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QUESTIONNAIRE ON SAFETY IN RAILWAY TUNNELS

Annexes 1-8 and Technical Regulations and Guidelines for Railways

Transmitted by the Government of Finland

Note: Annexes 1-8 and Technical Regulations and Guidelines for Railways (The Finnish Rail Administration Board has accepted RAMO Section 18 “Railway Tunnels”) reproduced in this Informal document were transmitted in conjunction with the reply to the questionnaire by the Government of Finland and should be considered together with the document **TRANS/AC.9/2002/12**.

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18 RAILWAY TUNNELS

The Section "Railway Tunnels" of the "Technical Regulations and Guidelines for Railways" (Finnish designation: RAMO) sets out the basic principles for the planning and design, construction and maintenance of railway tunnels. Notified in accordance with Council Directive 83/189/EEC as amended by Directives 88/182/EEC and 94/10/EU.

18.1 Definitions

18.11 Tunnels

A railway tunnel *consists of one or several* rail tunnels *and other* tunnels *or* shafts *that are* connected *to the* rail tunnels.

A ***rail tunnel*** is a tunnel which has one or several rail tracks, is used by rail traffic and is termed either a single or double track tunnel, etc., depending on the number of rail tracks running through it.

A ***mixed traffic tunnel*** is a rail tunnel used both by passenger traffic and goods traffic.

A ***goods traffic tunnel*** is a rail tunnel used exclusively by goods traffic.

A ***double tunnel*** consists of two parallel rail tunnels, which may share other tunnels connected to the rail tunnels.

Tunnels connected to rail tunnels include *connecting tunnels* between rail tunnels, *work tunnels* and *service tunnels* as well as *ventilation tunnels, exit tunnels* and *rescue route tunnels*.

A ***rescue route*** is an access tunnel used by fire and rescue crews and equipment in a fire or other emergency situation.

Shafts may include ventilation and smoke outlet routes that are connected to the tunnels, as well as service routes, exit routes and rescue routes.

A ***rock tunnel*** is a tunnel in which the principal load-bearing structure consists of consolidated and reinforced rock.

A ***concrete tunnel*** is a tunnel in which the principal load-bearing structure consists of reinforced concrete.

A ***steel tunnel*** is a tunnel in which the principal load-bearing structure consists of steel.

A ***longitudinally sloping tunnel*** slopes down over the entire length of the tunnel from the upper tunnel mouth to the lower tunnel mouth.

A diving tunnel is a tunnel in which both tunnel mouths are on a level higher than the lowest point of the tunnel.

A ***tunnel sloping towards the tunnel mouths*** is a tunnel in which both tunnel mouths are on a level lower than the other parts of the tunnel.

A ***tunnel system*** is the entirety that consists of a railway tunnel (= rail tunnels and their associated other tunnels or shafts) and the related technical and safety areas as well as any equipment and

technical systems that may be installed in these tunnel areas. Tunnel systems also include any open cuts to the extent that these are required by any drainage, [access] route, maintenance, service and/or safety layout arrangements.

18.12 Structural parts of a tunnel

18.121 Load-bearing structures

The ***load-bearing structures*** consist of the structures of the tunnel's main load-bearing system which have an influence on the tunnel's load-bearing capacity and stability or which are subjected to traffic loads. Load-bearing structures are also considered to include both rock and soil to the extent that these have an influence on the tunnel's load-bearing capacity and stability.

Tunnel mouth structures include all the load-bearing structures by means of which the tunnel is connected to the atmosphere outside.

Reinforcement structures include all the structures (components) directly connected to the load-bearing structures and that function as part of the load-bearing structure.

18.122 Interior structures

Structural parts belonging to the ***interior structures*** include all the structural parts which do not belong to the tunnel's main load-bearing system but which must be shown to have a load-bearing capability and stability. Structural parts belonging to the interior structures include, for instance, lining structures such as the tunnel's ceiling and wall structures, as well as any railings and superstructure.

Lining structures include water-proofing, heat insulation, fire protection and cladding structures that are separate from the load-bearing structures, or any parts of such structures.

Substructures include any structural strata and any drainage equipment located underneath the rail track supporting layers as well as any thermal insulation and vibration isolation structures.

Superstructures include the supporting layers and the rail tracks themselves.

18.123 Equipment installations

A tunnel's equipment installations include:

- The rail track's electrification and safety equipment
- The safety, monitoring, data transmission and radio equipment
- The ventilation and lighting equipment
- The sewer installations
- The cable routes.

