Shoulder: antero-posterior projection

- The area to be examined is the head and neck of the humerus, including the proximal third of the shaft.
- The radiograph should show the articular surface of the humeral head unobscured by overlying bony structures, and should give good definition of the trabeculae of the head and shaft.
- A 24 cm x 18 cm screen film is recommended with high definition or rare-earth intensifying screens and moving grid.
- The examination is best carried out on a horizontal table.
- From the supine position, the patient is rotated through about 45° towards the side under examination until the blade of the scapula is parallel to the table top. The raised shoulder is supported on sandbags.
- The arm under examination should be straight, supinated and abducted 10°. An extending pull should be applied to the arm so that the humeral head is clear of the bony processes of the scapula.
- The X-ray beam should be at right angles to the film and centred over the head of the humerus. The beam should be collimated to show only the head and proximal third of the humerus.
- The patient should hold his or her breath while the exposure is made.

Hip joint and proximal third of the shaft of the femur: antero-posterior view

- The radiograph should show good definition of the articular surface of the femoral head and of the trabeculae of both head and shaft. The underlying acetabulum cannot be avoided.
- A separate radiograph of each hip is required.
- A 30 cm x 24 cm screen film is recommended with fast tungstate or rare-earth intensifying screens and a moving grid. Fast tungstate screens are recommended in this situation to reduce the radiation dose. 2.5 to 5.0 kV more than normal should be used to increase penetration.
- *The gonads must be protected*, but care should be taken to ensure that the protection does not obscure the femoral head.
- With the patient supine, the plane across the anterior superior iliac spines should be horizontal. The foot of the side under examination should be at right angles to the table top and sandbagged into position.
- The X-ray beam should be at right angles to the film, centred over the head of the femur, and collimated to show the head and proximal third of the femur.

Knee joint: antero-posterior projection to show the distal two-thirds of the femur and the proximal third of the tibia

- The radiograph should show clear trabecular detail in the lower two-thirds of the femur and the upper third of the tibia.
- There is a variation of density between the middle and lower thirds of the femoral shaft, so that it is necessary to increase the kilovoltage, reduce the milliamperage, and use a moving grid to produce a radiograph of even contrast. Care should be taken not to underpenetrate the shaft of the femur.
- Either a 40 cm x 15 cm screen film with high definition is recommended or rare-earth intensifying screens and a moving grid.
- The patient should sit on the X-ray table with legs extended.
- Each knee should be examined separately.
- The X-ray beam should be at right angles to the table top. In order that the lower two-thirds of the femur are included, the beam should be centred at the upper border of the patella - not through the joint space. The beam should be collimated to show only the area under examination.

Knee joint: lateral projection to show the distal two-thirds of the femur and the proximal third of the tibia

- A lateral radiograph of the lower femur and upper tibia may demonstrate slight variations in bone density and trabecular detail which are not apparent in the antero-posterior projection.
- The requirements of definition are the same as for the antero-posterior projection. The gradation of density along the femoral shaft is also evident in the lateral projection, and the exposure should be adjusted to give a radiograph of even contrast.
- Either a 40 cm x 30 cm or a 40 cm x 15 cm screen film with high definition is recommended or rare-earth intensifying screens and a moving grid.
- Using the wide film, positioning should be as for a normal lateral projection of the knee with the knee flexed and the tibia parallel to the long axis of the film. Care should be taken to include the distal two-thirds of the femur.
- If the narrow film is used, the leg should be straight and parallel to the long axis of the film to include the distal two-thirds of the femur.
- The X-ray beam should be at right angles to the film and centred over the femur level with the upper border of the patella. The beam should be collimated to the area under examination.

Appendix 9 Compression and decompression procedures approved by the Health and Safety Executive

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, breathing air. Decompression from pressures of 1.0 bar and over is required to be in accordance with the tables (known as the Blackpool Tables) shown on pages 67-68. Decompression from pressures of less than 1.0 bar should be at a rate not greater than 0.4 bar per minute.

- 5 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, ie 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 appropriate stage pressures and times at stage pressures from the decompression tables on pages 67-68;
 - (d) noting the starting time and starting the stop-clock where provided;
 - (e) reducing the pressure at a rate not faster than 0.4 bar per minute to, but not lower than, the first stage according to the decompression tables being used;
 - (f) 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; and
 - (g) ventilating the manlock at intervals of no more than 15 minutes. This 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.

6 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 medical lock attendant is informed immediately.

