Guidelines For The Provision of Refuge Chambers In Tunnels Under Construction

ITA - Working Group N°5
Health And Safety In Works

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Guidelines For The Provision of Refuge Chambers In Tunnels Under Construction

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At its meeting in Helsinki in 2011, International Tunnelling Association Working Group 5, identified the need for guidance on the provision of refuge chambers in tunnels under construction. A refuge chamber is a place of relative safety in a shaft or tunnel where tunnellers can be accommodated with access to basic life support services until rescued or it is safe for them to exit the tunnel.

Refuge chambers should be easily identifiable and readily accessible by tunnellers at risk and by the emergency services

This document will be reviewed and revised as necessary in the light of practical experience with the provision of refuge chambers in tunnels under construction. Comment and feedback is welcomed and should be made to the ITA Secretariat through the website www/ita-aites.org.

Status of this document – this document is not intended to replace or override national standards. The “Guidelines” provide guidance and recommendations for good practice only. Compliance with the “Guidelines” is voluntary unless they form part of contractual requirements.

This guideline was revised in 2018 to include guidance on the use of refuge chambers when there is a risk of flammable gas being present. Changes were also made in requirements concerning atmospheric monitoring equipment and controls for air conditioning equipment.

>> Contents

>> Glossary of terms and abbreviations

INTERNAL DIAMETER : the internal diameter of the lining through which the backup equipment is being towed. For unshielded machines, the internal diameter is that within the planned rock support

REFUGE CHAMBER : a refuge chamber is a place of relative safety in a shaft or tunnel where tunnellers can be accommodated with access to basic life support services until rescued or it is safe for them to exit the shaft or tunnel.

MECHANISED TUNNELLING : tunnelling using a tunnelling machine which would conform to EN 16191

CONVENTIONAL TUNNELLING : tunnelling other than mechanised tunnelling in any ground type

ZONE : A hazardous area classification relating to explosion protection - see EN 60079-10 “Explosive atmospheres. Classification of areas. Explosive gas atmospheres”.

Refuge chamber for small TBM

Refuge chamber on large TBM

1 >> Introduction

1.1. BACKGROUND

In recent years the provision of refuge chambers in shafts or tunnels under construction has become widespread in the tunnelling industry. There is no single consistent set of requirements for such chambers. This document draws on the requirements for chambers, from different countries and jurisdictions, to produce what ITA WG5 hopes is an internationally applicable single guidance document.
Refuge chambers are also used in mining where different requirements can apply.

1.2 SCOPE

These guidelines apply to the provision of refuge chambers in mechanised and conventional tunnels under construction. Depending on circumstances, a chamber could also be located in the base of a large or deep shaft. The guidelines are intended for use by regulatory authorities, clients, designers, contractors, site safety coordinators, insurers and others involved in tunnel construction. Similar criteria could be applied, when assessing whether there are requirements for the provision of refuge chambers in tunnels being refurbished.

These guidelines apply to refuge chambers in tunnels where flammable gas can occur but is not likely to be continuously present. Methane is the most commonly encountered flammable gas in tunnelling. For the more arduous condition of flammable gas being likely to be continuously present i.e. Zone 0 conditions, the design of the refuge chamber should be agreed between the manufacturer and chamber user where flammable gas is likely to be continuously present i.e. Zone 0 conditions, then the design of the refuge chamber should be agreed between the manufacturer and chamber user.

1.3 EMERGENCY SCENARIOS

The main emergency scenarios, in response to which tunnellers might use a refuge chamber are smoke and atmospheric contamination. A refuge chamber is not designed to protect against direct exposure to fire, hence in the event of a fire in the vicinity of the refuge chamber, tunnellers should not use the chamber but should evacuate the tunnel.

In the event of an evacuation due to the presence of flammable hydrocarbon gas, the refuge chamber should not be used. A refuge chamber is not normally designed to resist the blast wave from a flammable gas explosion (see clause 4.5). Even when designed to resist the overpressure from blasting, a refuge chamber is not explosion proof and hence should not be used when flammable gas levels exceed those at which evacuation of the tunnel is required. There is considerable variation in the explosive limits for hydrocarbon gases hence where the source of hydrocarbon gas is ground pollutants, some of which can be toxic, the project risk assessment should be used to assess whether there is a risk from explosion in addition to the risk from toxicity.