18.13 Tunnel's cross-sectional area

The term 'tunnel's cross-sectional area' refers to the free area delimited by the structures of a completed tunnel; this is expressed in square metres with the accuracy of one decimal digit. Load-bearing structures, reinforcement and lining structures as well as the substructure and superstructure are considered as structural parts, which are outside the tunnel's cross-sectional area.

The cross-sectional area of a rail tunnel includes the following areas:

- The open area's dimensions ('reach')
- The service and maintenance areas
- The safety layout arrangement areas
- The equipment installation areas.

The normal cross-sectional areas of a single-track railway tunnel are shown in Appendices 1 and 2. The normal cross-sectional areas of a double track railway tunnel are shown in Appendices 3 and 4.

18.14 Technical systems

The electrical systems include:

- The rail track electrification systems, see Item 18.42
- The constructional electrical systems.

The constructional electrical systems consist of electricity and data systems. The constructional electrical systems serve the electrically operated functions of the tunnel system such as motorised ventilation, heating, smoke removal, sewerage, pumping, power distribution, lighting and data transmission as well as the safety and monitoring functions.

The ventilation systems include all the systems and equipment for either natural or motorised ventilation that are used for ventilating and removing the smoke from the tunnel areas.

The lighting systems include all the systems that are used for both the normal lighting and for the back-up and safety lighting of the tunnel areas.

The sewerage systems include all the piping systems, wells, basins and equipment serving the tunnel system which are used for the collection, removal and handling of water for drainage, fire-fighting, etc., as well as any fluids which may leak in accident situations.

The safety systems include all the systems that are used to ensure the safety of traffic operations and any movement in the tunnel areas, to assist operations in accident situations and to try to prevent any acts of vandalism against the tunnel system.

The monitoring systems include all the equipment that is used to monitor and to control the use of the tunnel system and the operation of the equipment.

18.15 Tunnel description

Name and location
Each railway tunnel has a name, which consists of a *proper name* describing the location and of the common noun *railway tunnel*.
The name of the tunnel is complemented by indicating the name of the track section where the tunnel is situated, plus the km + m figures for the ends of the tunnel (= the points where the covered section starts on the centre line of the rail track).

The type definition

The type of structure of a tunnel is described by means of a type definition, which must include, to the extent that this is deemed necessary, the details listed under items 18.11 to 14.

18.2 Classifications

18.21 Classification by length

Rail tunnels are divided into three categories on the basis of their length:

1) *Short tunnels*: length less than 500 metres

2) *Medium length tunnels*: length between 500 and 2,000 metres

3) *Long tunnels*: length over 2,000 metres.

The length of a tunnel is defined as the length of the covered part of the tunnel, measured at the rail track centre line.

The length of a tunnel is used as a basis for the planning and design of the technical rail track equipment, safety layout, technical systems and aerodynamics of the railway tunnel in the manner described below under the appropriate headings.

18.22 Classification by speed

Railway tunnels are divided into three categories on the basis of their design speed:

1) $Speed_{dim}$ max 160 km/h

2) $Speed_{dim}$ between 160 km/h and 220 km/h (a high-speed rail track)

3) $Speed_{dim}$ between 220 km/h and 300 km/h (a very high-speed rail track)

Tunnels, which have two rail tracks, and tunnels intended for goods traffic only are always included in speed category 1.

The design speed is used as a basis for the planning and design of the aerodynamics, cross-sectional dimensions and structures of the railway tunnel and the technical rail track equipment and other

equipment thereof in the manner described below under the appropriate headings.

18.3 General principles of tunnel planning and design

Sections 18.31 to 18.39 set out the general principles for the planning and design of railway tunnels. Technical rail track requirements are set out separately under Section 18.4. The actual railway tunnel planning and design process is set out in Sections 18.5 to 18.7.

18.31 General requirements

The planning and design basis for all load-bearing structural parts is a useful life span of one hundred (100) years.

The planning and design basis for all interior structures and equipment installations is a useful life span of fifty (50) years.

Any rail network development measures with regard to electrification and target speed must be taken into account in the planning and design of tunnels.

Each of the persons responsible for the various areas of the planning and design of railway tunnels should have adequate technical qualifications as well as up-to-date knowledge of and adequate experience in the planning and design of traffic tunnels with regard to the following duties:

- Technical planning and design of rail tracks
- General planning and design of tunnel systems
- Planning and design of aerodynamics
- Planning and design of rock construction and rock structures
- Planning and design of drainage and sewerage
- Planning and design of electrification and safety equipment
- Planning and design of safety, monitoring, data transmission and radio [communication] systems
- Planning and design of ventilation and lighting
- Planning and design of the layout of areas, tunnels and shafts and any related structures and technical systems as required by safety and by fire-fighting and rescue operations, and the dimensional design of the same in view of fire safety.