Blackpool Tables

<i>Pressure in bar</i>															
<i>Table number</i>	<i>Maximum working pressure</i>	<i>Exposure period (hours)</i>	<i>Time (minutes) at stage pressure of:</i>								<i>Total decompression period (min)</i>	<i>Line number</i>			
			1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4			0.2		
1	1.0–1.15	0–0.5									3	1			
		0.5–1.0									3	2			
		1.0–1.5									3	3			
		1.5–2.0								5	8	4			
		2.0–2.5								5	8	5			
		2.5–3.0								10	13	6			
		3.0–4.0								15	18	7			
		4.0–9.5								20	23	8			
2	1.2–1.35	0–0.5									4	1			
		0.5–1.0									4	2			
		1.0–1.5								5	9	3			
		1.5–2.0								10	14	4			
		2.0–2.5								20	24	5			
		2.5–3.0								5	20	29	6		
		3.0–4.0								5	30	39	7		
		4.0–9.25								5	35	44	8		
3	1.4–1.55	0–0.5									4	1			
		0.5–1.0								5	9	2			
		1.0–1.5								10	14	3			
		1.5–2.0								5	20	29	4		
		2.0–2.5								5	30	39	5		
		2.5–3.0								10	35	49	6		
		3.0–4.0								15	40	59	7		
		4.0–8.75								5	20	40	69	8	
4	1.6–1.75	0–0.5									5	1			
		0.5–1.0								5	10	2			
		1.0–1.5								5	15	25	3		
		1.5–2.0								10	30	45	4		
		2.0–2.5								15	40	60	5		
		2.5–3.0								5	20	40	70	6	
		3.0–4.0								5	25	45	80	7	
		4.0–8.5								10	30	45	90	8	
5	1.8–1.95	0–0.5									5	1			
		0.5–1.0								10	15	2			
		1.0–1.5								5	30	40	3		
		1.5–2.0								5	15	35	60	4	
		2.0–2.5								5	25	40	75	5	
		2.5–3.0								10	30	40	85	6	
		3.0–4.0								5	15	30	45	100	7
		4.0–8.0								5	20	35	45	110	8
6	2.0–2.15	0–0.5									5	11			
		0.5–1.0								5	15	26			
		1.0–1.5								5	10	35	56		
		1.5–2.0								5	25	40	76		
		2.0–2.5								5	10	30	45	96	
		2.5–3.0								5	15	35	45	106	
		3.0–4.0								10	20	35	45	116	
		4.0–7.75								5	10	25	40	50	136

Note: Decompression both to the first stage and between stages must be at rates not faster than 0.4 bar/min.

Blackpool Tables (continued)

<i>Pressure in bar</i>														
<i>Table number</i>	<i>Maximum working pressure</i>	<i>Exposure period (hours)</i>	<i>Time (minutes) at stage pressure of:</i>									<i>Total decompression period (min)</i>	<i>Line number</i>	
			1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2			
7	2.2–2.35	0–0.5									5	11	1	
		0.5–1.0								5	20	31	2	
		1.0–1.5							5	20	35	66	3	
		1.5–2.0							5	10	30	40	91	4
		2.0–2.5							5	20	35	45	111	5
		2.5–3.0							10	25	35	45	121	6
		3.0–4.0						5	15	25	40	45	136	7
		4.0–7.25						10	20	30	40	55	161	8
8	2.4–2.55	0–0.5										5	12	1
		0.5–1.0									10	25	42	2
		1.0–1.5								10	25	40	82	3
		1.5–2.0							5	20	35	40	107	4
		2.0–2.5					5	10	25	35	45	127	5	
		2.5–3.0					5	15	30	35	45	137	6	
		3.0–4.0				5	5	25	30	40	45	157	7	
		4.0–6.75				5	15	25	30	45	60	187	8	
9	2.6–2.75	0–0.5										5	12	1
		0.5–1.0							5	10	35	57	2	
		1.0–1.5							5	10	30	45	97	3
		1.5–2.0						5	10	25	35	45	127	4
		2.0–2.5						5	20	30	35	45	142	5
		2.5–3.0				5	10	20	30	35	45	152	6	
		3.0–4.0				5	15	25	30	40	45	167	7	
		4.0–6.5			5	10	20	25	30	45	70	212	8	
10	2.8–2.95	0–0.5									5	5	18	1
		0.5–1.0								5	15	40	68	2
		1.0–1.5							5	20	35	45	113	3
		1.5–2.0						5	15	30	35	45	138	4
		2.0–2.5				5	10	20	30	35	45	153	5	
		2.5–3.0				5	20	25	30	35	45	168	6	
		3.0–4.0			5	10	20	25	30	40	45	183	7	
		4.0–5.75			10	15	20	30	40	50	80	253	8	
11	3.0–3.15	0–0.5									5	5	18	1
		0.5–1.0							5	5	20	40	78	2
		1.0–1.5						5	10	20	35	45	123	3
		1.5–2.0				5	10	20	30	35	45	153	4	
		2.0–2.5			5	5	15	25	30	35	45	168	5	
		2.5–3.0			5	10	20	25	30	40	45	183	6	
		3.0–4.0		5	5	15	25	25	30	40	45	198	7	
		4.0–5.0		5	15	15	25	30	45	55	100	298	8	
12	3.2–3.45	0–0.5									5	10	24	1
		0.5–1.0							5	10	25	40	89	2
		1.0–1.5						5	15	25	35	45	134	3
		1.5–2.0				5	15	25	30	35	45	164	4	
		2.0–2.5			5	10	20	25	30	40	45	184	5	
		2.5–3.0		5	5	15	25	25	30	40	45	199	6	
		3.0–4.0		5	15	20	25	30	30	40	45	219	7	
		4.0–4.25	5	10	15	20	25	35	45	60	120	344	8	

