Recommendations for the Use of Refuge Chambers on Underground Construction Sites

DAUB-Working Group

Deutscher Ausschuss für unterirdisches Bauen e. V.
German Tunnelling Committee (ITA-AITES)

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0 Glossary, definition of terms

Refuge chamber
A refuge chamber is a place of temporary safety on a shaft or tunnel construction site, into which the people present below ground can withdraw in case of a fire incident. Protected against fire gases in the refuge chamber, they are supplied with breathing air and other media that is important for survival and remain there until rescued by the emergency services or until they can leave the refuge chamber safely without assistance.

Safe area
Area, in which people can remain out of danger for the duration of an incident. This is normally achieved by providing an escape route to the surface.

Conventional tunnelling
The tunnel is excavated by blasting, excavator or roadheader and supported with shotcrete.

Mechanised tunnelling
The tunnel is driven by a tunnel boring machine in accordance with the harmonised European standard EN 16191 „Tunnelling machinery – Safety requirements" and is normally supported with segment lining.

Fume container
Protective space with an autonomous air supply, which is entered by the miners before blasting and only left after the clearance of blasting fumes has been confirmed by measurement.

1 General notes about the application of the recommendations

1.1 Background

The „D-A-CH guideline for the planning and implementation of health and safety plans on underground construction sites", published in 2007, describes in „Annex A – Germany" basic configuration requirements for protection and rescue containers, although solely depending on the described hazard category or the determined escape route distance. Reactions from the tunnelling industry in Germany have made it clear that there are still open questions regarding the use of protection and rescue containers, specifically concerning the construction and equipment of the container, measures to ensure operational readiness in case of an incident and ensure the operation of containers on underground construction sites. This equally affects client organisations or the consultants and health and safety coordinators appointed by them under the construction site regulations, manufacturers of containers and their operators or contractors on underground construction sites. This was the reason why DAUB has addressed this subject once more in a working group. The objective was to answer open questions, if possible without contradicting the existing D-A-CH guideline, but rather to sensibly supplement the guideline.

The terms „protection container" and „rescue container" as used in „Annex A – Germany" do not exist in international parlance. Therefore the working group agreed in the future to use the internationally usual term „escape chamber" or in English „refuge chamber". The different requirements for refuge chambers are described in the introduction to the categories.

1.2 Scope of application

The present recommendations apply to the provision and use of mobile refuge chambers designed for use on underground construction sites during conventional or mechanised tunnelling. Refuge chambers are normally located in the tunnel, but can be in a shaft, from which tunnel excavation is undertaken. The recommendations can be analogously transferred and applied to underground construction sites, where the refuge chambers are in the form of refuge rooms permanently integrated into the structure, for example in niches or cross passages. It can also be necessary to use a refuge chamber on projects to refurbish underground structures. The recommendations are intended for clients, designers, contractors, safety coordinators as well as insurers and others involved with underground construction.

1.3 Decisive incident scenarios for the planning of refuge chambers

The incident, during which people withdraw into a refuge chamber, is smoke propagation due to fire on the underground construction site.

If the refuge chamber is also to be used as a fume chamber, the notes under **Section 2.2.8** and **Section 3.8** are to be observed.

A refuge chamber is not designed to ensure protection against the direct effects of temperature from a fire in the immediate vicinity of the refuge chamber. It is also not designed to ensure protection for the people below ground against flooding or rockfall in the event of a collapse.

The use of a refuge chamber for breaks or as a waiting room is not permissible since otherwise there would be a danger that sensitive and important plant components of the supply equipment, which is important for survival, could be misused, damaged

or removed and the safe operation of the refuge chamber in case of an incident would no longer be ensured.

1.4 Access controls to the underground construction site

In order to know how many people including visitors are present in the underground site at any time, it is necessary to implement a reliably operating access control system. This makes it possible in case of an incident below ground to quickly check whether the people below ground have been able to escape above ground or are in the container. Only in this way can dangerous sorties by emergency services to search for missing persons be reduced to the necessary minimum. The access control system should also ensure that there are not more people on the underground construction site than the available places in the refuge container.

1.5 Hierarchy of protection measures

General principle: The use of a refuge chamber on an underground construction site is not a protection measure equivalent to the provision of escape routes for people into permanently safe areas.

Next to preventative fire protection measures, measures to ensure that people can escape above ground have the highest priority. The use of a refuge chamber is always absolutely necessary as a protection measure in case people becoming trapped in an underground working area cannot be securely ruled out with the former measure.

If a tunnel is being built with two parallel tunnels joined by cross passages, then the construction sequence should be planned as far as possible so that the cross passages serving as escape routes are completed as early as possible. This makes it possible to use the tunnel unaffected by an incident for safe escape. For this purpose it must be possible to control the ventilation system so that no smoke can propagate into the tunnel being used as an escape route.

1.6 Hazard assessment

In the course of hazard assessment according to clauses 5 and 6 of the occupational safety law (ArbSchG), and if particular hazards are present in terms of clause 9 ArbSchG, which can generally be assumed to be the case in tunnel building, then effective measures are to be taken to ensure first aid, fire fighting and evacuation of the workforce under the terms of clause 10. A fire protection and rescue plan is to be produced and documented in the course of the hazard assessment. This should take into account all conceivable incident scenarios, which could make escape and/or rescue necessary.