The head designer of a railway tunnel should have adequate knowledge and adequate experience of the planning and design of railway tunnels in all the above-mentioned areas of planning and design.

18.32 Planning and design stages

18.321 Stage 1 - Establishment of requirements

When establishing the requirements of a rail track line, a railway tunnel must be the subject of a feasibility study of the construction project, and this must include all details of technical and legal feasibility as well as all details of the costs and environmental effects involved. The feasibility study

for a railway tunnel must include the following:

- The surveys discussed in Section 18.33 to the extent that the feasibility of the building project can be considered to be ascertained and that the environmental effects can be assessed with the accuracy required for taking the decision in question.
- Draft versions of the general drawings specified under Item 18.341, in such a way that all area layouts and all the terms and conditions relating to the construction work have been established as accurately as required for ascertaining the feasibility of the building project and for the assessment of the costs involved.
- Initial design dimensions and draft drawings of the plans specified in Items 18.342 to 348, as accurately as required for ascertaining the feasibility of the building project and assessing the costs involved.
- An estimation of the costs and a detailed plan.

18.322 Stage 2 - General planning and design

A general plan of a railway tunnel must include the following:

- The surveys specified in Section 18.33 as extensively and as accurately as required so that a general plan for the tunnel system, complete with drawings, can be prepared and decisions taken between the alternative structural options.
- A general plan for the tunnel system, including the drawings specified under Item 18.341.
- Assessment of environmental effects (YVA), unless this has already been carried out at the project planning stage or after that as a separate stage.
- Operational and risk analyses of the [rail] traffic.
- Design dimensions and draft drawings of the plans specified in Items 18.342 to 348, as accurately as required in order for the structural solutions and structural dimensions as well as the technical systems to be established so that the general drawings can be prepared.
- An estimation of the costs and a detailed plan.

The general plan can be divided into a preliminary general plan and a general plan, provided that proper grounds for this exist. The degree of accuracy in the preliminary general plan should be determined separately in each individual case. In order for the YVA (assessment of environmental effects) and the operational and risk analyses to be carried out it is required that at least preliminary general drawings are available.

18.323 Stage 3 - Constructional planning and design

A construction plan of a railway tunnel must include the final surveys specified in Section 18.33 and implementation plans in accordance with Sections 18.3 to 18.7.

18.33 Surveys

18.331 Soil surveys

For the area influenced by the railway tunnel, ground and soil surveys must be carried out as extensively and as accurately as is required by the geotechnical and foundation engineering plans for the load-bearing structures. A survey programme must be drawn up to cover all the various surveys to be carried out. The extent and type (quality) of these surveys must be defined in the programme in such a way that the structures and their foundations can be planned and designed in a reliable manner using the correct safety factors. The extent and type (quality) of the surveys must be defined by the planners and designers in charge of the project in such a way that adequate parameters are at the disposal of the planners and designers for the purposes of analysing the interaction between ground and structures, determining stability values and performing settlement analyses as well as for the planning and design of the structures and their foundations.

The survey programme must be drawn up and the surveys carried out in compliance with the current foundation engineering and ground survey guidelines as well as current drilling guides and laboratory test guidelines /1 to 6/.

18.332 Bedrock surveys

The purpose of the bedrock surveys is to establish the type of the rock and its suitability for the construction of a railway tunnel in accordance with a survey programme to be drawn up separately for each particular site. These surveys must be carried out as extensively and as accurately as is required in order for all the necessary parameters to be established in a reliable manner for the planning and implementation of the quarrying operations, use of the blasted rock, consolidation injections, reinforcements and structures as well as for any mechanical rock analyses that may be required. These surveys must be carried out in compliance with the current bedrock surveying, rock classification and rock construction guidelines /7 to 14/.

The minimum survey to be carried out must always consist of a visual survey from the point of view of engineering geology and the establishment of the topology of the rock surface with adequate accuracy, particularly in areas covered [by soil].

In addition to the minimum surveys the type (quality) of the rock must be examined by means of drillings, soundings and laboratory tests as extensively and as accurately as required by the planning and construction of the project. For rock tunnels, see Section 18.61.

The rock construction planner is responsible for the scheduling and adequacy of these surveys.

