GUIDELINES FOR GOOD OCCUPATIONAL HEALTH AND SAFETY PRACTICE IN TUNNEL CONSTRUCTION

ITA Working Group
Health and Safety in Works

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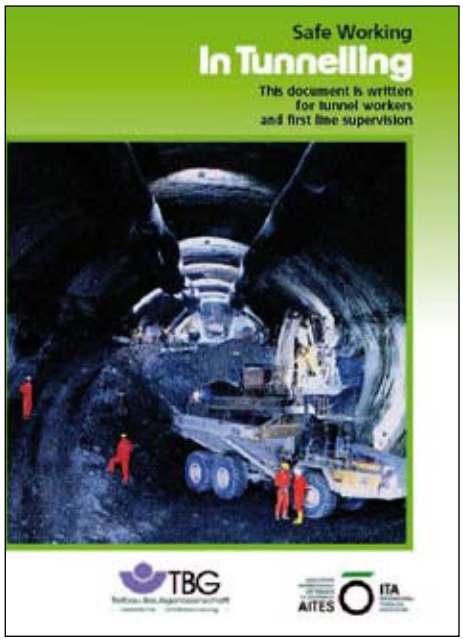
Introduction



ITA booklet – Safe working in tunnelling

Not all countries have a comprehensive framework of regulations and guidance to ensure that underground construction work is conducted in a safe and healthy manner. In those which do, the regulations normally lay down as broad principles the measures that are to be adopted, but detailed guidance may be left to national standards or industry publications.

The "Guidelines for Good Occupational Health and Safety Practice in Tunnel Construction" are not intended to replace existing national regulations or guidance but to provide guidance on basic good practice where none exists. As such they should be incorporated into contract documents where appropriate.

These guidelines contain details of publications relevant to health and safety in tunnelling from countries represented on WG5.

A glossary of terms and definitions relating to tunnelling, hazard and risk can be found at www.ita-aites.org. A short table of terms not defined in the ITA glossary is included on page 5 of this document.

Throughout this text reference is made to "competent" persons – the competence required for each role is different and is thus not defined but "competence" as a concept is defined as "the combination of education, skills and experience appropriate to the task to be undertaken".

This text is a revision by ITA WG5 of its document "Health and Safety in Works" first published in 1991. This revision was sponsored by the UK Health and Safety Executive.

Contents

1 >> Safety at the design and planning stage

1.1. HEALTH and SAFETY PLAN (HSP)

1.1.1. Before any design or planning work begins, an occupational health and safety strategy for the project should be drawn up and set out in a health and safety plan. The health and safety plan should form the basis for the identification and management of all health and safety risk arising from the works. The client or promoter of the project should join with the designers and contractors in setting the strategy and drawing up and maintaining the plan and should monitor its implementation.

1.1.2. Tunnelling involves both general construction risks and risks which are specific to the tunnelling environment and therefore establishing a health and safety plan should be done by competent staff.

1.1.3. To be effective, the planning of health and safety risk identification and management measures must begin during the project design stage. The implementation during the construction phase should be monitored, so that any revisions be made when necessary.

1.1.4. The plan should also contain details of emergency procedures as well as welfare and first aid facilities. A copy of the plan should be made available to everyone on site.

1.1.5. The main hazards to be addressed in the plan are covered in some detail in the sections which follow.

1.1.6. The design and planning stage of any tunnelling project should be adequately resourced in terms of money, staff and time.

1.1.7. Resources - time, money and expertise - spent on design and planning as well as on ground investigation and its interpretation should result in a more informed choice of excavation and lining methods and in more effective planning of safe construction methods.

1.1.8. Preliminary work should include:-

- Research of existing historical data, existing regional and site specific geological data, local engineering expertise etc.
- Consultation with national bodies concerned with the natural environment, geology, mineral workings, planning and transport.
- Consultation with utility service providers, particularly in urban areas, including the electricity, gas, water, communications, highway and railway authorities and owners of other nearby underground and surface services.
- Ground/site investigation by means of seismic methods, boreholes, trial pits, exploratory shafts and tunnels etc.
- An assessment of the hydrogeology of the area.
- An assessment of the risk of encountering methane or other hazardous gas in the ground or hazardous substances such as asbestos or industrial waste – solid or liquid.
- An estimate of the levels of atmospheric and other contamination in the tunnel during construction e.g. dust from rock drilling, concrete spraying etc.
- A thorough review should be made of the ground/site investigation results and how they may affect:
- The selection of the most appropriate tunnelling and shaft sinking methods.
- The selection of suitable tunnelling machinery.
- The selection of appropriate lining methods.
- The monitoring scheme to be put in place to evaluate the safety of the working environment during the construction phase.

1.1.9. All the information from the site investigation together with any interpretative reports which could possibly affect the safety of persons during the construction period should be given to the tunnel constructor.

1.1.10. An audit should be made of the technical competence i.e. qualifications and experience, of the key personnel to be assigned to all stages of the project – this should extend to competence in health and safety matters.

1.1.11. Safety policies should be established for all the parties involved in the project which will include a clear chain of authority and communication. These policies should also specify responsibilities for safety.

1.1.12. Careful consideration should be given to the design and siting of any temporary works associated with the tunnelling project. These could include: temporary access shafts and adits, temporary cofferdams and caissons, pilot tunnels, thrust pits and walls, any temporary ground support etc along with materials storage areas, working areas and site offices.

1.1.13. Appropriate training courses should be designed and put in place for persons unfamiliar with the nature of the tunnelling work to be undertaken.

1.1.14. There is a need to survey the condition of adjacent buildings or subsurface structures whose structural integrity may be affected by the proposed tunnelling works.

1.1.15. Once the tunnel construction contract has been awarded but before any construction work takes place, the tunnel contractor should undertake a risk assessment, having identified the likely hazards, and for each risk determine the probably of occurrence along with an estimate of the resulting consequences.

1.1.16. Based on that assessment the contractor should consider the appropriate risk mitigation and control measures to be taken to control or minimise the risks

1.1.17. On-going risk assessment will be needed during the construction phase, particularly if design changes are made or unforeseen ground conditions encountered.

1.1.18. Particular hazards are associated with tunnelling projects passing through or near to landfill areas, sites known to contain industrial waste, near to abandoned mine workings etc. The control of risks from these hazards should receive special consideration at the planning stage.

2 >> Safety requirements in all stages of construction

2.1.OVERALL CONSTRUCTION PLANNING

2.1.1. The contractor should ensure that suitable and sufficient tunnelling equipment for the type of work to be done, is provided and is operated and maintained in accordance with manufacturers' instructions.

2.1.2. The contractor should reduce risk to workers underground through elimination or control of hazardous materials and processes. Only where such risks cannot be reduced to acceptable levels should personal protective clothing and equipment be provided in accordance with local statutory requirements or with the recommendations of these guidelines.

2.1.3. The contractor should provide appropriate safety signs in accordance with ISO 3864:2002 (see 22.1.10).

2.1.4. The contractor should provide adequate training facilities and courses relevant to the construction methods to be used.

2.1.5. The contractor should provide adequate fire fighting equipment.

2.1.6. The contractor should provide trained first-aid personnel and equipment along with first aid stations as necessary.

2.1.7. The contractor should provide adequate welfare facilities including washing and toilet facilities along with a supply of drinking water.

2.1.8. The contractor should provide adequate atmospheric monitoring and ventilation to ensure a safe and healthy environment.

2.1.9. The contractor should provide adequate artificial lighting to ensure a safe environment.

2.2. PORTAL DEVELOPMENT

2.2.1. Where necessary the work site should be fenced to control entry to the site.

2.2.2. The contractor should ensure that the portal area is stable and that surface water is adequately diverted from the portal area.

2.2.3. Adequate rock fall protection methods should be deployed such as barriers, canopies, check fences, to prevent rock falling on the work site.

2.2.4. Adequate resources for dewatering the face should be available.

Site installation (Lötschberg tunnel, © BLS Alptransit)

2.3. SHAFT CONSTRUCTION etc

2.3.1. A protective barrier should be erected around the shaft top to prevent falls of men or materials into the shaft. The barrier should also prevent surface water draining into the shaft. When the shaft is unattended protective covers or a suitable fence should be used to prevent access to the shaft if appropriate.

2.3.2. Man-access to the shaft bottom should be by ladder with landings at not more than 10m intervals, hoist or man riding skip. An alternative means of access should always be available for use in an emergency when hoists or man-riding skips are used. In deep shafts an emergency winder with its own power supply should be considered.

2.3.3. Materials transport should be separated from personnel transport by a substantial barrier. Materials transport is covered in detail in.

2.3.4. Daily during shaft sinking operations, the whole shaft shall be carefully examined for loose material which shall be removed. The bottom of the shaft shall be free of fallen rock.

2.3.5. All services including ventilation, lighting and communications should be securely attached to the shaft wall. They should be adequately protected from damage.

2.3.6. The use of explosives in shaft excavation should follow the recommendations in Section 10.

2.3.7. Platforms of raiseboring equipment should be properly guarded to prevent falls of men or materials.

2.3.8. The section of a tunnel below a shaft being raisebored should be securely fenced off when raiseboring is being carried out. Appropriate safety signs should be erected.

2.3.9. Shafts may be sunk as caissons with or without the use of compressed air. When undertaken, compressed air working should be done in accordance with the guidance in this document.

Shaft construction (Neudong road tunnel-Korea)

2.3.10. Bulkheads and air decks in shafts subject to compressed air working should be designed and constructed to withstand all loads on them from the least favourable combination of air pressure/no air pressure and kentledge/no kentledge. Variations in loading due to fluctuating water levels should also be considered.

2.3.11. When spoil is removed through a vertical lock, a protective system should be fitted to prevent damage to the lock due to overwinding.

2.3.12. Appropriate temporary support should be provided to the shaft lining as the tunnel opening is being formed through the shaft and for as long as necessary thereafter. Appropriate measures should be taken to prevent water entering the shaft and to drain the shaft.

2.4. TUNNEL EXCAVATION

2.4.1. Safety signs should be provided in accordance with ITA recommendations or in accordance with local statutory requirements.

2.4.2. Equipment and material for primary ground support should be available on site, e.g. rockbolts, arches, shotcreting.

2.4.3. Adequate dewatering equipment must be available when required.

2.4.4. Adequate ventilation equipment must be provided in accordance with the recommendations in this document.

2.4.5. All electrical installations must be suitable for the underground environment and must conform to local statutory requirements or should be in accordance with the recommendations of this document. Guidance on lighting standards is also included.
A back-up power supply should be installed within the tunnel in case of power loss to critical equipment such as pumps, fire fighting systems etc.

2.4.6. Compressed air installations must be properly designed, installed and maintained.

2.4.7. Adequate supplies of water for construction work should be provided. Special provision for drinking water should be made and such supplies should be regularly tested for contaminants and thereafter treated as necessary to purify it.

2.4.8. Proper washing and toilet facilities should be provided for all underground workers.

2.4.9. Good communication throughout the underground work is necessary for safety and efficiency.

2.4.10. Underground transport accidents are one of the major causes of deaths and injuries. It is essential that rolling stock and vehicles be properly selected and maintained to ensure the safety of the workers. The recommendations in Section 5 should be followed to ensure maximum safety.

2.4.11. Adequate underground storage areas, properly demarcated and fenced, should be provided.

2.4.12. The main dangers to health in tunnelling are dust, noxious gases, noise, heat and humidity. Every effort should be made to provide a healthy environment for workmen and for this purpose the condition of the environment should be monitored regularly. The recommendations in this document should be followed to ensure a healthy environment.

2.4.13. Probing ahead of working faces should be undertaken according to the risk assessment to identify potential hazards such as water, gas, unstable ground conditions, etc.

2.4.14. Adequate fire detecting, warning and fighting equipment properly maintained, should be provided.

Steel arches (Gothard tunnel, © Alptransit Gothard)

2.5. TUNNEL LINING

2.5.1. Most of the safety requirements mentioned above are also applicable to the lining phase of construction.

2.5.2. Adequate ventilation should be maintained during the lining process (see Section 7),

2.5.3. Mechanical segment handling equipment should be properly designed and maintained. Mechanical handing and erection of segments should be carried out in preference to manual systems. Safe systems of work should be established and strictly adhered to. Training is very important.

2.5.4. It is important to note that until a full ring has been completed the ring of segments is inherently unstable and temporary support should be used.

Tunnel segment in the Cologne light railway network

3 >> Planning for emergencies

3.1. EMERGENCY PLANS

3.1.1. These should be prepared for foreseeable emergencies which could arise during the tunnelling operations. Such emergencies could include:

- Serious and multiple accidents including personal injury.
- Plant or other power failures (especially in compressed air tunnels).
- Ground collapse at the tunnel face.
- Failure of temporary or permanent ground support some distance behind the excavated face.
- Substantial water or mud inflow leading to flooding.
- An explosion, perhaps caused by a concentration of a naturally occurring gas such as methane.
- Oxygen deficiency.
- Fire in the shaft or tunnel.
- Misfires in the use of explosives.
- Transport accident

3.1.2. In contingency planning, particular attention should be given to:

- Means of escape in an emergency situation. (Specific escape routes should be marked by signs).
- The maintenance of essential power, firefighting, inundation pumping, atmospheric monitoring, lighting and communications systems during an emergency.
- Clear labelling of power supplies and switches – including emergency lighting, pumping, ventilation and signalling.
- Ensuring a reliable and clear means of communication from, to and within the tunnel even in the event of power failure

3.1.3. On every site there should be a clearly defined chain of authority for emergency action. Contingency and emergency plans should be made known to all the workforce.