The result of the hazard assessment determines whether a refuge chamber is needed or not on an underground construction site. It should normally be assumed that a refuge chamber is needed on every underground construction site.

1.7 Planning of the use of refuge chambers in small diameter tunnels

Refuge chambers are normally designed so that they can be installed and operated in tunnel boring machines with an internal diameter of the segment lining of about 4.0 m (≈ 12 m^2 cross-sectional area) and larger. If the diameter is smaller, then the design (geometry and dimensions) of the chamber will have to be adapted to the space available on the specific project as a special construction.

Note: If the placing of the refuge chamber on the backup of the tunnel boring machine is not possible for lack of space, then it can be continuously towed at the end.

If the diameter of a conventionally excavated tunnel is too small to provide the necessary space for the refuge chamber within the cross-section, then space can be created for the refuge chamber by excavating niches. The niches should have a regular spacing of less than 250 m.

1.8 Determination of the necessary stay time in the refuge chamber

The refuge chamber is to be entered by people below ground when they are trapped by a fire incident and it is no longer possible to escape to a permanently safe area. The necessary stay time of the employees in the refuge chamber, i.e. the time after which they can safely leave the refuge chamber, or the time until they can be rescued by the emergency services, essentially depends on how long the fire incident lasts. For the estimated fire duration, smouldering incidents without full fire also have to be considered, since these can sometimes lead to a longer period of fire and smoke.

The flow chart (**Figure 1**) shows the relationship between the influential factors for the hazard assessment and the most unfavourable escape and rescue route resulting from each considered incident scenario. As a result, the flow diagram delivers two categories with different required stay times. In Category 1, the refuge chamber has to provide protection for up to 12 hours and in Category II for 24 hours, during which time the refuge chamber has to provide safe accommodation. Since detailed construction sequences are not yet known in the design phase of a

tunnel, in case of doubt the tendering of the refuge chamber has to conservatively estimate which of the two categories is required on the specific project.

1.9 Location of the refuge chamber

1.9.1 General

A refuge chamber is to be installed at each location on an underground construction site where, according to the hazard assessment, people may become trapped below ground in case of an incident.

The area between the face and the location of the refuge chamber is normally a working area, in which various conceivable fire loads could confront the employees. The employees are therefore in a position to immediately start combatting an incipient fire. If combatting of the incipient fire fails, then the working area is to be evacuated immediately with the employees escaping. In order to ensure that the people still in the working area can escape successfully to a safe area, further protection measures are necessary. These include primarily the minimisation of fire loads in the working area, marking and keeping free of escape routes, provision of oxygen breathing apparatus and instruction of all people present below ground.

The minimum distance between the refuge chamber and a fire load on the side of the refuge chamber away from the face, which in case of fire could trap people in the working area, must be:

- ≥ 100 m for parked construction machines and vehicles with a high fire load
- ≥ 50 m for other fire loads, e. g. transformers or flammable construction.

Refuge chambers must be placed so that they are easily accessible at all times and that sufficient clear space is available for the use of stretchers to transport injured people.

1.9.2 Mechanised tunnelling

Due to the large escape route distances in mechanised tunnelling, at least one refuge chamber is normally to be provided on a tunnel boring machine