Note: Decompression both to the first stage and between stages must be at rates not faster than 0.4 bar/min.

Appendix 10 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. 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 (eg depth-time profile)

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

(Reference: Francis T J R and Smith D (Eds) *Describing dysbarism* Bethesda, Md.: Undersea and Hyperbaric Medical Society 1991)

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:

- (a) loss of consciousness. This may occur during the later stages of manlock decompression or soon after its completion;
- (b) collapse, with signs and symptoms of shock;
- (c) giddiness (the 'staggers');
- (d) difficult breathing (tightness of the chest or 'chokes');
- (e) visual symptoms (flashes of light, spots before the eyes or tunnel vision);
- (f) headache;
- (g) abdominal pains, with or without vomiting;
- (h) weakness or paralysis of limbs;
- (i) 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, while not in themselves requiring treatment as decompression illness, should 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 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 (see page 68) devised by the former Medical Research Council Decompression Sickness Panel, Compressed Air Working Group may be of help.

14 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 acclimatisation, temporary unfitness or inadequate decompression. A check needs to be made on the adequacy of decompression following all cases of decompression illness.

15 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 8 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.

16 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.

17 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*.

18 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.

Compressed air worker's decompression illness case sheet

Please tick appropriate boxes

Employer..... Date..... NI No.....
 Full name of worker..... Works No.....
 Contract..... Occupation..... Activity: manual/supervisor/sedentary.....
 Age..... Height (cm)..... Weight (kg)..... Body mass index.....
 Date of last medical assessment..... Result: fit/conditions.....

Have you had decompression illness before? Yes No If yes, how many times?.....
 When?.....

Details of work in 8 shifts previous to this attack

Day	1	2	3	4	5	6	7	8
Date								
Maximum working pressure (bar)								
Working period								

Any decompression illness? Yes No

Details of exposure immediately preceding illness

Maximum working pressure (bar)..... If multiple exposure, how many?.....
 Date and time of start of last compression.....
 Date and time of start of last decompression..... Time last decompression completed.....

Decompression tables used (give details)..... Was anyone else affected? Yes No

Shift: Day Night Back Head cold? Yes No Chest cold? Yes No

Pain only (bends)

How soon after decompression?..... Site of pain.....

Localised? Yes No Spreading? Yes No Any injury to affected part Yes No

Excessive use of limb during shift? Yes No Any symptom other than pain?.....

Skin mottling? Yes No Skin irritation? Yes No Vomiting? Yes No

Serious

Signs and symptoms.....

Circulatory? Yes No Respiratory? Yes No Visual? Yes No Neurological? Yes No

Treatment (pain only or serious)

Time commenced..... Pressure of relief.....
 Highest pressure used..... Time at that pressure.....
 Method of decompression.....
 Number of recompressions..... Time treatment completed.....
 Residual symptoms.....

Evidence of recurrence after above treatment Yes No

Treatment apparently successful Fit to work in compressed air again? Yes No

Signed Signed.....
 Medical lock attendant Medical adviser

19 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.