3.1.4. The authority for directing emergency action should rest with one postholder - for example the site manager or other nominated senior site person.

3.1.5. The first priority in any emergency action is to minimise the risk to persons working underground. To achieve this objective it is necessary to know the number of persons working within the underground system at any one time.

3.1.6. The site management should discuss the handling of possible emergencies with the public rescue services. Such discussions should be commenced before the construction stage of the project begins. There is a need for on-site familiarisation of the emergency fire and rescue services.

3.1.7. It shall be the duty of every person on site to report any circumstances that could lead to an emergency, thereby enabling effective action to be taken at the earliest moment.

3.1.8. Contingency planning should ensure that essential equipment and personnel for major emergencies (for example rescue equipment, fire fighting equipment, suitable breathing apparatus, stretchers, temporary lighting etc) can be obtained at short notice if they are not already on site.

3.1.9. If the underground works are complex, a clear, durable and up-to-date diagram of the layout of the underground workings should be posted at each of the access points into the underground works.

Fire test

Emergency exit signs (Lötschberg tunnel, © BLS Alptransit)

EMERGENCY EXERCISES SHOULD BE CARRIED OUT FROM TIME TO TIME. TO OBTAIN MAXIMUM BENEFIT FROM SUCH EXERCISES, OBSERVERS SHOULD BE PLACED AT KEY POSITIONS (FOR EXAMPLE IN CONTROL ROOMS, AT BOTTOMS OF ACCESS SHAFTS ETC), TO EVALUATE THE PROGRESS OF THE EXERCISE. KEY PERSONNEL SHOULD BE DEBRIEFED AFTERWARDS AND ANY LESSONS NOTED. THE EMERGENCY PROCEDURES SHOULD BE AMENDED IF NECESSARY.

4 >> Personnal safety equipment

4.1. GENERAL

4.1.1. Personal safety equipment serves as an additional measure to ensure safety where it is not possible to improve the environment by engineering means, e.g. reduce noise to an acceptable level to obviate use of (ear) hearing protection.

4.1.2. Personal safety equipment should be provided, e.g. hard hats, high visibility overalls, adequate foot protection, hearing protection, eye protection, respiratory protection.

4.1.3. Means of identifying and accounting for personnel in an emergency situation.

4.2. ITEMS OF EQUIPMENT TO BE PROVIDED

4.2.1. Hard hats for head protection should be issued to every person entering the works and the wearing of hard hats should be made compulsory.

4.2.2. During shotcreting operations eye protection should be worn.

4.2.3. Where noise levels exceed the threshold limits (see Section 11) and levels cannot be reduced then hearing protection should be used, e.g. ear muffs or ear plugs.

4.2.4. Under all conditions where dust levels are high (see Section 11) or where specified by local statutory requirements, appropriate respiratory protective equipment should be used, e.g. during shotcreting operations.

4.2.5. All underground workers should be provided with safety boots of acceptable quality. Such boots should be suitable for both dry and wet conditions.

4.2.6. Hand protection in the form of gloves should be provided where the type of work requires some form of protection. A general purpose type of glove may be adequate for most types of work but special conditions would require special gloves, e.g. special gloves required for welding operations.

4.2.7. High visibility clothing including waterproof clothing, should be provided and used by all workers underground.

4.2.8. Cap lamps should be issued to all persons entering the underground works except where adequate lighting and emergency lighting systems are installed. The minimum operating time should be 12 hours.

4.2.9. Recharging facilities should be provided.

4.2.10. A register of each cap lamp issued should be kept in which the condition of lamps is recorded.

4.2.11. Self-rescuers should be issued to each worker underground. They should always be carried by the worker or in close proximity to his working place.

4.2.12. Where necessary, safety harnesses should be provided and used for persons working unprotected at height.

Personnel equipment (© Alptransit)

5 >> Underground traffic

5.1. PEDESTRIANS

5.1.1. All pedestrians in the tunnel should be equipped with high visibility protective clothing incorporating reflective stripes on body, arms and legs.

5.1.2. The tunnel should be equipped along its full length with adequate lighting and emergency lighting (the latter could include the use of cap lamps).

5.1.3. Pedestrians should only be allowed to walk on one side of the tunnel. For this purpose, suitable signs should be erected at the tunnel portal and in the tunnel, indicating the side where pedestrians will be allowed. All signs should be reflective or illuminated

5.1.4. A pedestrian walkway of adequate width and with adequate overhead clearance should be provided. In choosing the side of tunnel where the walkway is to be provided, the type of equipment in use should be considered.

5.1.5. Each pedestrian or group of pedestrians should carry a flashing or steady light depending on local practice. Pedestrians must be seen as well as being able to see. This requirement may be dispensed with where no moving plant is in use.

5.1.6. An access control system should be operated to account for all personnel underground and to restrict access to the underground workings to authorised persons only.

5.1.7. No person should be alone at any work site underground. If this precaution cannot be observed, an adequate alarm system must be provided.

5.1.8. There should be procedures for the handover of safety critical information from the outgoing to the incoming shift. A written record of this information should be maintained.

5.1.9. Visitor groups should only enter the tunnel when they are not endangered by operation and traffic. Visits shall be organised accordingly.

Pedestrian side walk

5.2. TRANSPORT INFRASTRUCTURE

5.2.1. Safety aspects, including adequate separation between pedestrians and vehicular traffic, should be considered in the layout of the transport infrastructure.

5.2.2. Roadways and rail tracks shall be carefully laid out and properly maintained. Vehicles and rolling stock shall be chosen according to the gradients to be traversed.

5.2.3. Where there is a risk that a runaway vehicle (road or rail) could unintentionally enter a workplace, means of diverting or stopping that vehicle should be provided.

5.2.4. Conveyor belt transport is preferred to rail or roadway transport for health and safety reasons (reduced engine exhaust emissions and traffic hazards).

5.3. ROAD and RAIL VEHICLES

5.3.1. Trains and free steered vehicles for use underground should be designed, assembled and equipped, so that the operator can fully observe the danger zone of his vehicle in both directions. Where the driver cannot fully observe the danger zone, a CCTV camera should be fitted to allow him to see persons in the danger zone or a signal person provided.

5.3.2. All rail or free steered vehicles underground should be equipped with an audible warning signal.

5.3.3. Road and rail vehicles should be provided with two white lights in the direction of travel and with red rear lights. When the direction of travel is reversed, the colour of lights should be reversed automatically.

5.3.4. Special transport units (explosives and emergency units) should be equipped with a special signal (revolving orange lights for example).

5.3.5. All vehicles on the surface should be similarly lit at night.

5.3.6. Vehicles should be capable of stopping within the sight distance of the operator.

5.3.7. Braking systems should be properly maintained.

Tunnel transport vehicle (Glendoe)

5.3.8. Muck cars and locos should be so designed that no person has to step between cars, e.g. for coupling or uncoupling.

5.3.9. All units in a train should be of similar width.

5.3.10. All locomotives should be fitted with a deadman control unit.

5.3.11. Trains should be equipped with adequate fail safe braking systems. Gradients for rail transport should not exceed 2% unless special precautions are taken.

5.3.12. The driver's position on a locomotive should be fitted with a protective structure to prevent the driver from being crushed by obstructions adjacent to or over the track or in the event of derailment.

5.3.13. All vehicles should be properly maintained

5.4. TRANSPORT of PERSONNEL

5.4.1. Passengers should be transported within specially equipped enclosed vehicles.

5.4.2. In the case of rail transport, the personnel vehicle should, where possible, be towed.

5.4.3. The transport of persons on a locomotive should only be allowed if provision has been made for carrying passengers. Standing other than in the cab should be prohibited at all times.

5.4.4. Personnel vehicles should be so constructed that passengers are prevented from reaching or leaning out the vehicle whilst it is in motion and are contained in the vehicle in the event of derailment. They should be so equipped that passengers are protected from internal noise and can easily request the driver of the locomotive to stop if required

5.4.5. Passengers should not be transported in tipping mine cars.

5.4.6. Instructions and training of transport personnel

5.4.7. Training of personnel is vital to the safety of the work and should receive high priority.

5.4.8. During training of operators the following matters should be covered:

- Speed of units or trains when loaded or empty
- Procedures to be observed when a team of workers is encountered
- Precautions to be taken with parked units and special transport
- Procedures to be observed during mucking operations
- Procedures to be observed whilst reversing a train. Reversing i.e. driving the train with the locomotive at the rear (also known as propelling) is always a dangerous operation as the driver's visibility of the track in front of the train is reduced. It should be avoided. Protective measures include the assistance of CCTV, a signal man in a protected position or other means to ensure no one is put at risk by the moving train.
- Procedure to be followed in case of a breakdown
- Instructions regarding priority units to be observed
- Maximum loading of mine cars
- Functional checks on the condition of braking, lighting and audible warning systems, to be undertaken at the start of every shift along with fault reporting procedures.
- Instructions concerning the maintenance of equipment.

Tunnel transport vehicle (Gothard tunnel © Alptransit Gothard)

6 >> Movements in shafts

6.1. LADDERS

6.1.1. Rest levels large enough for at least two persons should be provided at intervals not exceeding 8 metres.

6.1.2. Ladders should be inclined and secured. They should be located away from other activities.

6.1.3. If ladders are vertical they should be provided with safety cages.

6.1.4. If the shaft is used for movement of materials and spoil, this activity should be physically separated from ladders used by personnel. In narrow shafts where this cannot be achieved by means of a partition, the simultaneous movement of personnel and materials shall be prohibited.

6.2. MECHANICAL HOISTS etc.

6.2.1. Mechanical hoists for personnel use are to be preferred in a shaft and shall be installed, used and maintained according to national regulations for such equipment.

6.2.2. When units are used to transport personnel as well as materials/equipment, the simultaneous transport of the two is prohibited.

6.2.3. Personnel shall be transported at appropriate speeds.

6.2.4. There shall be alternative means of emergency escape from a shaft This shall be either by the provision of an emergency hoist which is supplied by a power source separate from that of the main hoist, or by the provision of ladders.

6.2.5. The condition of cables, guides, braking systems, skips and lighting units shall be checked regularly by a competent person and the result of these checks recorded in a register

6.2.6. Persons operating mechanical hoists should be competent and duly authorised in writing to operate the equipment. Such authorisation should be kept in a safe place and a copy thereof displayed in the engine room.

6.2.7. Persons entering or leaving a hoist cage should do so under supervision.

6.2.8. Properly designed barriers to prevent vehicles, plant, materials or persons falling down the shaft should be erected around the top of the shaft.

6.2.9. The area around the shaft should be fenced off on all sides and no storing or stacking of materials should be permitted within the fenceline. The size of the area on each side should be commensurate with the length of the largest item normally transported in the cage.

6.2.10. Every cage used for the conveyance of persons should be of substantial construction and be provided with a proper roof and inward opening doors so arranged that they cannot be opened accidentally. Tipping skips or cages shall not be used. When closed, the cage should prevent any part of a person therein protruding.

6.2.11. Provision should be made for adequate ventilation of the cage.

6.2.12. The cage should be clearly marked with its safe working load and the maximum number of passengers permitted. This safe working load should be determined by using a Safety Factor of 10 or as otherwise prescribed in national regulations.

6.2.13. No person other than the signalman, should be allowed to travel in a cage transporting materials. (With the exception of someone accompanying detonators, safety fuse, igniter cord and lighting torches).

6.2.14. No ancillary materials such as detonators, safety fuse and igniter cord should be transported together with explosives in any conveyance.

Shaft (Portugal)

6.2.15. Explosives may only be placed in or removed from a conveyance under the immediate supervision of an authorised person.

6.3. EQUIPMENT and MATERIAL MOVEMENTS

6.3.1. When the shaft head does have a floor, materials must not be loaded into the skip when the hatches are open.

6.3.2. Equipment or materials should not protrude above the sides of the skip or kibble.

6.3.3. Skips should not to be loaded with spoil to within 200 mm from the top of the sides.

6.3.4. When it is necessary to transport equipment or materials protruding above the top of the skip sides the load must be properly secured.

6.3.5. When the skip can not be used, equipment may be transported only by using lifting units specifically designed for this type of equipment.

6.3.6. Where tipping skips are being moved in the shaft, unintentional tipping should be prevented by the use of two independent fastening devices fitted to the tipping system.

6.3.7. When a tipping skip does not travel within guide rails, it should be secured during movement.

6.3.8. The safe working load on the headframe must be indicated.

6.3.9. Spoil conveyors should be adequately guarded and fitted with emergency stop devices. It should be possible to operate the device from anywhere along the conveyor.