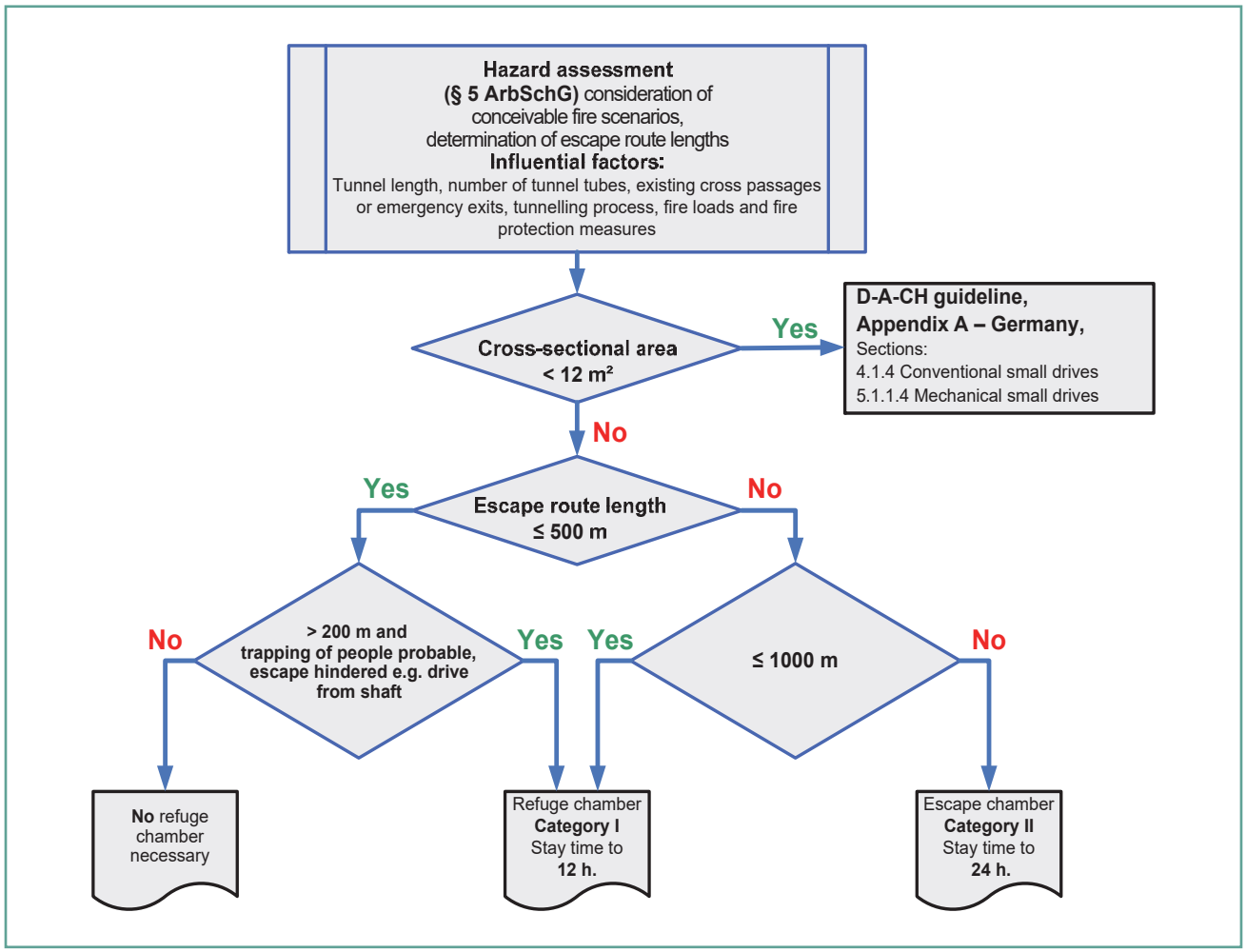


Figure 1 *Flow chart of the determination of the necessary stay time in the refuge chamber*

(TBM). Refuge chambers on the TBM are to be placed in the immediate vicinity of the signed escape routes. Further refuge chambers (stationary or mobile) are to be provided in accordance with the hazard assessment and depending on the escape route length and fire loads between the TBM and the tunnel portal.

1.9.3 Conventional tunnelling

In conventional tunnelling, the refuge chamber should not be more than 150 m to 300 m away from the face and should be easily accessible at all times. Measures are to be taken to protect the refuge chamber itself and the associated equipment against vehicle impact.

1.9.4 Particular requirements for blasting

In drill and blast tunnelling, the minimum distance of the refuge chamber from the face also depends on the explosive charge quantity and the excavated cross-section. The blasting area is specified as part of the hazard assessment, which is performed before the start of blasting. If a location for the refuge chamber is selected within the blasting area, then the notes in **Section 3.7** and **Section 3.8** are to be observed.

2 Supply of the refuge chamber with breathing air, electricity and communication

2.1 Operating modes

Refuge chambers are designed for various operating modes, which can change according to design and incident:

- Readiness (standby operation)
- Incident (autonomous operation)
- Incident (external operation)

Operating mode	Electricity supply	Breathing air supply
Readiness – standby operation	External electricity supply cable to maintain the battery charge	Gas storage completely full, soda lime available
Incident – autonomous operation	External electricity supply cable/battery supply	Supply from gas storage/ regeneration system
Incident – external operation	External electricity supply cable	External air supply pipe

2.1.1 Readiness – standby operation

In this operating mode, each refuge chamber is ready for operation at its intended location on the underground construction site. No employees are in the refuge chambers, but they are continuously maintained ready for operation so that the systems to preserve life can be activated immediately in case of an incident. In order to keep the batteries charged, the refuge chamber is to be permanently connected to an external electricity supply during operational readiness. The communication systems are permanently activated. Technical and organisational measures are undertaken in accordance with the instructions of the manufacturer to ensure that the refuge chamber is ready for operation at all times.

2.1.2 Incident – autonomous operation

Every refuge chamber must ensure autonomous operation in case of an incident, which means operation independently of all external supply pipes and cables for the minimum operation time. The autonomous operating mode is activated when the incident „fire and/or smoke" has occurred and the employees have to withdraw to the refuge chamber. The air and oxygen supply is then provided exclusively from sources inside the refuge chamber. This must be capable of supplying breathing air in the necessary quantity and quality over the entire duration of the minimum stay time for the specified maximum number of people. The interior atmosphere must also be maintained within the specified thresholds with regard to heat and air humidity. In case of an interruption of the external electricity supply due to an incident, the batteries must be capable of supplying the refuge chamber with electricity over the entire duration of the minimum operating time.

2.1.3 Incident – external operation

This operational mode is intended as an additional option for mechanised tunnelling, when a hydroshield or earth pressure machine is used and an air supply (of breathing air quality) is already provided for compressed air working. For external operation, the manufacturer of the refuge chamber is to provide connection points to the refuge chamber, to which an external air supply can be connected. The external supply pipes are used for temporary supply to the refuge chamber. If and when the external supply is damaged due to the incident and fails, then the refuge chamber is to switch to autonomous operation.