Note : many hazardous organic contaminants found in former industrial sites have lower explosive limits (LEL) which are significantly lower than that of methane (LEL 4.4% methane in air by volume) e.g. for benzene, toluene etc, the LEL is around 1% gas in air by volume.

Likewise, a chamber should not be used as protection against flooding or inundation. Similarly refuge chambers are not designed to withstand a lining collapse, ground collapse or major rock fall. However, in the event of entrapment as a result of a collapse or rock fall a chamber with its communications, water and supply line, would act a muster point for survivors.

1.4 ACCOUNTING FOR PERSONNEL

It is important that there is an effective system for controlling access to the tunnel(s) and for accounting for personnel in the tunnel including visitors. If all personnel who were known to be underground are accounted for and are safe either on the surface or in a refuge chamber, the need to commit a rescue team to enter the tunnel during a smoke or atmospheric contamination incident can be reduced with a consequent reduction in risk to team members' safety.

1.5 HIERARCHY OF MEASURES TO BE TAKEN

As a priority, measures should be taken to prevent the occurrence of smoke or atmospheric contamination in the first place and to provide means of immediate escape to the surface. The use of the chamber should be looked upon as the last resort in mitigating the risk from these hazards. It is not a substitute for evacuation to the surface.

Note : measures for prevention of fire are set out in documents such as EN 16191, EN 1889, EN 13478. Measures for ventilation are set out in documents such as SIA 196, BS 6164, AFTES GT27. Measures for identifying the possible presence of flammable gas include comprehensive ground investigation and routine atmospheric monitoring.

Where parallel tunnels are being constructed with cross passages, it is preferable to construct cross passages as close to the advancing tunnel faces as practicable and to maintain separation of airflow in these tunnels to enable one to act as a safe haven in the event of smoke or atmospheric contamination in the other. Similarly, in a large tunnel where the cross section is subdivided perhaps to form a utility channel, in the tunnel invert and which could be slightly over-pressurised, that channel could possibly form an independent means of access and egress.

1.6 TUNNEL PROJECT RISK ASSESSMENT

The need for refuge chambers should be assessed as part of the tunnel project risk assessment **however, it is the recommendation of ITA WG5 that every tunnel should have refuge chamber(s) unless it is shown not to be necessary by the Tunnel project risk assessment.** Guidance on risk assessment is set out in documents such as those listed in 2.1. The risk assessment process should involve the whole underground team. Assessment of fire risk should include likely fire load, occurrence, duration, smoke development, location of the fire, detection, alarm and suppression systems. Assessment of the risk from flammable gas should include a review of the ground investigation data and in-tunnel atmospheric monitoring. The number and location of refuge chambers to be provided should be determined by an assessment of the number of persons at

risk, the risks to which those working underground are exposed and the options for means of escape to a place of relative safety. If the project has alternative means of escape such as two separately ventilated tunnel tubes with availability of frequent cross passages close to the excavated faces, the risk assessment can show no need for refuge chambers. Refuge chambers provided should be in accordance with these guidelines. The results of this risk assessment should be documented.

Note : the refuge chamber manufacturer is able to make recommendations but cannot be responsible for the project risk assessment.

As a refuge chamber is intended to be a place of relative safety in the tunnel (or shaft), its correct location, capacity and duration can be critical in determining the consequences arising from the emergency.

1.7. MINIMUM TUNNEL PARAMETERS FOR REFUGE CHAMBERS

Refuge chambers should be considered for installation on TBMs of 3.5 m internal diameter and larger. However, for TBMs at the smaller end of the size range, chambers may be custom designed.