6.3.10. Conveyors should be fitted with an audible prestart warning device.

6.4. SIGNAL TRANSMISSION

6.4.1. In order to control working, communications and a signal code between the bottom and the top of the shaft shall be established. At least two systems should be provided, one of which should be a voice system and one of which should be capable of working in an emergency.

6.4.2. As a general rule, operating should always be controlled from the shaft bottom.

6.4.3. When a skip is lowered in a shaft under construction, the operator should always stop it at about 10 metres from the shaft bottom and wait for the signal from the shaft bottom before lowering the skip to the shaft bottom.

6.4.4. The adopted signal code should be displayed at the shaft top and the shaft bottom.

6.4.5. The operator should work to commands or signals communicated to him by the signaller and onsetter (who travels in the cage).

6.4.6. The operator, signaller and onsetter should be competent in signalling.

6.4.7. The signalling system should be arranged so that the operator can easily distinguish between signals received from different sources.

6.4.8. The system should be so arranged so as to effectively prevent unauthorised persons from giving signals.

6.4.9. In shafts where the operator has no direct visual contact with the signaller in the shaft bottom, an automatic device should be in operation to prevent the conveyance being moved until the operator has received a reply or replies to his signal.

6.5. MOVEMENTS in INCLINES (ADITS)

6.5.1. At any place in incline or adit where it is necessary for workmen to pass from one side to the other, provision should be made for them to do so without entering or crossing an area in which winding is taking place. Such parts should be securely fenced off from moving parts or machinery and from any cage.

6.5.2. No person should enter a shaft in which winding is taking place other than that for the purpose of entering or leaving a cage or for doing necessary work in such shaft.

6.5.3. Nobody should be permitted to travel in a cage, operated by a winding engine, if it is loaded with spoil.

6.5.4. Persons should only be raised or lowered in a purpose-built cage.

7 >> VENTILATION

7.1. GENERAL

7.1.1. A purpose-built forcing, exhausting or circulation ventilation system should be employed, depending on the contaminants which have to be rendered harmless.

7.1.2. The concentration of oxygen, dust, toxic or potentially explosive fumes or harmful gases in the tunnel atmosphere should be routinely monitored and steps taken as necessary to ensure contaminant levels do not exceed those laid down by national legislation or guidance. Where a specific work activity known to generate significant contamination, such as welding, is being carried out, local monitoring should be undertaken.

7.1.3. In the absence of national legislation or guidance, legislation or guidance from another nation giving contaminant exposure levels should be selected as the base standard. Records of all routine monitoring should be maintained.

7.1.4. As a guide, the quantity of air supplied or extracted from the face should be such that the average flow in the full cross section of the tunnel or shaft should be between 0,3 m/s and 2m/s at all times.

7.1.5. Minimum quantity of air for personnel to be 1,5m^3 per minute per man and 4m3 per minute per kW rated power for diesel machines. Additional air may be required for cooling purposes.

7.1.6. Ventilation air entering a tunnel should be free from dust, smoke or other impurity.

7.1.7. Ventilation should be such that in every underground working area, healthy conditions exist and fumes or gases shall be diluted to the extent that they are rendered harmless. A minimum oxygen concentration of 19% should be maintained at all times when persons are at work underground. No-one should remain underground when the ventilation system is not operating.

7.1.8. The wet globe bulb temperature should not exceed 27°C. Ventilation can be used as a means of removing excess heat from the workings.

7.1.9. To minimise dust generation, wet drilling techniques should be used in a tunnel in preference to drilling machines fitted with appropriate dust collection equipment. Other machines and processes creating dust should be fitted with appropriate dust suppression and collection equipment.

7.1.10. Diesel-driven internal combustion machines should be fitted with particulate filters. These machines should be kept in good order and should not be left idling in the tunnel.

7.1.11. In a tunnel with risk of potentially explosive atmosphere, safety critical equipment such as fire fighting equipment, pumping equipment, ventilation equipment, communications and atmospheric monitoring equipment should be explosion protected as necessary so that it remains operational even when potentially explosive gases are present.

Ventilation (Ring Road Prague © Hochtief)

7.2. CONTROL OF CONTAMINATION

7.2.1. The air in tunnels should be continuously tested for oxygen concentration and the presence of toxic gases. Tests for dust levels should be conducted at regular intervals whilst work is in progress.

7.2.2. Dust levels in working areas should be maintained within national limiting values of acceptable dust concentrations. In the absence of national limits those from another country should be adopted.

7.2.3. Dates, locations, conditions and results of tests should be recorded in a register.

7.3. OXYGEN DEFICIENCY

7.3.1. Accidents have occurred when workers have entered unventilated tunnels and been overcome by a lack of oxygen in the air.

7.3.2. It is imperative when entering underground works which have not been ventilated, to keep this risk in mind. When the oxygen content falls below 19% the works should be evacuated until ventilation is installed to restore the oxygen concentration to above 20%.

7.3.3. If the old workings still have forced ventilation equipment, it is essential to adequately ventilate the works and test the return air flow before entering. No one should enter the works without being equipped with both CO and CO2 detectors and also an oxygen monitor

7.3.4. During freezing operations where liquid nitrogen is being used, it is essential to continuously monitor the oxygen concentration in the air as the fracturing of a freezing pipe can increase the nitrogen content of the air and result in oxygen deficiency.

7.4. EXPLOSIVE ATMOSPHERES

7.4.1. Checks using electronic atmospheric monitoring equipment should always be made to ensure that methane or other potentially explosive gas (e.g. Hydrogen) is not present in the ground to be traversed. Tests for potentially explosive gas should be specifically carried out before charging a face and after blasting.

7.4.2. Where water (in which gas such as methane can be dissolved) or gas is expected, and probe boreholes have been drilled, tests should be carried out to identify and quantify any gas emission from the probe holes.

7.4.3. It is strongly recommended that ventilation should be used to maintain the concentration of methane or other explosive gas below 10% of the lower explosive limit.

7.4.4. If potentially explosive gas is detected further precautions including the use of explosion protected equipment, the use of special explosives, specific training for operators and supervisors etc should be considered.

7.4.5. In potentially explosive atmospheric conditions, water cooled engines should be preferred because of lower surface temperatures than encountered in air cooled engines.

7.4.6. If more than 20% of the lower explosive limit of the gas is detected in the tunnel atmosphere, all persons must be withdrawn, and all non-explosion protected electric and mechanical power switched off until a competent person has supervised the venting of the gas.

Pajares (© ADIF)

Greece

Switzeland

8 >> Illumination

8.1. GENERAL

8.1.1. The methods of lighting and levels of illumination in all parts of the tunnel and works should meet the requirements of national legislation or guidance, In the absence of national legislation or guidance, legislation from another nation or guidance such as this document should be selected as the base standard.

8.1.2. All working areas should be constantly illuminated throughout their length to an intensity of 60 lux at floor level. Access ways should be constantly illuminated to an intensity of 10 lux at floor level.

8.1.3. Adequate fixed lighting should be provided at all established stations, working faces, landing and loading places and other similar places in vertical and inclined shafts, tunnels and underground workings, and at night at all places on surfaces where work is being carried out.

8.1.4. Where static machinery is used, the area should be illuminated so that the external moving parts of such machinery are clearly visible. The recommended level of illumination is 100 lux at the moving part.

8.1.5. When work is taking place under potentially explosive atmospheric conditions, only an explosion protected light or lamp, approved by the appropriate Authority, shall be permitted underground.

8.1.6. An emergency lighting system should be provided.

Lighting in tunnel

Lighting in tunnel

9 >> Drilling

9.1. DRILLING GENERAL

9.1.1. Appropriate precautions should be taken before drilling commences including barring and scaling the tunnel face and crown adjacent to the face, clearing the face and examining it and the muck pile for misfires. These should be dealt with in accordance with appropriate regulations.

9.1.2. Mark round on tunnel face with material which can easily be seen and not removed, e.g. paint. Avoid drilling into existing sockets.

9.1.3. Accurate marking, drilling and loading of the round will minimise shattering of surrounding rock.

Drilling with a jumbo
(Chavanne tunnel, ©RFF / www.imatec-photo.com)

9.2. DRILLING MACHINES

9.2.1. There are various ways of drilling but certain precautions are required irrespective of drilling method used:

9.2.2. Flush with water to prevent dust formation.

9.2.3. Use well maintained equipment to reduce noise and vibration emissions

9.2.4. Further reduce exposure to noise by using hearing protection during drilling.

9.2.5. In many underground projects drilling is done by jumbos. These are normally hydraulic or compressed air driven from electric engines. Drill rigs should conform to EN 791 (Drill rigs, Safety) (see 22.1.9). Diesel power may be used for moving between drilling sites. Each power source gives rise to specific risks and in the design of drilling machines the matters set out below should be considered:

9.2.6. Electric equipment should be designed and constructed to minimise the risk of electrocution to workers.

9.2.7. Hydraulic and compressed air fittings should be properly fitted and maintained.

9.2.8. Diesel engines should be of a low emission type and fitted with adequately designed and maintained particulate filters.

9.2.9. Petrol engines should never be used underground.

9.2.10. Suitable access to the various operating and maintenance points should be provided on all equipment. In the design of these accesses consideration must be given to the fact that surfaces are always oily which could lead to such hazards as slipping.

9.2.11. Where there is a risk of falling, working areas must be properly protected with suitable guardrails.

9.2.12. Adequate safe working space for operators should be provided. Control systems should be protected from inadvertent operation and be laid out in an ergonomically correct way. Adequate numbers of emergency stops devices should be provided.

9.2.13. Machines should be fitted with adequate floodlights.

9.2.14. When installing and removing the jumbo the basic recommendations for traffic movements set out in Section 5 should be observed where applicable and in particular every backward movement should be controlled by a signal man who should also safeguard the workers and the power cables

9.2.15. Detachable bits should not be replaced whilst drilling is in progress. Changing bits or rods can be dangerous and adequate care should be taken. Correct equipment must always be used.

9.2.16. Before withdrawing drilling rods the holes must be flushed.

10 >> Use of explosives

10.1. GENERAL

10.1.1. Only competent shotfirers should be authorised to handle and use explosives. They should be aware of local regulations, if any, and manufacturers recommendations.

10.1.2. At change of shifts the shotfirer should fully inform his relief of the state of the work at the face.

10.2. EXPLOSIVES

10.2.1. Explosives and detonators not required for immediate use should not be stored in the tunnel.

10.2.2. Only water resistant explosives should be used in tunnelling.

10.2.3. Under freezing conditions only explosives not susceptible to the cold should be used. In order to ensure adequate transmission of the detonation, cartridge diameter must be more than 30 mm and the space between explosives and surrounding material should be as small as possible.

10.2.4. The destruction of old or damaged explosives is a hazardous operation and should be done in accordance with accepted safe practice.

10.2.5. Explosives should in all cases, be used in accordance with local or other appropriate regulations.

10.3. DETONATORS

10.3.1. Various types of initiation systems are available and selection should be made with local conditions in mind. Detonators should be stored and transported separately from explosives

10.4. FIRING SETS – FIRING LINES

10.4.1. The initiator should match the detonators used.

10.4.2. Initiators should be adequately maintained.

10.4.3. Electrical firing lines should be installed on opposite sides of tunnel from power lines or other conductors such as water lines.

10.4.4. All electrical firing lines should be kept short-circuited when not in use.

10.5. BLASTING

10.5.1. A blasting plan should be drawn up before any blasting is undertaken.

10.5.2. All blasting should be carried out in accordance with the plan.

10.6. TRANSPORT of EXPLOSIVES

10.6.1. Detonators and other explosives should be transported separately and should be stored apart until used.

10.6.2. Only sufficient explosives for immediate use should be transported to the working face.

10.6.3. Explosives should be transported in containers and/or vehicles specially designed for the purpose. Such containers and/or vehicles should be clearly marked to distinguish them from other vehicles.

10.6.4. A responsible person should always accompany the explosives during transport.

10.7. CHARGING of the ROUND

10.7.1. Charging should not be undertaken until all drilling in that area has been completed

10.7.2. In the event of the threat of thunderstorms, charging with electric detonators should be stopped immediately and the working face evacuated. Non-electric detonators should be used in that case.

10.7.3. Charging and blasting should be done by authorised persons.

10.7.4. Electric detonators shall only be used where stray currents can be excluded.

10.8. PRECAUTIONS before BLASTING

10.8.1. Before proceeding with continuity testing of the firing circuit, care should be taken to remove all persons from the danger zone and guards should be placed to prevent access to the danger zone. Persons in working areas adjacent to the blasting site should be warned of pending blasting operations.

10.8.2. Guards must remain at their posts until they have received definite instructions to leave.

10.8.3. Consideration should be given to the use of non-electric systems or electronic (micro-chip) blasting systems

Mobile blasting truck (Lötschberg tunnel, © BLS Alptransit)

10.9. PROTECTION against FLY ROCK

10.9.1. People should be removed from the blasting area to a safe place where they will be protected from projectiles or flying rock.