2.2 Breathing air supply

2.2.1 General

The equipment for the air supply to the refuge chamber should be specified at the start of the project depending on the tunnelling process and the required minimum operation time.

2.2.2 Autonomous air supply

For the autonomous air supply to the refuge chamber, two systems have to be differentiated. These are on the one hand systems with which the inside of the chamber is flushed with breathing air from bundles of cylinders and the oxygen and nitrogen levels as well as the air humidity and temperature are thus kept within the specified thresholds. The alternative is a regeneration system, which prepares the exhaled air back to breathing quality with dosed addition of oxygen and absorption of CO_2. When the regeneration technology is used, particular attention needs to be paid to the development of air humidity and temperature inside the chamber, as there is no exchange of air inside the chamber with this system, as is the case when air is supplied from a bundle of cylinders. The oxygen cylinders necessary for a regeneration system are to be housed in a safe location within the refuge chamber.

2.2.3 External air supply from above ground

The pipeline for the external air supply to the refuge chamber must be fed from a compressed air plant, which is capable of delivering breathing air quality. Appropriate filters have to be provided in order to remove odours and oil residues from the breathing air supply.

In order to achieve the longest possible function in case of an incident, the external air supply from above ground needs to be protected against mechanical damage and fire.

Since the functioning of the external air supply in case of an incident cannot be adequately guaranteed, a second redundant breathing air supply is necessary. The refuge chamber is therefore always to be designed for autonomous operation for the entire determined operation time of the air supply.

2.2.4 Air quality in the refuge chamber

The oxygen concentration is to be kept stable in the range 21 % ± 2 % by volume. The concentration of carbon dioxide should not exceed 10 000 ppm and of carbon monoxide should not exceed 60 ppm. The stated values are to be monitored with instruments.

2.2.5 Control of the air supply

In order to be able to regulate the supply of breathing air according to the number of people in the refuge chamber, whether the breathing air comes from the cylinder bundle or from an external air supply pipeline, a valve is to be provided to control the flow quantity. In addition to the control system, a diagram/table is to be displayed, from which settings can be read for the air supply depending on the number of people in the refuge chamber.

Note: The operation of the air supply control is to be laid out as simply and clearly as possible since the operator would be confused by too many possible settings in case of an incident.

2.2.6 Noise damping in the air supply

Since the blowing of the breathing air causes noise in the refuge chamber, measures are to be provided to reduce noise at the supply vent, e. g. silencers to limit the noise level to a maximum of 80 dBA. Earmuffs should be provided.

2.2.7 Use of masks for breathing air supply

The provision of breathing air through masks is expressly not recommended.

2.2.8 Air supply in drill and blast tunnelling

Should refuge chambers in drill and blast tunnelling also be used as „fume containers" or protection rooms, this is only permissible if the manufacturer of the refuge container has designed it for this type of operation and permits this as an intended use in their operating instructions.

Operation as a fume container must not impair the required minimum period for autonomous operation of the refuge chamber. Therefore a second air supply, which is independent of the surrounding air does not use the resources intended for the supply of the refuge chamber, must be installed to the chamber.

In addition measuring equipment is to be installed to enable the users of the fume container or the protection room to measure the main components carbon monoxide (CO) and nitrous oxides (NO, NO_2) in the tunnel after blasting. This should determine whether the thresholds for hazardous gases in the fumes are maintained and the fume container can be safely departed.

2.3 Limitation of the inside temperature

For the sizing of the air conditioning and insulation, the refuge container is to be designed for at least the following external temperature curves in the tunnel:
If a higher rock mass temperature than the external temperatures given in the table for rescue phase 2 is

	Category I 12 h min. operating time	Category II 24 h min. operating time	External temperature
Fire phase	2 h	2 h	60 °C
Rescue phase 1	10 h	10 h	40 °C
Rescue phase 2	—	12 h	30 °C

to be expected, then this should be taken into account in the sizing.

The inside temperature of a fully occupied chamber may not exceed an effective temperature of t_{eff} = 30 °C. The effective temperature (t_{eff}) is an overall measure of climatic conditions, a summary of the simultaneous effect of various factors on human comfort. The determination of the effective temperature according to Yaglou (source: DGUV Information 213-002, hot working – recognise – assess – protect, formerly BGI 579) is normally undertaken using nomograms, in which the three measureable quantities dry-bulb temperature, wet-bulb temperature (normally determined from the dry-bulb temperature and the relative humidity) and air speed are the inputs.

In the diagram (**Figure 2**), the threshold line for effective temperature t_{eff} = 30 °C is entered, so that the maximum permissible relative humidity can be read off depending on dry temperature. The air speed is set at 0.1 m/s to be on the safe side. In order to fulfil the climatic requirements inside the refuge chamber, the intersection of the measured dry temperature and the relative air humidity must be below the t_{eff} = 30 °C threshold line. If the intersection is above the line, then the cooling has to be improved, the insulation improved and/or a higher air exchange rate should be set.

2.4 Electricity supply

The refuge chamber in standby mode is permanently connected to the external power supply. This ensures that the batteries are always in a fully charged state in case of an incident and electricity supply to the refuge chamber is guaranteed. In the event of damage due to an incident with failure of the external power supply, the capacity of the batteries must be sufficient to supply the refuge chamber with electricity over the entire operating period (corresponding to the refuge chamber category). The case also has to be considered that an air conditioning system is operated to maintain the inside temperature.