20 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.*

21 For further information on the derivation and use of the standardised decompression illness ratio, see CIRIA Project Report No. 6, *Results of the analysis of compressed air records in the Decompression Sickness Central Registry*, September 1992. Table 1, which gives values of decompression illness rates for different time and pressure exposure cells is derived from Table 1 of Section 2 of that report.

Table 1 Decompression illness rates for different exposure times and working pressures (%)

Pressure (bar)	Length of exposure (hours)				
	0-2	2-4	4-6	6-8	8 or more
1-1.2	0.02	0.04	0.05	0.20	0.43
1.3-1.5	0.03	0.11	0.17	0.49	0.43
1.6-1.8	0.12	0.21	0.50	0.67	0.48
1.9-2.1	0.12	0.20	0.89	1.25	0.95
2.2-2.3	0.19	0.78	1.18	1.35	1.60
2.4-2.6	0.14	0.74	1.18	2.26	1.49
2.7-3.5	0.26	1.65	5.90	2.97	2.61

Note: The rates are derived from the records held in the former Decompression Sickness Registry of the Medical Research Council at Newcastle University. They are for normal decompressions, ie excluding decanting, and using either the 1958 or the Blackpool Tables. The pressure bands have been rounded to the nearest 0.1 bar from the original and should not be considered to be exact.

Appendix 11 Decompression illness initial assessment checklist

All workers presenting with 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.

Name
Date
Time of assessment
Maximum pressure of last shift
Duration of last shift
Any other exposure to compressed air in last 24 hours
Time since decompression
Symptoms
Worker's complaints - general
Walking and balance
Breathing
Mental function - general
Level of consciousness
Vision
Hearing
Peripheral numbness - tingling
Pain - limbs Pain - other
Skin
Physical assessment Vital signs: pulse rate Vital signs: blood pressure Vital signs: respiration rate

Neurological system	Left	Right
Pupils - size		
Reaction to light		
Reaction to accommodation		
Eye movements		
Nystagmus present		
Facial nerve, smile, clench teeth, equal		
Hearing		
Tympanic membranes		
Speech, quality		
Tongue, any deviation		
Co-ordination: finger nose test		
Eyes open		
Eyes closed		
Muscle strength		
Shoulder shrug		
Grip strength		
Raise arms to shoulder height		
Push with flexed arm		
Pull with flexed arm		
Straight leg raising		
Dorsiflexion of foot		
Plantarflexion of foot		
Reflexes: plantar Reflexes: arms Reflexes: legs		
Sensation: light touch arm Sensation: light touch leg Sensation: pin prick arm Sensation: pin prick leg		

Appendix 12 Therapeutic recompression

1 Management of the treatment of decompression illness is the responsibility of the contract medical adviser. The following procedures were developed by the Medical Research Council Decompression Sickness Panel and have been 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*. Contract medical advisers can, themselves, decide whether to use these procedures or to use oxygen treatments which are now standard practice in treating decompression illness which occurs in diving. For work at pressures of 1.0 bar or above, HSE guidance is that medical locks need to be equipped for, and able to provide, the administration of oxygen. 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 0 7153 0100 4).

Therapeutic procedures, using air only for pain only decompression illness

2 The following procedures have been found to be successful when treating pain only decompression illness:

- (a) recompress to 0.1 bar above the maximum working pressure to which the patient has been exposed;
- (b) if pain is not relieved in 15 minutes, raise pressure 0.1 bar;
- (c) if pain still persists, raise the pressure another 0.1 bar and repeat if necessary at 15-minute intervals. It is only on rare occasions that pressure as high as 0.7 bar above working pressure is required to relieve the symptoms;
- (d) wait at the pressure which has given relief for 10 minutes after all pains have completely gone, then commence decompression;
- (e) reduce the pressure at the rate of 0.1 bar every 2 minutes to half the maximum working pressure, then reduce to atmospheric pressure at the rate of 0.1 bar every 25 minutes;
- (f) should the symptoms return during the last stages of decompression, or after it has been completed, the patient should be recompressed again. This recompression may be as above;
- (g) after 10 minutes at this pressure, continue the decompression at the rate of 0.1 bar every 25 minutes.

3 During recompression, pain, particularly below the knee, may occasionally intensify. While breathing oxygen, pressure should only slowly be increased as the patient is able to tolerate the pain. If treatment is on air only, the pressure will require to be reduced to allow the pain to subside, followed by a slow recompression.