Note 1 : the refuge chamber may be towed permanently behind the TBM if that were to be the contractor's preference.
Note 2 : where a chamber cannot be provided in small TBMs, means of mitigating the risk in addition to the use of self rescuers, should be provided such as :

- *Minimising fire risk in the tunnel,*
- *Automatic extinguishing systems on mechanical and electrical plant,*
- *Avoidance of routine work behind the tunnelling machinery involving fire risks,*
- *Additional water curtains in tunnel connected to safe water supply from outside,*

Where the project risk assessment shows a chamber to be necessary, the minimum tunnel diameter may be influenced by the minimum diameter to accommodate the chamber rather than by the size needed for operational requirements. Tunnels of less than 500m in length may not require a refuge chamber. However, the need for chambers should be considered when assessing the risks associated with the construction of complex underground structures such as metro stations and for tunnels involving deep shafts. In conventional tunnels and tunnels in rock a purpose-built niche can often be constructed to house the refuge chamber if necessary.

1.8. DURATION OF USE

The period of time for which the chamber could be in use should be assessed on the likely time required to affect a rescue. It is recommended that refuge chambers are designed for a minimum occupancy time of 24 hours. Where this is considered insufficient, the project risk assessment should include a determination of the minimum occupancy time.

1.9. CHAMBER LOCATION

1.9.1. General

A refuge chamber should be available for every active face of a tunnel project unless workplaces are sufficiently interconnected or close together to share a chamber. The area around the chamber should be free from combustible material including non-essential power cables and hydraulic hoses. Where possible a chamber should not be located directly below points of constant leakage or inflow or where water can pond.

1.9.2. TBM tunnelling

When so equipped, a refuge chamber should normally be located towards the out-bye end of the TBM back-up equipment, in a location accessible from all workplaces on the TBM irrespective of whether trains or other vehicles are under the gantry. The refuge chamber should be located close to a stairway or other access from the tunnel invert. If the refuge chamber is located on an upper deck, it should be close to a stairway or ladder leading to all other decks. The refuge chamber location, should also be accessible by a rescue team coming from outbye the TBM. The location and path to the refuge chamber should be clearly indicated using signs made from a retro-reflective material.

1.9.3. Conventional tunnelling

In conventional tunnels, the refuge chamber should be located between 150 m and 300 m from the tunnel face. Measures should be taken on site to protect the refuge chamber and any externally mounted gas cylinders required for its operation, from vehicle impact. The refuge chamber door should not open towards traffic routes.

1.9.4. Drill and blast tunnelling

Where blasting operations are being undertaken in the tunnel, the refuge chamber should be located clear of explosive magazines or other underground explosive storage facilities. Measures should be taken on site to protect the chamber against fly rock.

Note : underground storage of explosives is subject to National regulations

Persons should only use the chamber as a blast shelter if it has been specifically intended for such use by its manufacturer.

1.10. OTHER USES FOR CHAMBER

Such use may only be permitted when additional safety measures and strict site procedures are in place. The chamber design should consider the prevention of misuse of any safety-critical equipment in the chamber, such as the life-support system.

Additional measures and site procedures shall ensure the readiness of a refuge chamber at all times and include as a minimum, daily cleaning and inspection along with regular maintenance to ensure that the chamber and its equipment are in a constant state of immediate readiness and free of flammable material. Records of inspections and maintenance should be kept.

This information should be included in the information for use.
The intention to use a chamber as a mess cabin or blast fume shelter should be notified to the chamber manufacturer at the time of purchase.

2 LEGISLAION, STANDARDS, GUIDANCE ETC.

2.1 PRIMACY OF NATIONAL LEGISLATION, STANDARDS AND GUIDANCE

These Guidelines operate in parallel with and do not derogate from statutory duties, responsibilities and requirements of local national legislation, national standards and/or codes of practice which will always take precedence in the provision of refuge chambers.

3 PROVISION OF ESSENTIAL SERVICESTO CHAMBER

3.1 GENERAL

The effectiveness of the chamber in providing a place of relative safety is critically dependent on the supply, for as long as is required, of respirable air to the chamber along with the maintenance of an atmosphere in the chamber which is neither excessively hot, humid nor contaminated and in addition a means of communication with the surface. There is likely also to be a requirement for the provision of electrical power either from the tunnel supply or from a stand-alone source.

3.2 OPERATIONAL MODES

A refuge chamber should be capable of operating in three separate but complementary modes;
- Stand by
- Externally supported
- Stand alone

3.2.1 Standby mode

In this mode, no incident has occurred and the chamber is unoccupied but ready for immediate emergency use. No survival system is activated but electricity from the tunnel power supply is supplied to the emergency power supply which is kept charged. Communication systems are enabled.