For protection against dust and sprayed water, the electrical system of the refuge chamber is to comply with at least protection type IP 54.

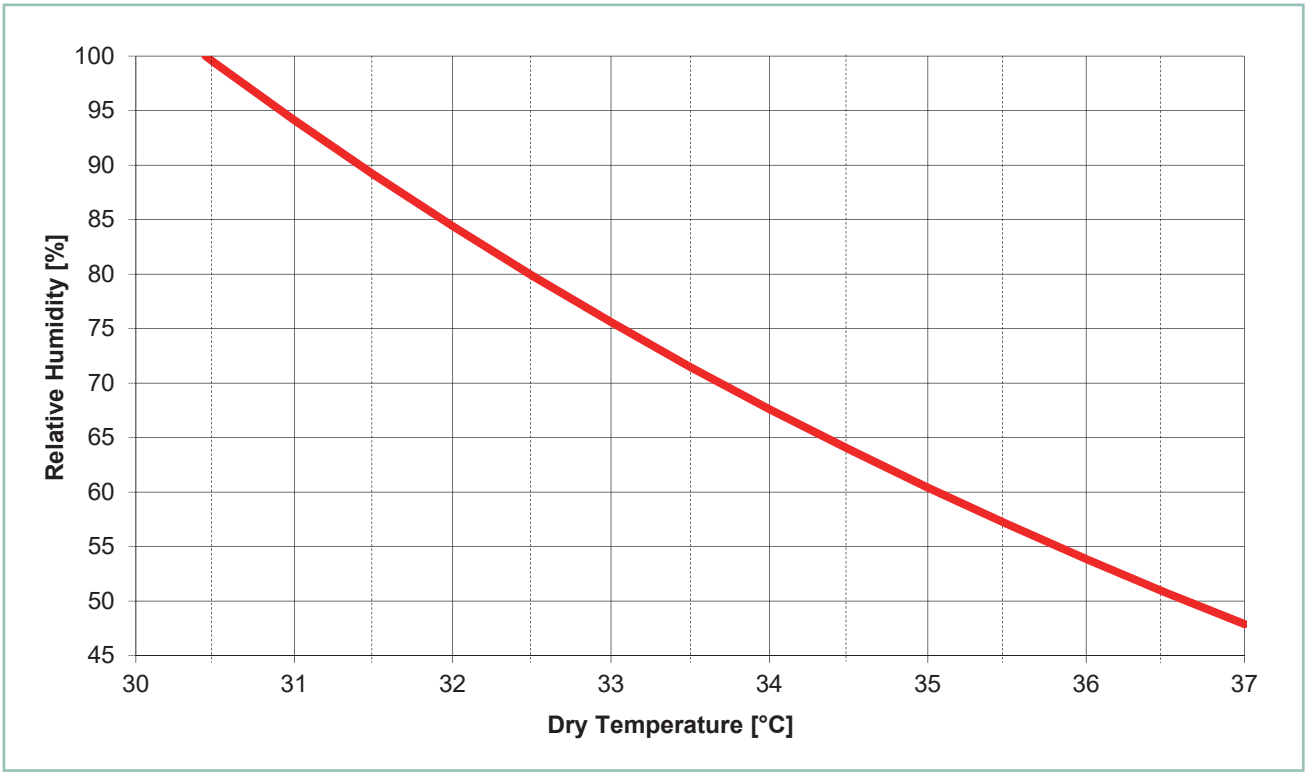


Figure 2 *Threshold for the effective temperature of 30 °C with an air speed of 0.1 m/s*

2.5 Communication

The refuge chamber is equipped with redundant communication systems in order that speech transmission to the occupants of the refuge chamber is ensured at all times in case of an incident. Communications systems are to be kept in continuous operational readiness, which means also during the operational readiness (standby mode) of the refuge chamber. This redundancy is sensibly achieved with a wired and a wireless system.

3 Construction and equipment of the refuge chamber

3.1 General requirements

The refuge chamber must be suitable for use on underground construction sites and should be built as a robust steel construction.

3.2 Capacity of the chamber

The maximum number of people, which the refuge chamber has to accommodate in case of an incident, is to be sensibly estimated in the course of design and tendering and then finally determined and specified by the operator, i. e. normally the contractor, as part of the hazard assessment.

The people who find protection in the refuge chamber in case of an incident include the miners, site management and workshop personnel (fitters, electricians), site supervision staff, surveyors, geologists, representatives of the client and any visitors to the tunnel.

It should be taken into account that at certain times, for example at shift changeovers, the number of people seeking protection can be considerably higher. The maximum number of people present on the underground construction site at any time must also be limited to the maximum number of people who can be accommodated by the refuge chamber.

3.3 Refuge chamber – dimensions

The dimensions of the refuge chamber depend on the maximum permissible number of people. For each person, a floor area of 0.5 m^2, a clear height of at least 1.5 m and a minimum volume of 0.75 m^3 are to be made available. As far as possible, the refuge chamber should offer a volume of 1 m^3 per person.

3.4 Windows

There must be one window with a diameter of at least 150 mm, either in the door or in the front wall next to the door, in order to ensure visual contract from inside to outside and vice versa.