Therapeutic procedures, using air only for serious decompression illness

4 Decompression illness with severe symptoms may present as paralysis of limbs and can lead to death; the need for recompression is urgent. Treatment should be under the supervision of the contract medical adviser, though the initial recompression should not be delayed for any reason whatsoever. The contract medical adviser should be informed immediately when serious decompression illness is diagnosed or suspected. As the resulting neurological signs may be quite subtle, the assessment of the medical lock attendant will need to be supplemented by that of the contract medical adviser in due course.

5 The basic procedure for treatment of serious decompression illness is immediate recompression to working pressure, or a higher pressure if required, the maintenance of the effective pressure for at least 30 minutes after all abnormal

signs and symptoms have disappeared, then decompression carried out very slowly and very carefully. Prompt treatment is rendered easier by the fact that the majority of people suffering from serious decompression illness develop symptoms before leaving the site.

6 In severe cases, particularly if decompression illness is detected early and treated properly, response to recompression is dramatic. If response is poor, higher pressure should be used, even up to the maximum working pressure for the lock. Treatment will need to be continued, for a period of days if necessary, as long as there continues to be improvement, however slight.

7 If a person collapses or appears to be dangerously ill on leaving the manlock at the end of a decompression, immediate recompression in the manlock is preferable to wasting valuable minutes by transporting the casualty to a distant medical lock.

8 The following decompression procedure is prolonged but has proved to be satisfactory. It is extremely rare for a patient who has received this decompression in full to require further recompression. Decompression should only be commenced with the authority of the contract medical adviser, who needs to be regularly informed of progress.

- (a) Reduce the pressure to 1.0 bar at the rate of 0.1 bar every 25 minutes.
- (b) Maintain a pressure of 1.0 bar for 4 hours (this is called 'soaking').
- (c) Reduce the pressure to 0.5 bar at the rate of 0.1 bar every 45 minutes.
- (d) Maintain a pressure of 0.5 bar for 1.5 hours.
- (e) Reduce the pressure to 0.2 bar at the rate of 0.1 bar every 45 minutes.
- (f) Maintain a pressure of 0.2 bar for 1 hour.
- (g) Reduce the pressure to atmospheric at 0.1 bar every 45 minutes.

9 During these procedures, the patient will need to be observed constantly. If symptoms return, the patient should be recompressed at once. This recompression may not necessarily be back to the original pressure but it will need to be to a sufficiently high pressure to remove all symptoms. Then, after a 30-minute wait at the new pressure, decompression should be started again.

10 After treatment has been completed and a final examination made, the patient will need to remain under observation near the lock for 2 hours before being transported home, and warned to return if any further symptoms develop.

Appendix 13 Use of high pressure oxygen

Compressed oxygen must be used in a safe manner in order to minimise the risk of fire or explosion.

- 1 Breathing quality oxygen should be supplied to a manifold in the lock into which orinasal masks (built-in breathing system (BIBS)) can be connected by the use of self-sealing, quick connect fittings. Fittings for two masks to be in operation simultaneously in the medical lock should suffice for most contracts.
- 2 Oxygen should be supplied from high pressure cylinders manifolded together. The pressure of oxygen supplied to the lock should not exceed 10 bar. Oxygen cylinders should be adequately protected from fire and from impact.
- 3 The installation should generally be in accordance with the requirements for oxygen pipework to hyperbaric chambers, of one of the offshore industry "Classification Societies".
- 4 All pipework for the oxygen system should be made up from copper tubing or an oxygen compatible alloy. Armoured flexible pipework, valves, joints and other fittings should also be oxygen compatible.
- 5 The installation should be oxygen cleaned on installation and after any alteration. When not in use all open-ended pipes should be capped.
- 6 There should be a valve, preferably a quarter-turn valve, at the lock attendant's station to isolate the supply of oxygen to the chamber, but only in the event of an emergency and the function of this valve should be clearly indicated. All other valves controlling the flow of oxygen should be slow acting.
- 7 No mineral oil or grease should be used on any surface or component likely to be exposed to oxygen.
- 8 The lock attendant should be able readily to ascertain the pressure in the supply cylinders from the lock control position. The lock attendant should ensure that sufficient oxygen is always available to meet the anticipated requirements for decompression.
- 9 The discharge of exhaled oxygen should be directly to free air outside the tunnel, lock or any weather protection structure around the lock (overboard dump) and in a location where it cannot be tampered with or collect rainwater.
- 10 The inside of any lock in which oxygen is likely to be used should be kept thoroughly cleaned. No unnecessary flammable material should be in the lock.
- 11 Well-fitting orinasal masks should be supplied for use with oxygen. The masks should have hoses for supply and exhaust, be fitted with an appropriate demand regulator and an appropriate discharge valve on the outlet. The free flow of oxygen from masks should be avoided at all times.
- 12 Each mask should be cleaned after use with an appropriate disinfectant solution compatible with the materials from which it is manufactured. Masks need not be connected when not in use. Spare masks should be available for use.
- 13 Only a lock attendant, trained and competent to operate a lock in which oxygen breathing is being carried out and who has had previous experience of such operations, should be permitted to operate the lock. Such lock attendants are likely to have worked in the offshore diving industry.