10.10. TESTING the FIRING CIRCUIT

(What about non electric or Electronic?)

10.10.1. Testing the electric firing circuit for continuity is necessary in order to prevent misfires. Testing consists of measuring the circuit resistance with an ohmmeter of an approved type.

10.10.2. Testing should be done from the firing point and if any fault is detected it should be rectified before the blast.

Blasting preparation (© Dyno-nobel)

10.11. PRECAUTIONS after BLASTING

10.11.1. Adequate ventilation should be provided and atmospheric monitoring carried out to ensure the removal of all hazardous gases before re-entry.

10.11.2. The shotfirer and assistant should check the face and make safe before allowing work to proceed.

10.11.3. Before mucking operations the responsible person shall check to ensure that safety precautions have been carried out.

10.11.4. Vehicles used for the transport of explosives or detonators should be regularly inspected and maintained to check that they do not present any risk to the materials carried.

Blast

11 >> Planning for emergencies

GENERAL

11.1.1. The main health hazards in tunnelling are exposure to dust, toxic gases, noise, vibration, heat and humidity, manual handling, and other hazardous materials. They are summarised in the table below.

TYPE OF INJURY	HAZARD	PREVENTION	CROSS REFERENCE (SECTION/CLAUSE)
Loss of Hearing	NOISE	Engineering control of noise or hearing protection	
Inhalation of harmful substances	ATMOSPHERIC CONTAMINATION CO, CO2, H2S, CH4,NO, NO2, NH3 , Welding fume; Dusts e.g. cement, silica	Atmospheric monitoring, Ventilation, Respiratory protective equipment	
Collapse/ Asphyxiation	CONFINED SPACES; oxygen deficiency	Atmosphere monitoring and ventilation	
Dermatitis, respiratory sensitisation	HAZARDOUS MATERIALS including wet cement, fuel and lubricating oil, grout, epoxy resins, adhesives, cleaning agents, concrete admixtures, soil conditioners and foams.	Avoid direct contact Wear personal protective equipment	
Decompression Illness	Work in compressed air	Adequate staged Decompression	
Hand arm vibration syndrome	VIBRATION; hand arm and whole body.	Engineering control of vibration Tool selection and maintenance	

11.1.2. Every effort should be made to provide a healthy environment for workmen. Personal protection should be regarded as the last line of defence, e.g. respiration and ear protectors.

11.2. DUST

11.2.1. The amount of dust generated should be minimised. All dusts are harmful and exposure should be kept within national limits.

11.2.2. The main consequences from dust exposure are pneumoconiosis and silicosis. The latter can occur after long exposure, where there is considerable quartz content in the airborne dust.

11.2.3. In its mildest form dust exposure annoys by making sensitive parts of the respiratory tract very uncomfortable. In addition dust reduces visibility and enters the respiratory tract.

11.2.4. Exposure to some dusts e.g. cement, can cause dermatitis.

11.3. PROTECTION against DUST

11.3.1. Wet flushing (preferred) or dust extraction should be used during drilling.

11.3.2. The working face, tunnel walls and muck pile should be watered for at least 15 minutes after every blast and before mucking operations begin. The muck pile should also be watered during mucking operations.

11.3.3. Dust extraction units or water sprays should be placed at sources of dust emission such as on tunnel boring machines, conveyor transfer points, shotcrete mixing units etc.

11.3.4. If the above measures are unsuccessful at controlling airborne dust concentrations, additional ventilation should be provided.

11.3.5. Dust masks for individual protection should only be necessary to use in exceptional cases and for short duration work at that.

11.4. GASEOUS CONTAMINATION

11.4.1. Toxic gases are generated through the use of explosives, diesel engines, from ground contamination or, more rarely, from natural sources.

11.4.2. Sufficient ventilation should be provided to prevent the build up of a toxic or potentially explosive atmosphere in the tunnel.

11.4.3. Gases from blasting operations are basically oxides of nitrogen, ammonia and oxides of carbon. Therefore it is necessary to provide powerful ventilation in order to reduce the re-entry time to a minimum. The characteristics of the fume emitted should be considered in the selection of the explosives.

11.5. EMISSIONS from POWER UNITS

11.5.1. Petrol driven internal combustion engines shall not be used underground because of their large emissions of CO (10% of exhaust gas) and the fire and explosion hazard.

11.5.2. Only low emission or "clean burn" diesel engines or electrically driven or battery operated motors should be used.

11.5.3. Engines should be properly adjusted and maintained to operate efficiently under prevailing conditions in order to reduce toxic exhaust emissions to the absolute minimum.

11.5.4. Engines should be effectively silenced so as to achieve a noise level not exceeding LAeg 85 dB(A) as measured in the open, at a distance of 1 m.

11.5.5. Exhaust systems should be fitted with an efficient catalytic converter and particulate filter.

11.5.6. Direct injection air cooled engines are preferred for reason of better exhaust emission characteristics.

11.5.7. Efficient air intake cleaners should be provided.

11.5.8. Idling of diesel engines should be kept to a minimum.

11.5.9. Storage of diesel fuel underground should be prohibited.

11.5.10. All vehicles underground, should have efficient fixed fire extinguishing systems.

11.5.11. Atmospheric monitoring in the vicinity of any engine should be carried out at least once per month, with the engine running at full load and when idling.

11.5.12. Exhaust gas analyses should be taken at least once every three months under full load and idling conditions.

11.6 VENTILATION

11.6.1. Ventilation of the works is always necessary to ensure that the atmosphere is safe for the workers.

11.6.2. Where diesel engines are used the ventilation capacity shall be rated accordingly.

11.6.3. For guidelines on adequate ventilation refer to Section 7.

11.7. NOISE and NOISE REDUCTION MEASURES

11.7.1. Deafness caused by noise at the working place is a recognised occupational illness, and tunnelling is one of the noisiest occupations. Exposure to a noise level of 85 dB(A) can cause damage to hearing. It has been found that exposure to a high noise level over a period of 40 years can reduce hearing by as much as 40 dB(A). Steps must therefore be taken to reduce the noise.

11.7.2. As far as possible noise in the environment should be reduced through the use of low noise emission plant and equipment. Where this cannot be done for technical reasons, personal hearing protective equipment must be provided.

11.7.3. Typical noise emission levels are:
- Vibrators for use on formwork: 110-115 dB(A)
- High pressure hydraulic pumps: 100-105 dB(A)
- Pneumatic drills: 115-120 dB(A)
- Pneumatic drills on jumbos : 110-115 dB(A)
- Diesel loco: 105-110 dB(A)
- Battery loco: 95-100 dB(A)

11.7.4. It is recommended that maximum noise levels of equipment be reduced to 85 dB(A)

11.7.5. These include reduction in noise emission at source of noise generated by machinery through improvement in design of equipment, reduction in exposure and as a last resort, the use of personal protective equipment.

11.7.6. A number of steps can be taken to reduce noise from a machine at source:
- Place covers over source of noise.
- Fit larger mufflers to exhaust and ventilation fans.
- Erect screens to separate the source of noise from the rest of the working area.
- Improved maintenance of machine
- Improvements in design of machines

11.7.7. The risk from exposure to noise can be reduced by reducing the exposure time however this leads to increased labour costs and may not be commercially viable for tunnelling. Consequently the measures outlined above should be taken.

11.7.8. Personal protection against noise should be used after all other measures have been taken and shown not to have worked.

11.7.9. Where the noise level is equal to or greater than 80 dB(A), hearing protection should be provided. This is however only a short term solution as the effect of hearing protection is to reduce the noise levels from between 15 and 20 dB(A). As maximum protection is only possible when the protective devices are properly fitted and worn, an effective assessment, fitting and training programme should be put in place.

11.8. HEAT

11.8.1. Cooling of the tunnel atmosphere should be undertaken when the temperature routinely exceeds 280C.

11.8.2. Cooling may consist of increasing the ventilation flow and/or installing cooling equipment.

Cooling equipment (Lötschberg tunnel, © BLS Alptransit)

12 >> Electrical installations

12.1. GENERAL

12.1.1. All electrical equipment and installations shall be so constructed, installed, maintained, protected and used as to prevent danger. Electrical equipment and its installation should be in compliance with relevant national, CEN, CENELEC and ISO standards, and national regulations.

12.1.2. Electrical equipment in the tunnel is exposed to mechanical damage and a range of adverse environmental factors including temperature, pressure, humidity, dust, the effects of blasting and potentially explosive gases. It shall be appropriately protected from such exposure. Protection against ingress of dust and moisture shall be to a minimum of IP 54 (see 22.1.8).

12.1.3. Electrical installations should be inspected and tested by a competent person after commissioning -or, modification and thereafter at regular intervals thereafter and the results of the inspection or test should be recorded.

12.1.4. Only persons who are competent should be responsible for the operation and maintenance of electrical installations.

12.1.5. Where there are no national guidelines for assessing competence, the following criteria shall be used:

- appropriate level of knowledge of electrical engineering principles;
- experience of electrical installation work;
- understanding of the installation to be worked on and practical experience of that work;
- understanding the hazards which can arise during the work and the precautions to be observed;
- ability to recognize at all times whether it is safe to continue working.

12.1.6. All the relevant technical documentation concerning the installations and the electrical equipment on site should be available on site.

12.1.7. To prevent accidents caused by people switching on electrical equipment while others are working on it, switches should be locked out with a lock-out device and a padlock. The padlock keys should be under control of the person doing the work.

12.1.8. Site specific guidelines should be prepared covering the operation and maintenance for electrical equipment and be made available to the appropriate persons working in the tunnel. These persons should also know the steps to take in the event of electric power outage as well as the relevant safety precautions. The guidelines should include:

- details of the competent person(s) responsible for electrical equipment;
- description of electric equipment and personal safety precautions;
- recommended working techniques and the necessary personal skills;
- potential risk identification;
- inspection periods;
- details of periodic inspections of electric equipment, maintenance strategy and maintenance intervals.
- procedures to prevent potential electric energy failures including the provision of back-up supplies,
- outline accident plans for dangerous exposures such as fire, absence of air ventilation, failures of dewatering pumps, lighting, etc..

12.1.9. Steps should be taken to restrict the effect of electrical energy on the surrounding construction work and installations including:

12.1.10. Protective zones and recommended stand-off distances from existing plant, overhead lines and cables within the high voltage distribution network;

12.1.11. Prevention of premature detonation of explosives by using non electric detonators when necessary (e.g. with effects of stray earth currents, electrostatic discharges and atmospheric electric energy);

12.1.12. Recommendations for placing and laying of firing wires.

12.1.13. Standby power should be provided, from an independent mains circuit or by diesel generators, where a power failure could endanger lives e.g. compressed air work, failure of dewatering pumps, failure of ventilation fans or fire-fighting pumps etc.

12.1.14. Electrical installations should be so planned that safety critical circuits are not broken when other circuits are disconnected or fail.

Electrical equipment (Glendoe)

12.2. ELECTRICITY

12.2.1. Designs of electric equipment must be compliant with the environment and site where the equipment is operated, especially with respect to electric current accidents and potentially explosive atmosphere.

12.2.2. The main causes of electric current accidents are:
- accidental contact with live parts;
- defective equipment or installations
- fault in a protective conductor in the circuit or equipment;
- other undesired effects of electric current.

12.2.3. All installations should be protected against overload and short-circuit by automatic disconnection from the supply. Continuity of earth protection should be ensured.

12.2.4. The circuits for portable equipment, accessories and lighting should comply with Clause 16 of EN 60204-1:1997 with the addition of the following measures to mitigate the problems associated with electrical equipment in a tunnel environment. These should include the use of a residual current protective device with a fault current rating of a maximum of 30 mA or the use of a 110 volt centre earth tap supply. Control circuits should comply with Clause 9 of EN 60204-1:1997, with the addition for handheld pendant controls, that they should operate at control voltages not exceeding 24 volts. Low voltage supplies are those from 50 V AC to 1000 V AC. High voltage supplies are those above 1000 V AC.

12.2.5. Underground electric equipment should be located in such a manner that it is protected against mechanical damage but remains readily accessible to operating and maintenance personnel.

12.2.6. A competent electrical engineer shall produce a written scheme for the methods and frequency of inspection and maintenance requirements.

12.2.7. Regular visual inspection should be undertaken to check that:
- electric installations and cabling are not damaged or misused;
- functionality of protection against accidental contact are in place (earth leakage circuit breaker, residual current circuit breakers, protective grounding system, enclosure, etc.);
- there is sufficient working space around the electric equipment
- the underground lighting including emergency lighting works properly.

12.2.8. Electric equipment which is unintentionally disconnected, should not be repowered until the relevant cause has been identified and any defect repaired.

12.3. CABLES

12.3.1. Cables for use underground should be selected and installed in accordance with national guidelines. They should be appropriately sized for the expected duty.