3.5 Doors

The doors must be robustly constructed. The closing mechanism of doors must lock at at least two points and must be capable of operation from the inside and the outside. The door is to be provided with a seal to prevent the penetration of fire gases.

3.6 Emergency exit opening

An emergency exit is to be provided in one wall in order to provide a second point of exit in case the door is blocked. The emergency door must be capable of operation from inside and outside. The position of emergency exits should be chosen so that blocking, for example by rockfall, is unlikely.

3.7 Resistance to blasting operations

If the refuge chamber is used in a tunnel with drill and blast excavation, the chamber must be adequately constructed for this use to resist pressure waves and flying stones after blasting. Additional protection against flying stones can be provided, for example with a blast protection wall of timber on the face side of the refuge chamber.

3.8 Use as a fume container

If the location of the refuge chamber is within the blasting area and if it is used by the miners as a fume container or protection room, then it must comply with the requirements for a cover space according to the technical rules of blasting law, SprengTR 310 „Blasting works".

3.9 Positive pressure

The refuge chamber must be designed so that a positive internal pressure of at least 100 Pa can be ensured in every operating mode. Appropriate measures must be taken in order to limit the positive pressure in the chamber to max. 1 kPa. The positive pressure must be monitored and displayed to the occupants.

3.10 Visibility and identification

The position of the chamber should be easily found in an emergency. For this purpose the chamber is to be

painted in easily discernible colours and marked with a reflective strip at least 100 mm wide all round.

In case of an incident or when a corresponding alarm is activated, the chamber must be equipped with a flashing light to show escaping people and/or emergency services the way to the entrance door.

3.11 Moving and lifting

The refuge chamber should be fitted with towing and lifting loops or if required with fork lift pockets in order to enable moving and lifting of the chamber in the tunnel.

4 Refuge chamber – fittings and equipment

4.1 Minimisation of fire hazard

All fittings and surfaces are to be chosen so that the fire load is a small as possible.

4.2 Interior fittings

The refuge chamber is to be provided with the following equipment.

4.2.1 Interior lighting

The interior lighting in the refuge chamber should have an intensity of at least 15 Lux on the control panel for the air supply.

This can be reduced to 5 Lux when the refuge chamber is in autonomous operation (incident). LED lighting is preferable.

In case of failure of the lighting, one battery-operated hand lamp per person is to be provided in the refuge chamber.

4.2.2 Seats

The backs of the seats should have a width of at least 500 mm for each person.

4.2.3 Toilet

The toilet is to be designed for an operation of 12 or 24 hours with the chamber fully occupied and partitioned from the seating, for example with a curtain. Toilet paper in sufficient quantity is to be kept available.

4.2.4 Storage

Sufficient storage space is to be provided for rescue equipment and devices (e. g. oxygen breathing apparatus, stretcher, first aid material) and water.

4.2.5 Oxygen breathing apparatus

One breathing apparatus per person according to the maximum permissible number of people is to be kept available in the refuge chamber, with an operating time that securely covers the longest escape route to a safe area, or to the next refuge chamber as appropriate. The necessary operating time can normally be calculated from an escape speed of 40 m/min. This figure is to be checked in individual cases.

4.2.6 Drinking water supply

A drinking water stock of at least 2 l for 12 h or 4 l for 24 h per person is to be provided in the refuge chamber.

4.2.7 Fire extinguisher

A 6 litre water fire extinguisher is to be mounted in the refuge chamber and a second externally next to the entrance door.

4.2.8 First aid material and stretcher

A small first aid kit according to DIN 13157 „First aid material – First aid box C" and a stretcher are to be provided in the refuge chamber.

4.2.9 Monitoring of the atmosphere

When the refuge chamber is put into operation, the temperature, relative humidity and the carbon monoxide, carbon dioxide and oxygen concentrations in the chamber are to be continuously monitored for the duration of use.

For the continuously displayed measurement of temperature and humidity, digital instruments with an accuracy of 0.5 °C and 3 % RH are to be used, with a resolution of 0.1 °C and 0.1 % RH.

An acoustic alarm must provide a warning when the measured values of oxygen, carbon monoxide or carbon dioxide exceed or fall beneath the preconfigured threshold values. To provide redundant measurement, a hand instrument must be available to enable measurement of the oxygen content and toxic contaminants in the chamber and adjustment of the air supply as appropriate.

4.2.10 Air circulation in the refuge chamber

Both in external and in autonomous operation, there must be air circulation inside the refuge chamber. If the air speed from the air intake is not sufficient, which will be the case above all in absorber operation, then air circulation can be supported by a fan.

4.2.11 Condensate drainage from the air conditioning plant

The condensate water produced by the air conditioning plant is to be drained outside the chamber

through a valve. The valve must not influence the required positive pressure of ≥ 100 Pa and ≤ 1000 Pa.

5 Operation of the refuge chamber

5.1 General

In order that the refuge chamber functions correctly in case of an incident, i. e. offers protection as a temporarily safe place, the chamber is to be installed, checked regularly and maintained according to the instructions of the manufacturer. The people who carry out this work are to be ordered in writing and must be capable of assessing the safe and functional condition of the refuge chamber.