A visible and audible warning device should be fitted outside the chamber to signal the interruption of the external air supply or electrical supply.

3.2.2 Externally supported

In this mode, an incident has occurred and the chamber is occupied with a respirable atmosphere in the chamber being provided by a reliable external compressed air supply from the surface. Prior consideration should have been given to the location of the airline to ensure a high level of protection from mechanical damage and fire.

The air flow rate needs to be sufficient for the number of persons in the chamber as well as flushing the chamber to remove heat, humidity, expired CO^2 and CO.

The emergency power supply should be sufficient to power the chamber for at least 24 hours.

3.2.3 Stand alone

In this mode, an incident has occurred and the chamber is occupied but disconnection of the external power and/or air supply has occurred. The occupants of the chamber now depend on life support from sources within the chamber. These should have the capability to provide full, independent life support to the occupants of the chamber including the immediate provision of a respirable atmosphere and the capability of conditioning the chamber atmosphere to maintain conditions inside the chamber within acceptable limits of heat and humidity. An uninterruptable power supply from batteries may be required for this and to power the chamber,

3.3 AIR AND OXYGEN SUPPLY

3.3.1 General

The reliability of the air supply should be assessed by the tunnel project risk assessment with a supply from the surface being preferred. In determining the capacity of the air supply the following should be considered:
- A reliable and continuous air supply from the surface will increase the confidence of the chamber users
- oxygen to counter depletion in standalone mode due to normal metabolic processes, should only be discharged into the chamber through the chamber ventilation system or by means of a diffuser nozzle attached to the cylinder. There should be a valve or other control device rather than the cylinder neck valve to control the discharge rate. If manually operated, it is preferable that the scale on this valve is calibrated to directly reflect numbers in the chamber rather than discharge flow rate.

3.3.2 Air quality in chamber

Air quality in the chamber should always be maintained to give an oxygen concentration of 21% +/- 2% by volume. The concentration of carbon monoxide should not exceed 60 ppm and the concentration of carbon dioxide should not exceed 10000 ppm. The concentration of other contaminants should not exceed their national long term exposure limits.

3.3.3 Piped air supply from above ground

The external air supply should be through a compressed air main in the tunnel. This main should be the compressed air main to the TBM or a separate main protected from mechanical damage and heat. Typical means of protection include burying it in the tunnel invert or protection by covering it with concrete. The manufacturer of the refuge chamber should provide a connection point to which the external air supply can be attached. Instructions for connection of the air supply should be described in the information for refuge chamber use.

Where the refuge chamber is mounted on or behind the TBM Back-Up and to allow for advance of the TBM, a non-rigid connecting line will be required between the protected tunnel air supply and the connection point on the refuge chamber. This will introduce a point of weakness into the air supply as it will be difficult to provide the same level of protection against mechanical damage and fire as for the tunnel air supply. A similar weak point could occur in a conventional tunnel at the transition between the top heading and bench.

3.3.4 Air supply volume

The air flow rate in externally supplied mode needs to be sufficient for the number of persons in the chamber as well as flushing the chamber to remove heat, humidity, expired CO_2 and CO.

Note 1 : The flow rate should be at least 85 l/min per person to remove expired CO_2 and CO but at least 255 l/min to provide adequate cooling and maintain comfortable conditions. The air inflow is assumed to be at a temperature of 26.5 0C and 65% relative humidity.
Note 2 : The information in Note 1 was taken from paragraph 23 of "Guidance and Information on the role and design of safe havens in arrangements for escape from mines" published by the UK Health and Safety Executive and freely downloadable at wwwhse.gov.uk/pubns/mines08.pdf

3.3.5 Smoke ingress

Measures should be taken to minimize smoke and contaminant ingress into the refuge chamber when the door is opened for entry.

3.3.6 Air filters, silencers and controls

Appropriate filtration shall be fitted to the incoming air supply to remove odour and oil vapour. A non-return valve should be fitted to prevent back flow into the tunnel air supply. Controls should be fitted in the refuge chamber to adjust the air flow. The noise produced by the air discharge into the refuge chamber should not exceed 80 dBA.