12.3.2. Where cables are buried, markers should be installed to clearly show the position of cables.

12.3.3. The voltage drop between the point of supply and any electric installation should not be greater than 10% of the nominal voltage. If the cable length makes the voltage drop greater it is necessary to alter the electric power transmission parameters, for example by transformation to a higher voltage.

12.3.4. High voltage cables are used in tunnelling and such cables must be properly supported and protected against mechanical damage and abrasion. Care should be taken when laying out cables to avoid introducing twists in the cables which could damage the insulation internally. Protection against fire damage should also be considered.

12.3.5. Cables should be insulated with materials that will not emit toxic gases or smoke when they burn.

12.3.6. Joints and connections should be suitable for the tunnel environment.

12.4. SUBSTATIONS AND SWITCHGEAR

12.4.1. Substations, distribution boards, cables, switches and circuit breakers should be dimensioned to accept the currents and voltages that might foreseeably occur at the particular site during various operational states.

12.4.2. Only competent persons should enter a substation.

12.4.3. Electric substations and switchgear should be, equipped by safety plates and inscriptions, and fixed fire extinguishing systems.

12.4.4. Oil filled circuit breakers, switchgear and transformers should not be used underground to minimise fire load. Vacuum and air switches are to be preferred.

12.4.5. Switchgear and distribution boards should be protected against damage. Installations and distribution boards should have sufficient clear working space to allow for operation and maintenance. Switchgear and control cabinets on TBMs should not open on to walkways.

12.4.6. Portable hand-held tools and apparatus should be double-insulated or should be used in conjunction with residual current circuit breakers with the rated residual current not exceeding 30 mA.

12.4.7. Effective means should be provided for every high voltage circuit to prevent danger arising from earth leakage currents.

12.4.8. Earth-fault protection can be used in an isolated system. Any fault current should be signalled in case the trip fails to disconnect the power automatically.

12.4.9. Every circuit or cable should be clearly marked at regular intervals with a unique reference which allows its function and route to be identified from the operating manuals for the installation.

12 >> Electrical installations

12.5. EARTHING

12.5.1. The earthing bonding system must meet the earthing wire mechanical strength requirements and accidental contact protection conditions and be accessible to visual inspection with the exception of structure earthing.

12.5.2. All neutral parts of any electric circuit which require earth protection and all conductive structures in the tunnel (pipelines, rails, etc.) should be adequately earth bonded. Continuity of earthing should be checked periodically.

12.5.3. It is advisable that earth leakage protection be provided to the following standards:

- voltage of or above 1000 V - leakage current not exceeding 5 A or 15% of maximum earth fault current
- higher than distribution nominal low voltage - leakage current not exceeding 750 mA
- distribution nominal low voltage - leakage current or core balance current not exceeding 300 mA for extensive electricity distribution lines, portable equipment and fixed lighting
- residual current not exceeding 30 mA for portable hand tools and apparatuses.

12.6. TRANSFORMERS

12.6.1. Transformer enclosures and switch rooms containing exposed conductors should be locked when the equipment is live unless access for operating purposes is required. The keys should be held by an authorised person.

12.6.2. Preferably only transformers with air-cooling or non-flammable coolants should be used underground.

12.6.3. Oil-cooled transformers should only be used in fixed sub-stations above ground remote from working areas.

12.6.4. Enclosure of the transformer and its location should take into account local operating and environmental conditions.

12.6.5. Safe means of access and adequate working space should be provided for inspection, maintenance and emergency purposes.

12.6.6. Suitable fire extinguishers should be provided at all transformer locations. Fire extinguishers should be mounted externally and their locations indicated with relevant safety symbols.

12.6.7. Appropriate safety signs should be provided adjacent to all electrical installations.

12.6.8. There should be a means of isolation on the primary side of any transformer unit which should preferably be by an integral isolator and for high voltages should be of the air-break or vacuum contactor

12.6.9. Any external tap change selector should be securely locked in the selected position.

13 >> Use of compressed air as source of power

This section deals with pneumatic systems, work in compressed air is covered in Section 14.

13.1. GENERAL

13.1.1. The use of compressed air involves hazards uncommon to any other source of power. Proper maintenance of compressors and air-powered equipment is vital to their continued safe operation.

13.1.2. Safety demands frequent inspection of all equipment. The frequency of inspections will depend upon the extent and severity of use.

13.1.3. Compressed air should not be misused to blow down dust from clothes, workbenches or floors. Compressed air entering a body opening can rupture the area creating serious injury or death. A single blast of air can burst an eardrum or permanently destroy an eye. Wearing of hearing protection is recommended.

13.1.4. Suitable attention should be given to noise levels of air-powered equipment. Refer to Section 11.7.

13.1.5. When using compressed air underground there can be a discharge of oil which means that the air in the tunnel could become polluted.

13.1.6. To drive machinery by compressed air (pneumatic power) it is essential to have some source of lubrication, if there is no oil in the compressed air supply then it is necessary to introduce an oil bottle into the pipelines.

13.1.7. The oils necessary for the compressor and the tools it drives should be of a high flash-point. They can cause atmospheric contamination.

13.2. AIR COMPRESSORS

13.2.1. Compressors used underground should be electrically operated.

13.2.2. Underground compressor stations should be properly protected against falling ground and moving plant.

13.2.3. The use of low flash point lubricants should be prohibited because of the explosive risk.

13.2.4. The supply of air should be drawn from the purest and coolest source available.

13.2.5. Guidance on maximum noise levels of all machinery including compressors is in Section 11.7.

13.2.6. Every air compressor having a rating exceeding 0,15 m3 of free air per second should be fitted with temperature control.

13.2.7. An over-pressure limiting device, capable of passing the entire flow from the compressor should be provided between the compressor and the stop valves on the discharge side.

13.2.8. A reliable pressure gauge should be provided to indicate the discharge pressure of the compressor.

13.2.9. Every compressor should be fitted with a nameplate with the following information:
- Manufacturer
- Type
- Year of manufacture
- Volumetric flow
- Maximum working pressure
- Maximum operating speed
- Motor output in kW

13.2.10. Every compressor should be maintained in accordance with the manufacturer's instructions.

Air compressor

13.3. PRESSURE VESSELS (AIR RECEIVERS)

13.3.1. Pressure vessels should be constructed and inspected in accordance with national statutory requirements.

13.3.2. Pressure vessels should be kept clean and free from mineral oil or other inflammable material which could ignite under working conditions and material which could cause corrosion or which is liable to chemical reaction resulting in an uncontrolled rise in pressure.

13.3.3. Pressure vessels should be maintained in a safe working condition at all times.

13.3.4. Daily maintenance should include draining of any liquid which may have collected in the receiver. For this purpose a suitable drain controlled by a valve should be provided at the lowest part of the receiver.

13.3.5. In the absence of national statutory requirements, every pressure vessel should be inspected and tested before being commissioned and thereafter inspected at regular intervals of not more than five years.

13.3.6. They should be hydraulically pressure tested at regular intervals of not more than two years.

13.3.7. Every pressure vessel should have a plate securely fixed to it in a conspicuous place bearing the following particulars:

- Name of manufacturer
- Manufacturing number
- Country of origin
- Year of manufacture
- Maximum safe working pressure and temperature
- Capacity
- Date of last inspection and test

13.3.8. Pressure vessels should not be modified on site.

13.3.9. Every pressure vessel should be provided with at least one reliable pressure gauge on which the maximum safe working gauge pressure shall be clearly marked with a red line.

13.3.10. Every pressure vessel should be provided with at least one over-pressure relief valve capable of passing the maximum inflow of air to the vessel.

13.3.11. To prevent tampering with such valves, they should be kept locked, sealed or otherwise rendered inaccessible to any unauthorised person.

13.3.12. Every pressure vessel should be provided with a shut-off valve at the outlet into the mains.

13.4. AIR LINES

13.4.1. Air lines should be manufactured to a recognised national standard and rated for the expected working pressure.

13.4.2. Only pipes and fittings in good condition should be used.

13.4.3. Quick coupling metal pipes (including flanged pipes) may be used for the main supply.

13.4.4. Reinforced polyethylene or rubber hoses may be used for smaller diameters (less than 200 mm) or for low pressures (up to 7 bar).

13.4.5. Reinforced polyethylene or rubber hoses should be fitted with sturdy couplings.

13.4.6. Restraints should be fitted across joints in flexible air lines to prevent danger in the event of unexpected disconnection.

13.4.7. The air line should not be disconnected unless the supply has been cut off and pressure has been reduced to zero.

13.4.8. Air supply lines should be adequately supported both above ground and in shafts and tunnels. They should be protected from mechanical damage.

13.4.9. Shut-off valves should be installed in all main supply air lines at regular intervals depending on size of air line but a maximum spacing of 500 m is advisable.

13.4.10. Shut-off valves should be fitted at the entrance to the works and near the end of the supply line to close off air supply in case of damage.

13.4.11. Discharge valves should be fitted in air lines to reduce air pressure in the air lines when equipment is shut down.

13.4.12. Air lines and their fittings should be maintained in good condition and leaks should be repaired promptly both to reduce air loss and control noise emission. A drain should be fitted to an air line to enable moisture present in the air line, to be drained off regularly before entering the equipment.

13.4.13. Filters should be installed in the air line near equipment to prevent solids entering the equipment.

14 >> Work in compressed air

14.1. GENERAL

14.1.1. Work in compressed air presents increased occupational health and safety risks. However alternative means of ground support also present safety risks and can be less effective and flexible than work in compressed air. Many nations have regulations governing work in compressed air. However in the absence of national statutory requirements the guidance below should be followed.

14.1.2. All those working in compressed air should be competent to do so or under the close supervision of a colleague who is competent. Personnel should undergo specific compressed air training prior to carrying out any work.

14.2. MEDICAL EXAMINATION

14.2.1. To be able to enter a compressed air environment the worker must present proof of hyperbaric medical fitness.

14.2.2. Personnel shall, except under exceptional circumstances, not be younger than 18.

14.2.3. Pregnant women, or women breastfeeding their young, should not enter a compressed air environment.

14.2.4. A comprehensive medical examination prior to entering a compressed air environment for the first time is required along with an annual comprehensive medical examination and periodic medical checks thereafter.

14.2.5. Workers suffering from the following ailments should not enter a compressed air environment:

- chronic infection of the nasal ducts (sinusitis)
- chronic ostitis, perforated eardrum, permanent obstruction of the Eustachian tube
- chronic lung infection (bronchitis, asthma, tuberculosis, etc)
- heart infections
- epilepsy
- serious loss of hearing and sight
- diabetes
- psychiatric deviations
- alcoholism
- ulcers
- hernia
- anaemia
- chronic kidney infections
- some skin infections.

14.2.6. The medical examination and checks should be undertaken by a doctor competent in hyperbaric medicine. The doctor should advise on the content of the examinations but as a minimum, the following examinations should be made:

- electrocardiogram including one under physical stress – annually
- ear, nose and throat – annually
- spirometry (functioning of the lungs) – annually
- blood tests – complete blood count – annually
- urine tests – annually
- pressure test in decompression tank or room.
- lung and long bone x-rays (at the doctor's discretion),

14.3. WORKING CHAMBERS

14.3.1. The dimensions of the chamber should be such that the workers can be in an upright position. The minimum diameter of the chamber should be 1,80m. The minimum diameter can be reduced to 1,50m if work is done mechanically and at low air pressure (i.e. not exceeding 1 bar).

14.3.2. Ventilation should be provided with a minimum of 40m3 (at working pressure) per hour per worker fresh air discharged at the workplace. The air supply should be from an uncontaminated source. The ventilation system must have a capacity at least 50% higher that the normal flow requirement.

14.3.3. All parts of the working chamber should be so designed that they can withstand the specified pressure. The effects of this pressure on the surrounding ground should be considered.

14.3.4. The electrical installations should be unaffected by pressure and be waterproof, dustproof and explosion protected.

14.3.5. An emergency power system via fire hardened cables should be provided to power safety critical equipment. In the event of power failure, the emergency lighting should switch on automatically. The power source for the automatic emergency lighting system should be above ground.

14.3.6. At the working face there should be adequate fixed lighting.

14.3.7. The air temperature in the workings should be maintained between 15°C and 30°C.

Air lock on TBM (UK)

14.4. LOCKS

14.4.1. The lock must allow workers to move and to sit normally or to lie down. The minimum cross sectional dimension should be 1.35 m if square or 1.5 diameter if round. The available volume per worker should be at least 1,25m3.

14.4.2. The workers must be able to put on dry warm clothes in the lock and the lock should be fitted with non-radiant heaters.

14.4.3. The doors of the lock must be so designed that the air pressure in the lock will keep them shut.

14.4.4. The lock must be equipped with the appropriate first aid equipment, an internal water spray system and hyperbaric fire extinguishers.

14.4.5. Pressure gauges and thermometers must continuously inform the lock attendant and the occupants of the lock of the pressure and temperature in the lock.

14.4.6. The air temperature should normally be maintained between 15°C and 30°C.

14.4.7. Inexperienced workers should never pass alone through the air lock but should be accompanied by a responsible and experienced colleague.