5.2 Operating instructions

The manufacturer is to produce operating instructions, which are to be handed to the operator with the refuge chamber. In addition to the statements about installation and commissioning of the refuge chamber, the intended operating modes (standby, autonomous, external if appropriate) are to be described in detail, for example in the form of process diagrams with photo documentation. The process diagrams are to be displayed in the refuge chamber and the relevant control elements are to be appropriately labelled (**Figure 3**).

For the operation of the refuge chamber, statements are to be made about the required quantities and properties of the supplies to be provided on site (breathing air in cylinder bundles [l], O_2 [l], soda lime [kg], battery capacity [Ah], etc.) in order that the minimum operating time is ensured in the event of an incident.

The operating instructions are also to specify the nature and extent of the required inspections as well as deadlines for the regular inspections.

5.3 Inspections

Inspections are to be differentiated between daily visual inspections with a mainly control character and the regular actual checks of the structure and the equipment of the refuge chamber. Accordingly the required knowledge on the part of the inspector is also very different. While instruction, e. g. by the site management, is adequate for daily visual inspections, which are sensibly performed using check lists (**Appendix 2**), the employee who performs the regular checks must be, for example, an electrician who may have to be instructed by the manufacturer of the refuge chamber. The results of inspections are to be documented and any discovered faults are to be remedied immediately. The appointment and instruction of employees, who will be responsible for the performance of inspections, should also be documented in writing (**Appendix 1**).

6 Instruction, training, practical exercises

6.1 General

The refuge chamber can only be used as intended if the people, who seek protection in the chamber in the event of an incident, are trained in theory and practice. The training measures are sensibly structured into:

- instruction about the functioning of the refuge chamber
- instruction about the correct behaviour in the refuge chamber and
- practical drills involving visiting, commissioning, sheltering in and leaving the refuge chamber.

The results of training measures, particularly practical drills, are to be evaluated. This can then be used to continuously improve the training measures.

The training measures are to be repeated regularly, with the state of knowledge of the participants being tested. The performance of training measures is to be documented.

6.2 Qualification of the trainers

A number of employees must be trained by the manufacturer or another expert body as trainers in order that they can then train people who should use the refuge chamber in case of an incident in the material stated in **Section 6.1**.

6.3 Notes concerning instruction in the function of the refuge chamber

The technical and organisational instructions for activating and sheltering in the refuge chamber are to be displayed in the container. It should be noted that people who enter the refuge chamber in an emergency situation will be in an exceptional situation and under stress. Therefore the instructions mentioned above are to be reduced to the absolutely necessary minimum and displayed in an easily understood form, e. g. as process diagrams. Of particular importance here are the instructions for the exchanging/replacement of consumables such as soda lime in the CO_2 absorber in order that the function of the refuge chamber can be safely maintained after putting it into operation.

"Stand-alone operation" - activate "Compressed air cylinders 300 bar"
(if there is no "Tunnel compressed air")

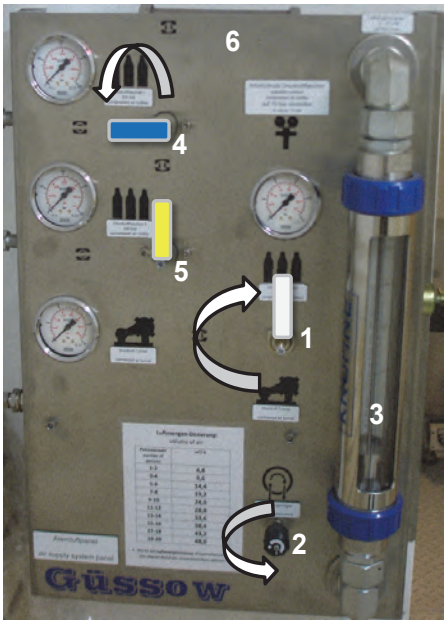
☞ **Switchover handle** (1) upwards open

Set **"Compressed air cylinders 300 bar"**

☞ Slowly open completely to the left **handle** (4) **"Compressed air cylinders 300 bar Circuit I"**, then

☞ **Turn air quantity regulator** (2) **to the left** and set **air quantity** according to the number of people **Air quantity gauge** (3) according to the table *(read off at top of floating body)*

⇨ **Compressed air can now be heard flowing** through silencer (6) behind breathing air panel in the container



⇨ **Too little or no air feed** is displayed at the gas monitor through insufficient positive pressure (min. 1 mbar) with **"Alarm1"** at **Channel 4** and **red alarm light** – check compressed air feed – Increase compressed air feed or switch over to **"CO_2 absorber operation"**.

Figure 3 *Excerpt from operating instructions "Air supply in case of an incident autonomous operation"*

With written instructions, it is important that they can be understood by all users of the refuge chamber (consider various native languages!). The content and form of the instructions should be discussed with the manufacturer as part of the purchasing process and are part of the operating instructions of the refuge chamber.

7 Declaration of functional suitability

The manufacturer of the refuge chamber shall declare the compliance of the technical dimensioning of the refuge chamber with these recommendations. All associated verifications are to be documented and kept available. The verifications have to cover the following points in particular.