3.3.7 Standalone Air Supply

For the standalone mode, the chamber may be supplied from an air regeneration system or bank of air cylinders.

This regeneration system should have an oxygen feed supplied from on-board cylinders inside the chamber. As part of the regenerative system there should be a means to control carbon monoxide and carbon dioxide levels in the chamber atmosphere such as a scrubbing system.

The presence of a large number of pressurised cylinders in the tunnel should be considered in the risk analysis.

3.3.8. Use of Face Masks

It is recommended that masks are not used as part of the air supply system.

3.4 POWER SUPPLY AND EMERGENCY BACKUP

The refuge chamber should normally be connected to the tunnel power supply. The refuge chamber structure should be bonded to the earthing circuit in the tunnel. Electrical equipment on the refuge chamber should be protected against dust or water ingress to a minimum of IP54.

The refuge chamber should be provided with its own emergency uninterruptible power supply capable of powering it and its services for at least 24 hours. Any batteries forming part of the uninterruptible power supply should be explosion protected for Zone 1 conditions – (flammable atmosphere likely to occur occasionally in normal operation). Either batteries complying with EN 60079-7 "Explosion protection by increased safety 'e'" should be provided or the batteries should be housed in a Zone 1 compliant enclosure. In addition, there should be a double pole switch at the battery container at which all power from the batteries can be disconnected. The switch should also be Zone 1 compliant.

The power supply to the refuge chamber should be considered "essential services" as defined in Cl 3.29 of EN 16191.

3.5 COMMUNICATION

The refuge chamber should have a communication system which is connected to the tunnel communication network.

3.6 INTERNAL TEMPERATURE CONTROL

It should be possible to maintain an internal temperature not exceeding 30 °C wet bulb globe temperature for at least 24 hours

Note 1: Cooling can be achieved by an external water spray system or by an air conditioning system or by a combination of both.

Refuge Chamber in a conventional tunnel.

4 >> Chamber design

4.1. GENERAL REQUIREMENTS

The refuge chamber should be of robust steel construction and should be designed for use in the tunnelling environment.

4.2. CAPACITY OF CHAMBER

The number of persons to be accommodated in the refuge chamber should be determined from the tunnel project risk assessment. As a minimum the number of persons accommodated should include the tunnelling crew including surveyors, inspectors, fitters and electricians normally in the tunnel plus two visitors. When shift change is at the face, chamber capacity for a double crew should also be considered. The number of tunnel visitors should be limited in accordance with the capacity of the refuge chamber.

4.3. STRETCHER ACCESS TO CHAMBER

The need for sufficient access for a stretcher shall be taken into account when locating the refuge chamber.

4.4. REFUGE CHAMBER DIMENSIONS

The dimensions of the refuge chamber should be sufficient to provide at least 0.5 m2/person of floor area, a minimum headroom of 1.5 m and a minimum volume of 0.75 m^3/person. Wherever practicable the volume should be should be 1.0 m^3 per person.

4.5. BLAST RESISTANCE

If the refuge chamber is for a tunnel where explosives are being used, the refuge chamber should be capable of resisting an external overpressure surge agreed between the chamber manufacturer and the user
The refuge chamber is not designed to resist blast loading from an internal or external flammable gas explosion.

4.6. WINDOWS

There shall be a window of at least 150 mm diameter, either in the door or in the wall of the refuge chamber adjacent to the door to allow for visual contact.

4.7. DOORS

Doors should be robust and outward opening. It should be possible to open the door from either inside or outside the refuge chamber. The door and its closing mechanism should resist blast loading when appropriate. Experience has shown that a two-point closing mechanism gives the necessary performance.

The door should be provided with a seal to prevent entry of atmospheric contaminants when shut. Seals should be maintained in good condition.

4.8. ESCAPE HATCH

There should be an emergency escape hatch in another wall or roof of the refuge chamber remote from the door. Escape hatches should fit properly and seals should be maintained in good condition. It should be possible to open the hatch from either side.

4.9. OVERPRESSURE

The refuge chamber should be under a positive pressure of at least 100 Pa when in externally supported or standalone mode but measures should be taken to prevent the pressure in the chamber exceeding 1 kPa. The actual overpressure in the refuge chamber should be monitored and indicated inside to the occupants.