14 The lock attendant should regularly ensure that the lock and its equipment including the fire suppression system is kept clean and ready for immediate use. In addition all gauges, valves and instrumentation should be calibrated as necessary and maintained in full working order and ready for use.

15 The lock attendant should continuously ventilate the lock while oxygen is being administered.

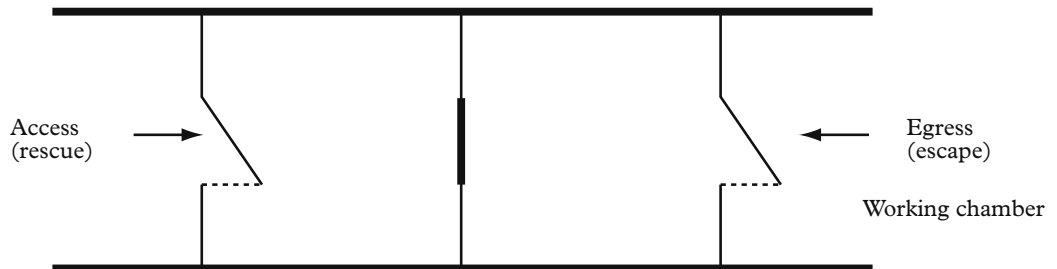
16 The lock should be fitted with equipment to monitor the volume concentration of oxygen in the lock atmosphere. The equipment should alarm when the volume concentration of oxygen exceeds 23%.

17 An absolute prohibition on smoking and the possession of materials for smoking in any lock fitted with oxygen breathing equipment must be rigidly enforced.

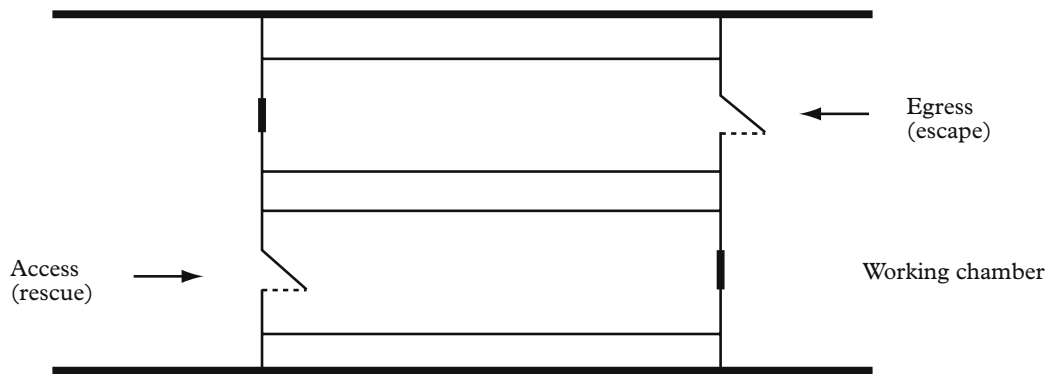
18 People entering the chamber for oxygen treatment should be given clean, flame-retardant clothing and should not have any traces of oil, grease or similar flammable substance on their skin.