7.1 Verification of the air quality over the period of use

This is verified by calculation. Generally the following consumption parameters should be assumed for each person:

- 0.5 l/min oxygen requirement
- 0.45 l/min CO_2 output
- 40 l/min of breathing air when supply is solely from the cylinder bundle

It should be stated in the operating instructions what quantity of consumables (oxygen, soda lime, compressed breathing air) is to be provided for the relevant period of use, depending on the type of breathing air supply.

Note: A certain reserve should be included in the sizing of the breathing air quantity in the cylinder bundles in order that brief test operation does not make it necessary to replace the entire cylinder bundle.

7.2 Verification of autonomous electricity supply

The supply is verified by calculating the demand and stating the chosen battery capacity. Generally all consumer devices necessary for autonomous operation are to be included. The consumption and the necessary battery capacity are to be started in the operating instructions.

7.3 Verification of the maintenance of inside temperature over the period of use

This is verified by calculation combined with a test on an operationally ready refuge chamber under the temperature conditions stated in **Section 2.3**. The test is to be carried out for two hours with full occupation and may only be ended when the measured values have been constant for half an hour. An inside temperature of t_{eff} = 30 °C may not be exceeded, and maintenance of the parameters for air quality in the refuge chamber stated in **Section 2.2.4** is also to be monitored by measurement.

8 Acknowledgement

The DAUB wishes to thank all members of the working group for the production of this document. In addition to the members appointed by DAUB, the following companies and institutions collaborated in the preparation of this document:

- BeMo Tunneling GmbH
- Dräger Safety AG & Co. KG
- DNVGL SE
- Güssow Drucklufttechnik GmbH
- HOCHTIEF Infrastructure GmbH
- Porr Deutschland GmbH
- Wayss & Freytag Ingenieurbau AG
- Ed. Züblin AG
- AUVA
- BG BAU
- BG RCI
- Landesbergdirektion des Regierungspräsidium Freiburg. ■

Appendix 1

Sample order to test refuge chambers

Commission for checking of refuge chambers

Mr/Ms

..... Site: ……...

..... Location: ……

.....

We hereby commission Mr/Ms …….. with the **putting into service, taking out of service, relocation, maintenance and checking of the refuge chamber + container for cylinder bundles.** This includes checking the proper function and completeness of the equipment.

The technical understanding of the handling, function and fitted safety equipment of the refuge chamber and the extent of the tests have been given to the commissioned person in an instruction session.

The tests are to be carried out according to the agreed extent and maintenance periods.

If the function is disturbed or items are missing, the site management is to be informed without delay. At the same time, immediate measures are to be undertaken to remedy defects!

Refuge chambers and containers for cylinder bundles with defects may not be operated!

(Persons for the 1x daily checks against the check list are not separately commissioned.)

……	…….....	.....
Place, date	Signature of commissioned person	Signature of site management

Distribution:
Commissioned person
Site management

Appendix 2

Sample check list for the daily checking of a refuge chamber

Check list **Refuge chamber type, *model XXX***

Site: …… Protocol No. ……

Location: …… Date ……

Component / equipment	Correct value	Test result: In order		Defect(s)
		yes	no	
Frame, insulation				
Doors, windows, seating				
Power supply, **400 Volt~**				
Emergency power supply: Battery voltage min. **50-55 Volt =**	…… Volt			
Changeover of power supply Mains / batter operation Test				
Tunnel compressed air 5-10 bar	……. bar			
Compressed air cylinders 300 bar, Fill level: (at least 280 bar) **Circuit 1** Stand-alone operation min. 280 bar **Circuit 2** Blasting fumes min.150 bar	……. bar ……. bar			
Breathing air panel, function				
Oxygen cylinders 300 bar fill level: Minimum 280 bar	……. bar			
CO_2- absorber fan, function				
Soda lime stock 6 pots each 15 kg = 90 kg	……. pots			
Air conditioning plant: Evaporator fan (inside) Temperature display (inside) Condenser cooler (outside) Filter dirty?				
Gas monitoring: Digital display, alarm light				
Maintenance of positive pressure approx. 1.0 mbar	…… mbar			
Water connection, sprinkler plant				
Telephone connection, emergency call system				
Lighting, inside and outside				
White flashing light, outside, Persons in container **Red flashing light,** outside on power failure				
20 Breathing apparatus – optical check and undamaged	……. Stk.			
20 torches + batteries	……. Stk.			

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Component / equipment	Correct value	Test result: In order		Defect(s)
		yes	no	
First aid kit, eye wash bottle, stretcher, first aid instructions				
Fire extinguisher, water 6 kg				
Chemical toilet, reserve chemical				
Toilet paper 10 rolls	……. rolls			
40 l. drinking water Sell-by date? Full?	……. l.			
Operating instructions: - Escape and refuge chamber - Breathing apparatus				
Labelling of valves/switches				
Emergency call list, report scheme, alarm plans				
Cleaning state, order				
Other				

Cylinder bundle container:

Skids, frame, sheet metalwork, doors, blasting protection wall				
Cylinder bundle: Frame, fixing, tie-downs				
Spiral compressed air hoses, fittings, valves. Leaks?				
Lighting				
Labelling, Instructions for changing cylinder bundle Safety data sheet for compressed air cylinders				
Other				

Defects and missing parts are to be remedied immediately! **Inform site management!**

…….
Date

…….
Name, Signature of checker