4.10. VISIBILITY AND RECOGNIZABILITY

The refuge chamber and its position should be easily recognizable from outside. It should be painted in a distinctive colour and have a reflective band at least 100 mm wide around the midsection. A high intensity flashing light or beacon should be fitted at a low level on the wall of the refuge chamber on which the door is fitted.

4.11. TOWING AND LIFTING

A refuge chamber which is designed to be used independently of the back-up equipment should be skid mounted and fitted with towing points at the front and rear end. The refuge chamber should also be fitted with lifting points.

5 >> Refuge Chamber Fittings

5.1. MINIMISING FIRE RISK

All fixtures and fittings should be chosen to minimize fire risk. The internal refuge chamber walls should have a surface finish chosen to minimize fire risk.

5.2. INTERIOR EQUIPMENT

The refuge chamber should be fitted with the following equipment :

5.2.1. Internal lighting

There should be internal lighting in the refuge chamber with an intensity of at least 15 lux at the air supply controls. This can be reduced to 5 lux when in standalone mode. LED lighting is to be preferred.

5.2.2. Seats

Seating, at least 500 mm wide per person, with back rest should be provided.

5.2.3. Storage

There should be sufficient storage space for rescue equipment (e.g. self-rescuers, stretchers, first aid
provisions) and water.

5.2.4. Toilet

This should be capable of providing waste containment for 24 hours. Toilet paper should also be supplied. There should be a flexible non-flammable screen to provide privacy.

5.2.5. Supply of drinking water

A supply of at least 3 litres per person for a 24-hour period should be stored in the refuge chamber.

5.2.6. Fire extinguishing

A water-based fire extinguisher should be provided internally and externally adjacent to the door.

5.2.7. First aid kit

Storage for a first aid kit, meeting national requirements, should be provided.

5.2.8. Atmospheric monitoring

There should be the capability to continuously monitor temperature and for carbon monoxide, carbon dioxide, and oxygen in the chamber during use in both externally supported or standalone modes. The monitoring equipment should be a fixed installation in the chamber. In addition, as backup, there should be the capability either to undertake monitoring using a portable monitoring device or to make spot measurements of oxygen levels and atmospheric contaminants. As a final precaution against failure of the monitoring equipment, there should be emergency instructions on the maximum time interval after which scrubber cartridges should be changed in standalone mode on the assumption the chamber is fully occupied.

An audible alarm should indicate when levels of oxygen, carbon monoxide and carbon dioxide exceed pre-set values.

5.2.9. Air circulation in refuge chamber

When in externally supported or standalone mode, there should be a circulation of air within the refuge chamber. This can be achieved by air flush generated by the discharge of the externally supplied air or by some form of fan-assisted ventilation.

5.2.10. Air conditioning unit

5.2.10.1. Location of controls

It should be possible to operate the air conditioning unit from a fixed control point mounted on the unit or elsewhere in the chamber. A portable remote control unit may be provided in addition.

5.2.10.2. Condensate drain

When the air conditioning unit is fitted with a condensate drainage system, any valves on the drainage system should be one-way valves. A water trap can be used to prevent air flow in the pipe when not in use if that is required. A water trap will not be effective when explosives are being used in the tunnel.

6 >> Inspection, functional testing and maintenance

6.1. GENERAL

It is vitally important for its correct functioning that a refuge chamber is inspected, functionally tested and maintained fully in accordance with the manufacturer's instructions. Those undertaking the work should have been nominated by site management to do so and have been trained and assessed as competent in accordance with the refuge chamber manufacturer's recommendations. All inspection, functional testing and maintenance should be carried out within a rigorous quality assurance system.

6.2. INSPECTION

Inspection is the periodic visual check for internal cleanliness, and obvious damage to or malfunction of the refuge chamber and its systems. It should be undertaken as instructed by the manufacturer and the outcome recorded. The inspection should verify that potentially portable items of refuge chamber equipment such as the digital gas detector, air conditioning control unit etc have not been tampered with or removed. Where a refuge chamber is used for "other purposes" (see Cl 1.10) a daily inspection should be undertaken.