14.4.8. Except in an emergency, locking out must be effected under the control of the lock attendant.

14.4.9. An air lock should always be under control of a competent lock attendant when men are in the compressed air workings.

14.4.10. Telephone communication, properly maintained, should be provided between the lock attendant, the lock, the first aid station, the compression station, the shaft, the site offices and the working chamber.

14.4.11. A window of at least 75mm diameter should be provided in each bulkhead such that the lock attendant can see all men in the lock.

14.4.12. Man locks, and in particular medical locks, should be protected against extremes of temperature and where possible be thermally insulated.

14.4.13. Medical locks should be provided when the working pressure exceeds 0.7 bar and are normally to be used for therapeutic purposes only. Therapeutic treatment must be done under the supervision of a competent doctor.

14.4.14. Medical locks should be of two chamber construction, an access lock and a main chamber having head room of at least 1,80m and length adequate for a couch of 2,00m.

14.4.15. Where working chambers are of sufficient size, chemical closets, regularly serviced, should be provided.

14.4.16. Under normal conditions a maximum working pressure of 3,6 bar is allowed in the working chamber. For pressures over 1 bar, only experienced workers who have undergone an appropriate medical examination should be used. Under such conditions the workers should be medically examined monthly.

14.4.17. Compressed air provides a greater absolute concentration of oxygen and therefore enhances all fire risks. The following measures should be observed:

- Batteries for plant should never be charged in compressed air workings.
- Hydraulic plant containing oil at high pressure can be particularly dangerous – a damaged pipe could release a large volume of flammable oil. Hydraulic systems should use low flammability oils.
- Transformers must be adequately protected against mechanical or electrical damage.

14.4.18. The use of burning or welding gear in compressed air gives rise to additional fire hazards. No burning or welding should be done unless there is a fire watchman in attendance equipped to extinguish any spark of fire. He should remain on watch for 30 minutes after burning or welding work has ceased.

14.4.19. The contractor undertaking compressed air work should employ workers who are competent in this type of work, and the responsible persons appointed for the job, must also be competent.

14.4.20. Before starting work in compressed air, an emergency plan should be drawn up. This plan should describe all the steps to be followed in case of foreseeable emergencies and should be posted in prominent places. Regular exercises of the plan should be held.

14.4.21. Sufficient standby compressors should be provided along with a back up power supply. In the event of one power supply failing the other should come on automatically.

14.4.22. The doctor should advise on the decompression regime to be used. This may include oxygen breathing.

14.4.23. Where oxygen is used for decompression purposes, the risks associated with the supply of pure oxygen, the enhanced fire risk from oxygen enrichment of the tunnel atmosphere and the risks to health from exposure to hyperbaric oxygen should all be addressed. Specialist advice should be sought as required.

14.4.24. The works must be provided with a fully equipped room for medical examination and a rest room for the workers.

Work in compressed air (USA)

14.5. FIRE FIGHTING EQUIPMENT

14.5.1. Water jets and sprays should be the principal means of extinguishing a fire in compressed air.

14.5.2. As normally pressurised fire extinguishers cannot be relied on to function effectively under pressure, hyperbaric extinguishers should be provided.

14.5.3. Breathing apparatus for use in smoke and fumes should only be employed by those trained in its use. Only self-contained compressed air breathing apparatus, (of the type that does not have an air cushion seal to the mask) should be used. The effects of working in a pressurised environment on the duration of the apparatus should be taken into account.

14.5.4. Fire fighting in compressed air calls for special training and a site fire squad should be designated and trained for fire fighting. Fire fighting should only be attempted to save life.

14.5.5. Methane gas in coal seams can occur at high pressures and could form an explosive mixture with the compressed air in the working chamber. Any possibility of the presence of methane therefore calls for careful study, detection, assessment and additional safety precautions.

14.6. GEOLOGICAL CONTROLS

14.6.1. During the construction of the works the geological data must be continuously compared with what is actually encountered. If necessary the construction methods may have to be adapted to suit changing conditions.

14.6.2. Allowance should be made for variations in ground water level due to the tides, the presence of water under pressure etc.

14.6.3. To minimise risk from working in compressed air, the lowest possible air pressure should be used at all times. To this end it can be beneficial to initially lower the groundwater level. The effect of this on the surrounding ground should be thoroughly investigated. The compressors should be able to counteract the full water pressure in an emergency.

14.6.4. In clay the pressure of preconsolidated layers could cause large distortions. By adjusting the air pressure the distortions can be limited but not eliminated and grouting may be necessary.

14.6.5. In highly porous ground (e.g. coarse sand) air loss can make it impossible to achieve the required working pressure. Air loss can be reduced by covering the face in an impermeable material such as plastic sheeting or clay or by injection grouting,

14.6.6. Materials used for injection grouting should not give off toxic gases,

14.6.7. Consideration should be given to the possible presence of obstacles like boulders or obstacles near the surface around which compressed air can escape (e.g. old sewers, shafts, boreholes etc),

14.6.8. The importance of sufficient ground cover above the works to prevent “blow-up” should be considered.

14.7. CONTROL of the AIR in the WORKING CHAMBER and the LOCK

14.7.1. The air in which the workers are working should be as clean as possible.

14.7.2. In the working chamber and especially at the face the air quality should be constantly monitored and additional ventilation air supplied as necessary. Allowance should be made for the fact that the air could be contaminated by the nature of the ground (lignite oxidising materials, grouting materials, presence of methane, etc) and by the equipment being used (e.g. oil mist from pneumatic tools).

14.7.3. Monitoring instruments should clearly indicate the build up of dangerous contaminants in the air (O2, CO, CO2, SO2, NOx, CH4). The ventilation system must allow for the size of the working chamber and the lock and also for the various contaminating factors.

14.8. COMPRESSION and DECOMPRESSION

14.8.1. These operations must be carried out with great care as they can adversely affect the health of the workers. The responsible person i.e. competent lock attendant, must be fully aware of the dangers involved in these operations. He must always be present during the execution of these operations. Additionally it should be possible to over-ride these operations from inside the lock but only in an emergency.

14.8.2. The rate of increase in pressure of 1 bar per 3 minutes is acceptable. The rate of increase should in fact be adjusted or the operation interrupted as soon as any worker in the lock feels uncomfortable (especially ear, nose or throat pain). A compulsory stop must be made at 0.3 bar to check that no one in the lock is experiencing trouble clearing his ears.

14.8.3. Decompression is of the utmost importance to the health of the workers and accepted safe procedures should be followed strictly. Where there is no relevant national legislation, the decompression practices of another country with a proven record of decompression safety should be adopted.

14.8.4. Decompression should be done gradually in accordance with prescribed rules. In general these rules do differ widely from country to country. However, in choosing which rules to follow current best practice should be taken into account. This is likely to include the practice of oxygen breathing during decompression.

14.8.5. A medical lock attendant should always be available when working in an excess pressure of 0.7 bar. The medical lock attendant should always be able to contact a doctor with hyperbaric medical experience when work is being undertaken at pressures in excess of 2.5 bar.

14.9. PRECAUTIONS TO BE TAKEN AFTER WORK

14.9.1. Those working under pressure should be instructed in the risks associated with such work.

14.9.2. Decompression illness can occur anytime during the first few hours after leaving the lock. During this period a worker should be able to easily contact the medical lock attendant on site and to reach a treatment chamber.

14.9.3. The worker should not participate during the first few hours in diving, flying, mountaineering or any strenuous sport or exercise.

14.9.4. Following treatment for decompression illness, the doctor should examine the worker and certify the period out of compressed air which is required before returning to compressed air working. In principle this should be at least 12 hours.

14.10. GENERAL

14.10.1. Exposure period will vary with pressure and includes the time for compression. The doctor may place a limit on exposure which he considers necessary in his professional opinion for the safety of an individual or the entire workforce.

14.10.2. If the shift lasts for more than 4 hours a break of at least 30 minutes hour should be taken under pressure.

14.10.3. When off-duty each worker should carry an identification card indicating that he works in compressed air. If working at pressures above 0.7 bar, this card should also indicate:

- the name, address and telephone number of the site ,
- the name and address of his employer,
- the maximum pressure under which the worker has worked.

14.10.4. If the working pressure is above 1,5 bar, the worker should also be instructed in the following precautionary measures:

- not to eat too much before work and not to consume any alcoholic or carbonated drinks,
- not to indulge in any strenuous activities after decompression,
- not to take a hot bath or shower within 6 hours after decompression. Lukewarm bath or shower is recommended immediately after decompression to get the nitrogen gases out of the body system,
- not to get cold within 6 hours after decompression.

14.10.5 Prior to carrying out any compressed air working, contact must be made with the local rescue services in coordination with the appointed doctor to establish suitable emergency procedures.

14.10.6 Procedures must be developed for evacuation of workers from a pressure environment. These procedures can include evacuation of personnel in an emergency pressure vessel or decantation/re-compression.

15 >> Tunnelling boring machines and road headers

15.1. GENERAL

15.1.1. Tunnelling machinery should comply with national standards or where these do not exist, with the relevant CEN standard (see Section 22).

15.1.2. Machines working in rock should have an efficient dust suppression and extraction system. (Water spraying is not always sufficient but should be used where possible). Equipment shall be properly maintained.

15.1.3. They should have a ventilation system which should provide sufficient fresh air for personnel and for cooling the work environment.

15.1.4. Adequate flows of fresh air shall be provided at all work places and can be achieved by a forced feed system, an exhaust ventilation system or a combination of exhaust and forced feed systems.

15.1.5. The end of the ventilation system shall extend as far through the machine towards the face or forward bulkhead as necessary.

15.1.6. Recirculation of contaminated air shall be avoided by ensuring sufficient overlap of exhaust and force feed ducting and the use of dust filters.

15.1.7. Dust hoods should be fitted to known dust sources (such as conveyor transfer points).

15.1.8. Where excavating in rock, where levels of airborne dust can be high in certain rocks and unacceptable for health reasons, dust suppression should be provided. Atmospheric dust may be invisible; high dust concentrations can reduce visibility. Additionally some dusts such as coal can be potentially explosive. Even with dust suppression , it may be necessary to wear dust protection masks.

15.2. TUNNEL BORING MACHINES

15.2.1. Machines should be provided with a means of safe access to and sufficient working space at all points where maintenance is required.

15.2.2. There should be a safe system of work for changing cutters and other maintenance work.

15.2.3. There should be a safe means of access to the face which may include an airlock system, and adequate working space at the face to work safely.

15.2.4. Machines should be fitted with a lock-out system to prevent accidental starting during maintenance.

15.2.5. Machines shall be so designed to allow for the installation of tunnel support systems immediately behind the cutting head and to allow for drilling of exploratory and grout holes ahead of the face.

15.2.6. Safe mechanical systems for erecting tunnel segmental linings shall be devised.

15.2.7. In the design of the machine, fire risk should be assessed. and the machine designed to minimise the fire risks. Low flammability hydraulic fluids and lubricants should be used. The amount of flammable materials on the machine should be minimised.

15.2.8. Suitable smoke and gas monitoring and alarm systems should be incorporated.

15.2.9. Fire suppression systems should be fixed manually operated systems supplemented by portable extinguishers as necessary. All workers should be trained in the use of portable fire extinguishers. For electrical requirements.

15.2.10. An atmospheric monitoring system should be provided which will shut down all non-explosion protected electrical and mechanical equipment on the TBM automatically in the event of an unsafe atmosphere being detected.

15.2.11. All safety critical electrical equipment should be explosion protected.

TBM (wienerwald tunnel, © Hochtief)

15.3. ROADHEADERS

15.3.1. Exhaust ducts and efficient dedusting systems should be installed to extract the dust. Preferably dry type dedusting systems should be used.

15.3.2. The exhaust ducts and the dedusting system shall be designed in accordance with the rock characteristics (e.g. quartz content) and the tunnel surface to be dedusted.

15.3.3. Exhaust ducts shall be so installed that the exhaust air is always extracted from the tunnel face

15.3.4. During operation workers shall not be in the area ahead or adjacent of the machine.

Roadheader (Energy Australia)

16 >> Dealing with water

16.1. GENERAL

16.1.1. Care should be taken to avoid the works being flooded from outside sources.

16.1.2. Fissures in rock often contain water under pressure. If water is anticipated, exploratory probing or drilling ahead of the face should be carried out, to confirm the quantity, the quality and the pressure.

16.1.3. Water containing suspended particles in particular fine sand, and entering a tunnel can over a period of time, create a void behind the tunnel lining.

16.1.4. The presence of water adversely affects the working environment and can affect the stability of exposed ground.

16.1.5. The presence of water increases the risk associated with the use of electricity.

16.1.6. Adequate protective clothing should be provided for those working in wet conditions.

16.2. DEALING WITH WATER

16.2.1. If water is anticipated, exploratory probing or drilling ahead of the face should be carried out to confirm the quantity, the quality and the pressure. Blowout preventers shall be used during drilling according to the risk assessment.

16.2.2. If ground water is encountered, and the ground requires sealing, this should be done ahead of the excavated face.