Appendix 14 Access to and egress from the working chamber

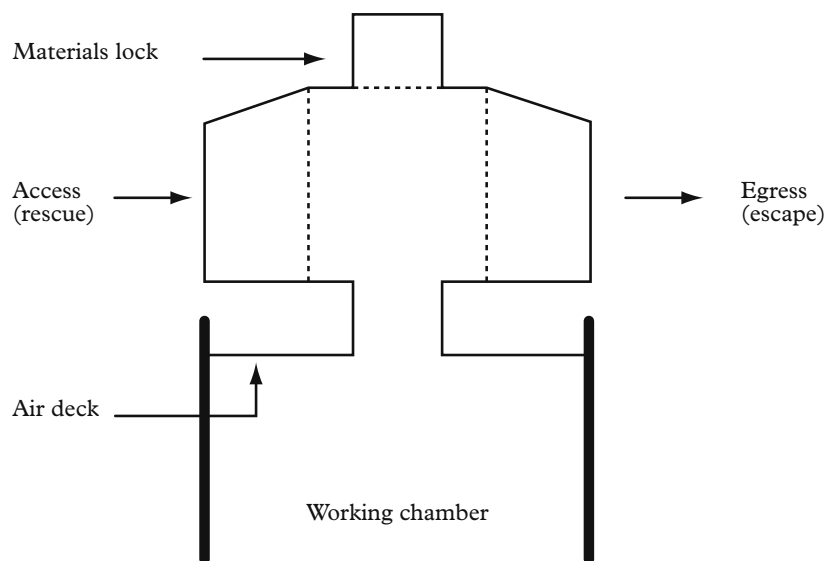
See regulation 13(2)(a) and (b)



Two-compartment tunnel airlock



Two single compartment tunnel airlocks



Two-compartment vertical tunnel lock

Appendix 15 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;
 - (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 may not 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 5 minutes. 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.

Appendix 16 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 The exposure record will need to contain personal details of the worker and record the date, time of entry, duration and maximum working pressure for each exposure to compressed air and decompression details of each exposure.

4 A part of the exposure record should be produced by the lock attendant each time a person is compressed and decompressed. In practice, a clean copy of the exposure record will be made by the medical lock attendant.

5 In addition, 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

6 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 150 in the guidance give full details of the information needed.

7 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

8 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;
- (d) that person is provided with a copy of the parts of the individual exposure record that relate to him or her.

The employer

9 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

10 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.

11 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.

12 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 150 of this guidance.

Keeping of the records

13 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.

14 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.

15 A copy of the decompression tables used needs to be included with the records.

16 It is recommended that the health and exposure records are retained on the computer system at the offices of the Building & Civil Engineering (B & CE) Benefits Scheme, Manor Royal, Crawley, West Sussex RH10 2QP. A fee will be charged for this service.

17 The records should be sent to the B & CE Benefits Scheme as soon as is reasonably practicable after the work in compressed air has ceased.

18 A disc containing a programme suitable for this purpose can be obtained from HSE at:

Directorate of Science and Technology
Magdalen House
Stanley Precinct
Bootle
Merseyside L20 3QZ

19 The B & CE Benefits Scheme's computer system can read any data from the most commonly used spreadsheet and database packages, but if in doubt check with the B & CE Benefits Scheme.

20 The employee's national insurance number needs to be included in the records which are retained by the B & CE Benefits Scheme because this number is the major form of identification.

Access to the records

21 The records should be accessible to:

- HSE;
- individual compressed air workers, or their representatives, who can retrieve their records by contacting their employers or the B & CE Benefits Scheme, 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 17 Summary of principal changes in requirements with increasing pressure

<i>Pressure*</i>	<i>Requirement</i>	<i>Guidance paragraph number</i>
0.15	Work in Compressed Air Regulations 1996 apply	3
0.5	Pressure Systems and Transportable Gas Containers Regulations 1989 apply to plant and equipment if relevant	48
0.7	Medical lock and 'person competent to operate it'	188,198,199
1.0	Medical lock attendant	25, 200
	Heating and seating in manlock	82, 88
	Vertical lock not to be used for decompressions of people	90
	Recording pressure gauge	104
	Radiology	130
	Intervals between medical examinations not to exceed 28 days	141
	Acclimatisation to work and pressure	165 et seq
	Limits on working period and number of exposures per day	174 et seq
	Staged decompression	177
	Oxygen in medical lock	192
Resuscitation equipment	201	
	Remain on site for 1 hour after decompression	250
2.0	More stringent acclimatisation procedures	167
2.8	People to remain on site for 1.5 hours	250
3.5	Maximum exposure pressure	Regulation 11

* Pressure (in bar) equals or exceeds stated value in table.

This summary is indicative only.

Further information

For information about health and safety ring HSE's Infoline Tel: 0845 345 0055
Fax: 0845 408 9566 Textphone: 0845 408 9577 e-mail: hse.infoline@natbrit.com or
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