6.3. FUNCTIONAL TESTING

Functional testing requires a demonstration that the system in question is in normal working condition. For refuge chambers, functional testing of all refuge chamber systems should be undertaken in accordance with the manufacturers' instructions. These are likely to identify the systems which require weekly testing and those which require more extensive monthly testing.

6.4. REMEDIAL WORK

Any remedial actions identified as necessary by inspection or functional testing should be undertaken immediately and recorded along with the inspection or test report.

6.5. MAINTENANCE

Maintenance as required by the manufacturer's instructions or maintenance which is identified as necessary by inspection and functional testing should be carried out immediately and recorded along with the inspection and test reports.

6.6. CHECK AND SERVICE BY MANUFACTURER

A check and service of the chamber by the refuge chamber manufacturer should be undertaken at the intervals specified by the manufacturer. The results should be recorded and stored along with the other chamber records.

6.7. REPLACEMENT OF CONSUMABLES

Consumables such as water should be replaced as necessary to ensure purity.

Filtration unit and air regeneration system – numerical symbols refer to steps in instruction manual.

7 >> Training, instructions and exercises

7.1. GENERAL

It is vitally important for the safety of those who may have to use a refuge chamber that they are instructed and trained in its correct operation and that they have regular opportunities for hands-on practice of their training. Operation particularly in standalone mode can require a level of competence in the use of gas detection and air filtration equipment. Periodic retraining for all, along with the specific retraining of those identified as not being capable of operating the refuge chamber should be undertaken.

7.2. OPERATING INSTRUCTIONS

It should be remembered when compiling the operating instructions, that those using them in the refuge chamber could be experiencing abnormally high levels of stress and therefore clarity, simplicity and avoidance of human error is of utmost importance. Full operating instructions for the refuge chamber should be available to the chamber occupants. These should be set out in as clear and simple a format as possible. They should be in each of the languages normally spoken on site. Consumables e.g. for the CO and CO_2 filtration systems, should be clearly and distinctively labelled. Labelling by function rather than by content, can be more important and hence should be more prominent. The use of colour coding and colour consistency e.g. for different filter systems, should also be considered by the chamber manufacturer. Font size on control panels and in instructions should be sufficiently large to be easily read at the minimum levels of illumination specified in Cl 5.2.1.

Note 1: The refuge chamber manufacturer should agree with the user over the use of pictures, colour coding, pictograms or numbering systems to aid clarity.

7.3. TRAINING AND THE TRAINERS

Training may be done either by the refuge chamber manufacturer or by site personnel who have been nominated by site management to do so. Site trainers should have been trained and assessed as competent by the refuge chamber manufacturer.

7.4. TRAINING THOSE UNDERGROUND

Everyone regularly working underground, should be specifically trained in the operation of the refuge chamber in both externally supported and in standalone mode.

The training should also include information on the limitations of the chamber – i.e. what it is not designed to withstand. The chamber is not designed to withstand direct exposure to fire, a flammable gas explosion, flooding and inundation or lining collapse, ground collapse or major rock fall. However, in the event of entrapment as a result of a flooding, inundation, collapse or rock fall a chamber with its communications, water and supply lines, could act a muster point for survivors.

The training should cover the need to switch off battery power to the refuge chamber in the event of an evacuation for the occurrence of flammable gas.

7.5. TRAINING EXERCISES

Regular training exercises should be undertaken to ensure everyone underground is fully familiar with the refuge chamber and its operation. Following training exercises, a review of the outcome of the exercise should be undertaken and any changes to procedures identified as necessary by the review should be put into practice. Those working underground should be made aware of these changes.

7.6. RECORDS OF TRAINING ETC.

Records of all training, training exercises and reviews should be kept as part of the site quality assurance procedures.

8 >> Acknowledgements

In addition to the contributions from its members, ITA WG5 acknowledges the direct or indirect contribution to the drafting of this document from AFTES, AUVA, BGBau, BSI Committee B/513, CEN/TC151/WG4, Crossrail, DAUB, Draeger, Health and Safety Executive, Herrenknecht, Hyperbaric and Tunnel Safety Ltd, JF Shea, MineARC, Politecnico di Torino, Suva, WE Walter.