16.2.3. Measures shall be put in place for the evacuation of workers in case of sudden flooding.

16.2.4. Water should be removed from the working area either by open drains or by pumps and pipes. Intermediate holding tanks and pumping stations should be set up where water has to be pumped over large distances.

16.2.5. If open drains are used they should be on the opposite side of the tunnel to the pedestrian walkway.

16.2.6. Sumps are hazards for persons walking in the tunnel and should be guarded and readily visible to avoid injuries to workers falling into them.

16.2.7. To avoid flooding, especially in downward sloping tunnels, pumps with adequate reserve capacity should be provided and so arranged that if flooding occurs they will not be put out of action.

16.2.8. Where the stability of the tunnel face or the tunnel itself is endangered by the presence of water, the tunnelling method shall be chosen accordingly.

16.2.9. If water from the tunnel is to be used for drinking or spraying purposes it should be regularly tested for contaminants and treated as appropriate.

16.2.10. Where water from the tunnel is discharged it may require treatment (settling ponds, etc) to avoid pollution of surface water.

16.2.11. Groundwater lowering may have a detrimental effect on surface structures and gas and water pipelines.

16.2.12. Where groundwater is lowered during construction adequate standby capacity should be available to prevent interruption of this process.

17 >> Underground communication systems

17.1. GENERAL

17.1.1. Good communication throughout the works is necessary for safety and is an aid to efficiency.

17.1.2. The system adopted should be chosen having regard to the size, length and complexity of the tunnel works; the number and distribution of personnel in the works; the method of construction to be used; the potential hazards in the tunnel; the noise level in the tunnel; the requirements of the emergency services and the client's requirements for the post-construction phase

17.1.3. An alternative power source should be available for the communication systems.

17.1.4. Communication equipment should be well maintained and regularly tested.

17.1.5. Communication cables should be adequately protected from fire and mechanical damage and should not be located adjacent to power lines.

17.1.6. Equipment should be protected against water and dust ingress to IP 55 where possible.

17.1.7. Where potentially explosive atmosphere may occur, communications equipment should be explosion protected.

17.1.8. Direction to the nearest communication set should be clearly signposted. They should be sited as near as possible to the working area, at regular intervals not exceeding 500m along tunnels, in workshops, in the site office, and at the tops and bottoms of shafts. Where compressed air working is being carried out, additional sets will be required to link the locks and plant installation to the site network. There should be a link to the public telephone network for emergency use.

17.1.9. Communications sets should have acoustic covers or earphones should be used. Large flashing lights are often preferable to a bell as a call sign.

17.1.10. Emergency lighting should be provided at the communication points.

17.1.11. Users of communication systems should not be exposed to traffic or other hazards.

17.1.12. A pre-arranged emergency signal system should be developed (tapping on rails or pipes) for use in emergencies.

17.1.13. Any signal system adopted, whether sound or visual, shall be clearly displayed adjacent to all telephone sets.

17.1.14. Radio systems, developed for underground work and utilising leaky feeder technology, may be considered instead of, or in addition to other systems.

18 >> Ground support

18.1. GENERAL

18.1.1. Ground support shall be used unless engineering experience indicates that it is not required. The ground shall be supported wherever loose or fractured material is encountered.

18.1.2. The type of support provided shall be appropriate to the nature of the ground exposed, the prevailing groundwater regime and the tunnelling methods used.

18.1.3. Support shall be installed as soon as possible after excavation.

18.1.4. A competent person shall inspect, and if necessary arrange to have made safe, all working areas before the start of each shift. Until an area is declared safe, no one should work in it except in connection with making the area safe

18.1.5. Supervisors should examine and check support and ground conditions during visits.

18.1.6. Methods of support normally used include precast concrete or cast iron segmental lining; rock bolts; shotcrete or sprayed concrete; steel ribs or other structural support (steel, concrete etc or a combination thereof).

18.2. PRECAST CONCRETE or CAST IRON SEGMENTS

18.2.1. Damaged, deformed or corroded support elements should not be used.

18.2.2. The segmental lining should be installed in contact with the ground.

18.2.3. All voids between the segmental lining and the existing ground should be filled with grout or other appropriate material.

18.2.4. Mechanical erection equipment should be used in the handling and erection of the segments.

Tunnel lining segments (©ADIF)

18.3. ROCK BOLTS

18.3.1. The bolt length and pattern etc should be designed and installed under the close supervision of a competent engineer.

18.3.2. Persons installing bolts should only do so from under the protection of a previously bolted area or temporary protective canopy. Appropriate access equipment should be provided for this operation.

18.3.3. Bolts may be mechanically anchored, friction bolts, or resin anchored, partially or fully bonded, tensioned or untensioned. Appropriate tools e.g. torque wrenches etc., should be used to ensure bolts are installed to the required tension.

18.3.4. Anchorage tests shall be carried out to determine anchorage capacity in the various ground types.

18.3.5. Where tensioned bolts are used, pre-set tensioning jacks or torque meters shall be available and always used.

18.3.6. Where mesh or netting is used it shall be installed between the ground and the anchorage plate.

18.3.7. Spherical washers shall be used between the nut and the anchorage plate when tensioned bolts are installed.

18.3.8. Mechanically anchored bolts shall be periodically checked to ensure that the plate is secure against the rock.

Rockbolting (Portugal)

18.4. SPRAYED CONCRETE/SHOTCRETE

18.4.1. Shotcrete application is skilled work and only competent operators should be used.

18.4.2. The mixture should be designed to meet the specification in terms of workability and strength. It should also be designed to minimise dust emissions.

18.4.3. Good ventilation and lighting of the shotcreter's work place are essential during shotcreting.

18.4.4. Shotcrete support is dependant on adequate bond with the rock. Surfaces contaminated with oil, dust or mud shall be safely cleaned before applying shotcrete. Shotcrete will not bond to excessively wet rock surfaces and in these cases remedial measures are necessary.

18.4.5. The quality of the shotcrete shall be verified by routine inspection and testing.

18.4.6. During shotcreting, no other operations should be carried out in the vicinity.

18.4.7. The wet mix shotcrete process should normally be used. It produces less dust and is less susceptible to rebound than the dry process.

18.4.8. Accelerators should be used in correct proportions as per 'manufacturers instructions. Non-caustic accelerators are to be preferred.

18.4.9. Protective clothing and respirators should be used only when no further reduction in dust emissions can be made through altering the mix.

Robot sprayconcrete (Uetliberg tunnel)

18.5. OTHER STRUCTURAL SUPPORT (Steel ribs, steel sets etc)

18.5.1. Damaged, deformed or corroded support materials should not be used.

18.5.2. The support system should be installed in contact with the ground.

18.5.3. Any voids between the structural support system and the ground should be filled with grout, concrete or shotcrete.

18.5.4. Structural supports are to be adequately braced to one another with connecting bolts or girders. Supports shall be fully and rigidly assembled with all bolts and plates in place.

18.5.5. Lagging, preferably of steel, and appropriate to the spacing of the support sets, should be fastened to the extrados of the sets over the area of ground where support is required.

18.5.6. Support ribs should not be supported on loose material.

18.5.7. Support systems should be inspected regularly to determine the condition of the arches and bases; the condition of the connecting pieces and braces and condition of the lagging

18.5.8. All necessary remedial work identified by the inspection shall be carried out expeditiously.

Sprayed concrete (Czech Republic)

19 >> Monitoring of the tunnel atmosphere

19.1. GENERAL

19.1.1. A summary of the most commonly encountered atmospheric contaminants and their properties is given below. This should be used as a guide when controlling the risks from these hazards.

19.1.2. In the absence of national statutory limits on exposure to harmful substances, the national limits from an adjacent country should be adopted.

19.1.3. Monitoring for oxygen concentration should be carried out routinely by the use of electronic atmospheric monitoring equipment. Where the presence of gaseous contaminants is foreseeable, continuous monitoring by electronic equipment should likewise be carried out.

19.1.4. Further guidance on the basic principles for a clean and healthy tunnel atmosphere is set out in Section 11.6 of this document.

19.1.5. A range of gases including methane, hydrogen sulfide and radon dissolved in ground water may enter the tunnel.

19.1.6. Ventilation should be used to dilute contaminants and to prevent the build up of an irrespirable atmosphere.

Atmospher measuring

19.2. SUMMARY OF THE MOST COMMONLY ENCOUNTERED ATMOSPHERIC CONTAMINANTS

GAS	HAZARD	PRINCIPAL SOURCES
Carbon monoxide	Toxic and potentially explosive	Internal combustion engines and explosives
Carbon dioxide	Asphyxiant	Occurs naturally, explosives, welding and internal combustion engines
Nitrogen monoxide Nitrogen dioxide	Toxic Toxic	Internal combustion engines, explosives and welding
Ammonia	Toxic and potentially explosive	Explosives
Hydrogen sulphide	Toxic and potentially explosive	Occurs naturally and may occur where sewage is present
Sulphur dioxide	Toxic	Occurs naturally
Methane	Potentially explosive (and asphyxiant)	Groundwater, decay of organic matter, urban domestic gas supplies, Carboniferous rocks
Propane Butane Acetylene	Potentially explosive (and asphyxiant)	Leakage from compressed gas cylinders Do
Oxygen deficiency	Asphyxiant	Natural/induced
Oxygen enrichment	Increased fire risk	Leaks from cylinders
Petrol/diesel vapour	Potentially explosive	Spillage
Ozone	Toxic	Welding
Radon	Radioactive	Ground

20 >> Fire

20.1. GENERAL

20.1.1. As part of the tunnel planning process a risk assessment shall be undertaken of the potential for fire underground. Sources of flammable materials and potential sources of ignition should be identified. A plan to minimise risk should be drawn up.

20.1.2. At the planning stage a decision should be taken whether to establish and train a special on-site rescue team to carry out rescue operations in emergency situations. Liaison with the public emergency services is essential for disaster planning.

20.1.3. Adequate evacuation of workmen shall be possible. Escape and rescue ways underground should be kept free of smoke by ventilation and/or other technical installations such as smoke barriers.

20.1.4. Strict safety rules and work permissions should be applied for all work with open flames

20.1.5. There should be one or more water spray curtains across the tunnel capable of being activated in an emergency to act as a barrier to the movement of smoke.

20.1.6. Low flammability hydraulic oils and greases should be used.

20.1.7. All flammable and combustible waste materials, grease, lubricants or flammable liquids shall not be allowed to accumulate where they can create a fire hazard.

20.1.8. Fire fighting equipment provided on the works shall be strategically located, readily accessible, plainly marked, properly maintained, and inspected periodically. All mechanical plant major items of electrical equipment should be fitted with fixed fire extinguishing equipment. Records shall be kept of such inspections.

20.1.9. Additional fire extinguishing equipment should be provided in accordance with the risk assessment..

Fire of a jumbo

20.1.10. Fire alarm systems adequate to warn all employees shall be provided and maintained in operating condition.

20.1.11. Gasoline or liquefied petroleum gases shall not be permitted underground.

20.1.12. An evacuation and fire fighting training programme for all underground workers should be undertaken in order to prepare for possible cave-ins, flood, gas, explosion, fire or other disasters.

20.1.13. Oxygen self rescuers should be carried by everyone underground.

20.1.14. Evacuation drills shall be held for each shift at least once every 6 months. This period could be shortened if shown to be necessary by the risk assessment. These evacuation drills shall involve all employees on each shift and shall include activation of the fire-alarm system followed by evacuation of all men from their work areas to the surface or to designated central evacuation points at some time other than a shift change.

20.1.15. All employees involved in the escape and evacuation plan for an underground operation shall be instructed at least once each calendar year on current escape and evacuation plans, use of self rescuers, fire alarms, and applicable procedures to be allowed in case of fire or other emergency.

20.1.16. When welding or cutting with an arc or open flame, or thawing pipes electrically (excluding heat tape) or soldering with an open flame, a adequate fire extinguisher shall be provided.

20.1.17. Fan housings and air ducts connecting main fans to underground openings shall be fire-resistant.

20.1.18. Electronic atmospheric monitoring equipment shall be used to test for oxygen deficiency.

20.1.19. The carrying of matches or other flame-producing materials shall be prohibited in all underground operations where fire or explosion hazards exist.

21 >> Appendix - Health and safety plan (HSP)

21.1. GENERAL

21.1.1. Before any tunnelling work begins, an occupational health and safety strategy for the project should be drawn up and set out in a health and safety plan for the project. The health and safety plan should form the basis for the identification and management of all health and safety risk arising from the works. The client or promoter of the project should join with the designers and contractors in setting the strategy and drawing up the plan and should monitor its implementation.

21.1.2. Tunnelling involves both general construction risk and risk which is specific to the tunnelling environment and therefore establishing a health and safety plan should be done by competent staff.

21.1.3. To be effective, the planning of health and safety risk management measures must begin during the project design stage. The implementation during the construction phase should be monitored, so that any revisions be made when necessary.

21.1.4. The plan should also contain details of emergency procedures as well as welfare and first aid facilities. It should be made available to everyone on site.

21.2. MAIN HAZARDS TO BE ADDRESSED IN THE PLAN

21.2.1. Moving plant and machinery, exacerbated by inadequate visibility for operators.

21.2.2. Collapsing/falling ground or rock

21.2.3. Fire and smoke

21.2.4. Electricity

21.2.5. Falling objects, specially in shafts and inclines

21.2.6. Handling of construction materials (concrete segments and steel arches)

21.2.7. Working in an environment polluted by

- Dust
- Soot Particles (Diesel engine emissions)
- Hazardous gases – toxic, potentially explosive, etc
- Noise
- Heat
- Emissions of potentially explosive gas

21.2.8. Unforeseen inflow of large quantities of water

21.2.9. Hazardous working conditions – inadequate machine platforms, ladders, walkways, greasy areas, obstacles, poor lighting, protruding obstacles

21.2.10. Work in compressed air

Rescue container

22 >> Contents of the HSP in respect of these hazards

22.1 SHAFTS, ADITS and PORTALS

22.1.1. Plan of equipment provided

22.1.2. Rules for accounting for and movement of personnel

22.1.3. Rules for operation of equipment Description of communication systems throughout the tunnel complex

22.1.4. Description of communication systems throughout the tunnel complex

22.2. WORKING UNDERGROUND

22.2.1. Segregation of plant, machinery and pedestrian traffic

22.2.2. Sketches showing the various tunnel routes and the areas reserved for pedestrians

22.2.3. Description of safety measures such as sound or light signals, safety signs, etc.

22.2.4. Rules governing vehicular traffic with particular reference to speed and right of way

22.2.5. Rules for pedestrians

22.2.6. Measures to be taken to ensure effective maintenance of accesses and tracks, signalling of vehicles and control over the safe working condition of machines, particularly at the change of shifts.

22.2.7. Measures to be taken for the transport of personnel

22.3. SUPPORT

22.3.1. Description of the main support techniques and their installation in response to the ground conditions encountered

22.3.2. Operating procedures for routine inspection and maintenance of the support system by a competent person

22.4. HANDLING of MATERIALS

22.4.1. Weights of the materials to be transported

22.5. TUNNEL PLANT and EQUIPMENT

22.5.1. Rules for the use of jumbos, tunnel boring machines, locomotives and other plant and equipment

22.6. EXPLOSIVES

22.6.1. Transport and storage methods

22.6..2. Blasting equipment to be used and the measures to be taken to keep them in good working condition

22.6..3. Steps to be taken in case of misfires

22.6..4. Steps to be taken in case of thunder storms

22.6..5. Tunnel re-entry following blasting

22.6..6. Measures to be taken to ensure the presence of at least one competent person to undertake blasting works at each working area.

22.7. ELECTRICAL EQUIPMENT

22.7.1. Measures to be taken to prevent damage to electrical equipment and lighting installations by flying rock or moving machinery

22.7.2. Manual or automatic circuit breakers (including earth leakage circuit breakers) provided to switch off power in an emergency

22.7.3. Rules and procedures for isolating and locking out, electrical power during maintenance work

22.7.4. Description of the normal and emergency lighting systems

22.8. PRESSURISED FLUIDS

22.8.1. Measures to be taken to prevent damage to or disconnection of flexible pipes

22.9. QUALITY of ATMOSPHERE

22.9.1. Ventilation plan for every construction phase

22.9.2. Procedures to be adopted to control dust during drilling, mucking and concrete spraying

22.9.3. Measures to be taken to ensure efficient watering of the face before and during mucking operations

22.9.4. Description of diesel particulate filter systems fitted to diesel engines and measures to be taken to maintain their efficiency

22.9.5. Method and frequency of atmospheric monitoring

22.9.6. Steps to be taken to prevent formation of fog

22.9.7. Cooling measures to prevent heat build-up in tunnel atmosphere

22.9.8. Air quality and flow should meet appropriate national standards

22.10. NOISE

22.10.1. Measures to be taken to lower the noise emission levels from plant and equipment at working areas

22.10.2. Individual protection provided for workers

22.11. WATER AND MUD INFLOW

22.11.1. Measures to be taken to prevent unexpected water and mud inflow.
22.11.2. Steps to be taken in cases of sudden flooding

22.12. LASER

22.12.1. Plan indicating locations of sets Rules for use of lasers

22.12.2. Means of preventing exposure to laser beam

22 >> Contents of the HSP in respect of these hazards

22.13. FIRST AID

22.13.1. Methods for evacuating injured persons

22.13.2. Measures to be taken to ensure the attendance of at least one first-aid worker at every working area and on every working shift

22.14. FIRE

22.14.1. Fire fighting equipment and instruction

22.14.2. Method of raising alarm

22.14.3. Methods and ways of evacuation

22.14.4. Steps to keep escape ways free of smoke

22.15. COMMUNICATION

22.15.1. Description of communication methods between the different working areas and the surface

22.15.2. Description of communication methods between one working area and another

22.15.3. Description of communication methods for emergency use.

22.16. DESCRIPTION of PROCEDURES for WORK in COMPRESSED AIR

22.16.1. Medical equipment

22.16.2. Therapeutic treatment

22.16.3. Exposure record keeping

22.16.4. Emergency procedures including fire, inundation, loss of air pressure, medical emergency etc

22.16.5. Compression/decompression regimes

22.16.6. Plant and equipment including air supply, locks etc

22.16.7. Welfare

22.17. OCCUPATIONAL HEALTH

22.17.1. The HSP should set out details of the occupational health arrangements The contractor should have a system to ensure that all employees have access to appropriate occupational health provision and health surveillance if this has been recognised as a requirement through risk assessment.

22.17.2. The occupational health system should describe how the contractor intends to monitor these procedures to ensure risk assessments, control measures and health surveillance programmes are effective and maintained. It should clearly define and allocate responsibilities.

22.17.3. Specific consideration should be given to establishing clear methods of communication to provide all employees with information on the occupational health provision and the policies for its effective implementation

22.17.4. Where health surveillance has been recognised as a measure required from the risk assessment process this should be provided and recorded.

22.18. WELFARE

22.18.1. The HSP should set out details of the welfare provisions on site. The contractor should have a system to ensure that all employees have access to welfare facilities including toilets, washing facilities, clothes drying and messing facilities as appropriate.

23 >> Informative references

23.1. CEN and ISO STANDARDS

23.1.1. EN 815 – "Safety of unshielded tunnel boring machines and rodless shaft boring machines for rock".

23.1.2. EN 1710 – "Equipment and components intended for use in potentially explosive atmospheres in underground mines".

23.1.3. EN 1889 - Machines for underground mines. Mobile machines working underground. Safety. Pt 1 - Rubber tyred vehicles, Pt 2 - Rail locomotives.

23.1.4. EN 12110 – "Tunnelling machines. Air locks. Safety requirements".

23.1.5. EN 12111 – "Tunnelling machines. Road headers, continuous miners and impact rippers. Safety requirements".

23.1.6. EN 12336 – "Tunnelling machines. Shield machines, thrust boring machines, auger boring machines, lining erection equipment. Safety requirements"

23.1.7. EN 60204:1997 – (various parts), Safety of Machinery – Electrical equipment of machines.

23.1.8. EN 60529:1991, Degrees of protection provided by enclosures (IP Code) (IEC 60529:1989).

23.1.9. EN 791 – "Drill rigs – Safety"

23.1.10. ISO 3864:2002, Graphical symbols — Safety colours and safety signs

23.2. ITA PUBLICATIONS

23.2.1. Safe Working in Tunnelling – available from www.ita-aites.org in various languages.

23.2.2. Guidelines for Tunnelling Risk Management. ITA Working Group 2., TUST Vol 19 page 217-237, 2004

23.3. UK PUBLICATIONS

23.3.1. BS 6164:2001 "Code of practice for safety in tunnelling in the construction industry" BSI, London.

23.3.2. "A Guide to the Work in Compressed Air Regulations 1996 - Guidance on Regulations", L96, HSE Books, Sudbury.

23.3.3 Addendum to "A Guide to the Work in Compressed Air Regulations 1996 - Guidance on Regulations, Guidance on OXYGEN DECOMPRESSION and the use of Breathing Mixtures other than Compressed Natural Air in the Working Chamber" Construction Division Technology Unit, HSE, Bootle

23.4. RUSSIAN PUBLICATIONS

23.4.1. PB 03-428-02 "Safety Regulations in Construction of Underground Structures", 2002, Moscow.

23.4.2. SNiP 12-03-99 "Safety of Labour in Construction", Moscow, Gosstroy, 1999.

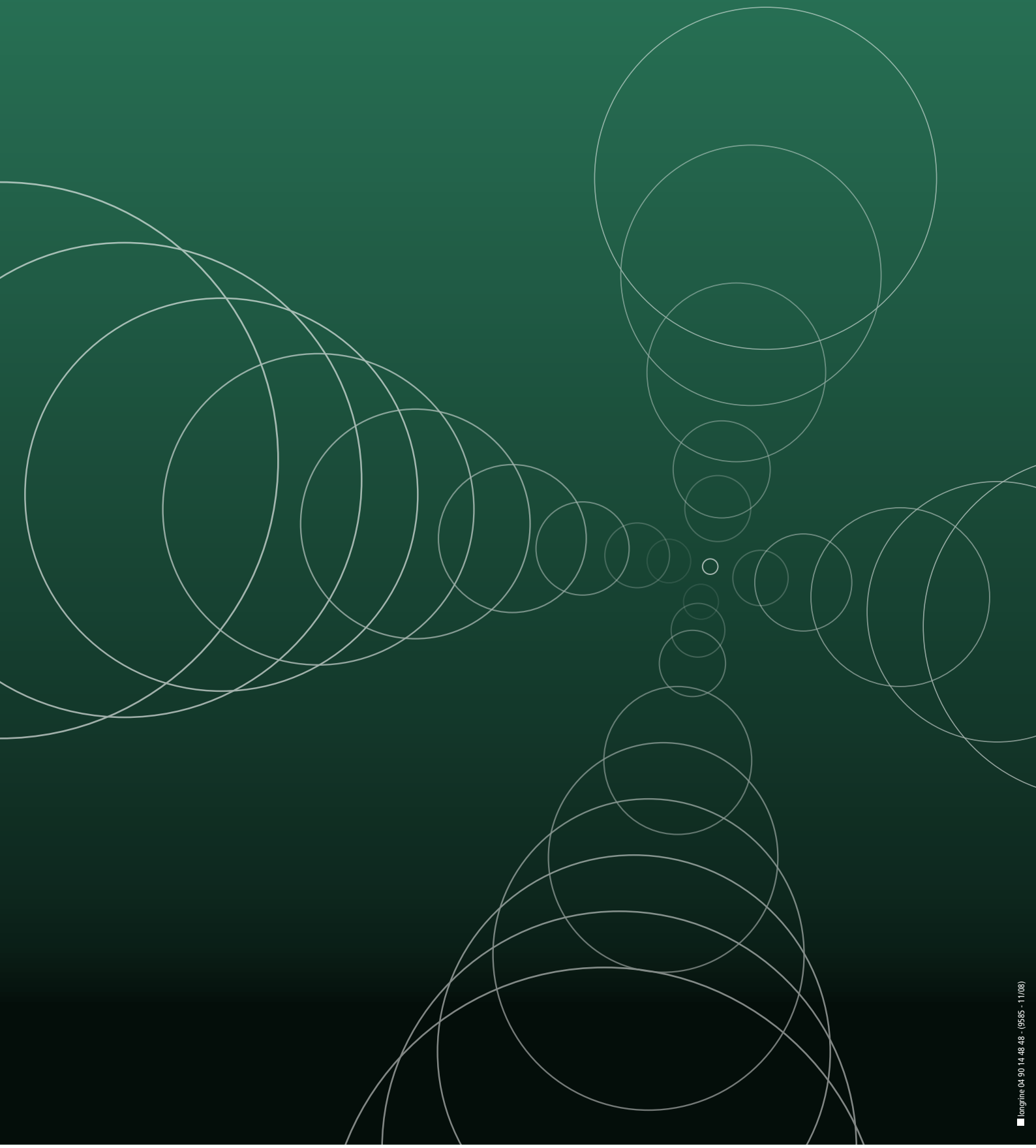
23.4.3. PB 13-01-92 "Common Safety Regulations in Blasting Operations", Moscow, Gosgortehnadzor, 1992.

23.4.4. RD 06-329-99 "Safety Instruction of Mining in Ore and Non-Ore Deposits, Underground Construction Objects, Rock Burst Inclined", Moscow, Gosgortehnadzor, 1999.

23.4.5. "Safety of Works in Compressed Air Regulations", Moscow, Mintransstroy, 1980.

23.4.6. RD 07-225-98 "Instruction of Abandonment And Temporary Closing-down Order of Unrelated to Minerals Extraction Underground Structures", Moscow, Gosgortehnadzor, 1998.

23.4.7. VSN 189 "Instruction of design and work of artificial ground freeze in Metro and tunnels Construction".



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