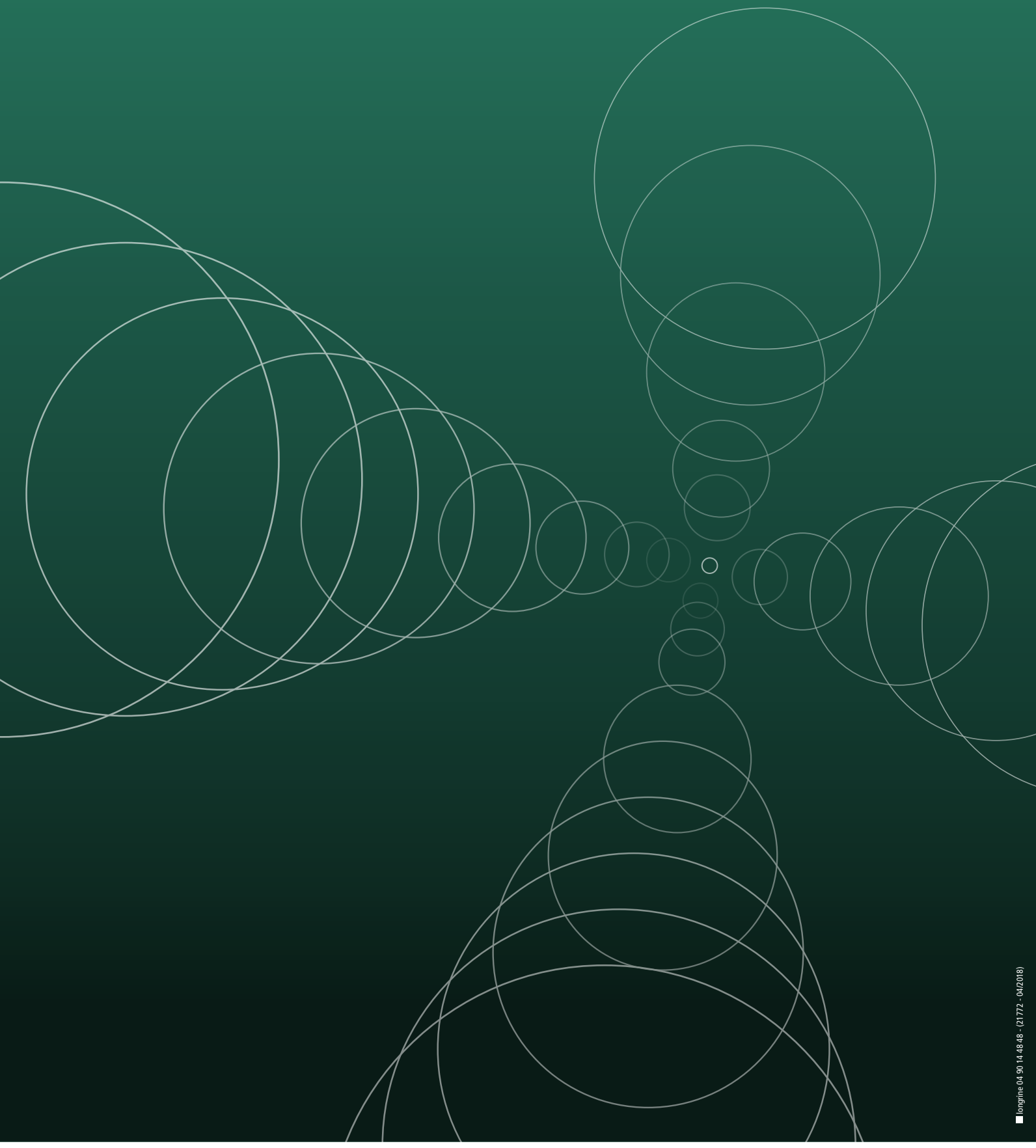
Refuge Frejus.

9 >> Informative References

9.1. N 16191:2014

EN 16191 “Tunnelling Machinery – safety requirements”, which requires the provision of refuge chambers on TBMs “where shown to be necessary by the project risk assessment”.

Refuge Robbins.



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