18.333 Perched water and groundwater surveys

The levels of perched water and groundwater must be determined within the area, which the tunnel is likely to cover. For the purpose of determining these, a sufficient number of observation pipes must be installed by means of which any fluctuations in the levels of perched water and groundwater must already be monitored with adequate frequency during the planning period. The same observation

pipes must then be used for monitoring the water levels during the construction phase and, where necessary, even after the construction work has been completed.

If necessary, the flow conditions and replacement of perched water and groundwater must be established by carrying out test pumpings.

If necessary, the quality of perched water and groundwater must be examined in order to establish chemical aggressivity or purity as required by the use for which the water is intended. Microbiological tests must be carried out whenever this is required by the woodpile foundations in the surrounding area.

18.334 Environmental reports

During the various planning and design stages the following environmental reports must be drawn up:

- The YVA (assessment of environmental effects) at the project or general planning and design stages.
- The perched water and groundwater surveys:
  - At the project planning stage as extensively and as accurately as is required for the YVA (the assessment of environmental effects).
  - At the general planning and design stage as extensively and as accurately as is required for the technical and financial comparison of alternative structural solutions, the analysis of the environmental effects and for the decision-making.
  - At the constructional planning stage as accurately as is required for the planning of the final structural and equipment solutions and for the analysis of the environmental effects.
- In connection with the perched water and groundwater surveys, a well report must be drawn for the area covered by the tunnel and this must include reports on the water levels and on the replacement of the water as well as on the quality of the water, with the accuracy required by each planning and design stage.
- An environmental risk analysis caused by the rock construction work at each planning and design stage with the accuracy required by the planning and decision-making, and at the constructional planning stage with the accuracy required by the quantity surveys and the building work.
- Reports on noise and vibration with the accuracy required by each planning and design stage.

18.34 Contents of the plan

A plan for a railway tunnel must include at least all the documents listed in Sections 18.341 to 18.349. The level of accuracy of these documents for each planning stage is set out in Section 18.32.

18.341 General drawings

- A layout drawing which shows the locations of all the tunnels and shafts in the railway tunnel as well as the locations of all the tunnel mouths and shaft top ends plus all the connecting roads leading to these locations.
- A general layout plan on the scale 1:500 covering the entire tunnel system. In the case of longer tunnels it is also possible to employ the scales 1:1,000 or 1:2,000.
- General layout plans on the scale 1:200 or 1:100 of particular areas: tunnel mouths, widenings, connecting points between tunnels and shafts, areas used for safety layout arrangements and systems, and technical areas.
- A longitudinal cross-sectional drawing of each tunnel on an appropriate scale.
- Cross-sectional drawings on the scale of 1:100 or 1:200, selected in such a way that all the typical cross-sections and all essential structures are depicted.

18.342 Dimensional, working and detail drawings and signs

- Dimensional, working and detail drawings for all the areas of the tunnel system, all load-bearing and interior structures and all equipment installations.
- Signs required for operation and maintenance
- Signs for rescue and emergency exit routes and normal exits.

18.343 Foundation engineering plan

The foundation engineering plans for the tunnel mouth structures for concrete and steel tunnels and rock tunnels must be produced in accordance with the foundation engineering guidelines in force at the time. This plan must include foundation engineering drawings complete with survey data and the work specification for the foundation work. The foundation-engineering plan should include the following in as extensive a form as necessary:

- Settlement analyses and stability surveys as well as analyses of interactions between the ground and structures
- Plans for the measures to reinforce the foundations
- Plans for the ground and foundation structures
- Types of structural foundations and target levels for piles
- Plans for construction site excavation and working order
- Environmental plans.

18.344 Rock construction plan

For all rock tunnels a rock construction plan must be drawn up which includes:

- Quarrying plans
- Consolidation injection diagrams
- Rock reinforcement drawings: reinforcement boltings, sprayed concrete applications, special reinforcements and reinforcement structures as well as any drainage and/or earthing plans relating to these
- Phasing of all quarrying operations, consolidation injection operations and reinforcement operations, particularly at the tunnel mouths, at any weak zones in the bedrock, at any rock ceilings that are 'thin' in relation to their span length, and at any tunnel sections which may be hazardous with regard to the environment
- A work specification for all rock construction work, setting out with sufficient accuracy all the working methods used, the materials and the quality requirements.
- A quantity survey list of the quarrying and rock consolidation work, showing at least all those masses, which cannot be determined on the basis of the drawings, together with the basis for charges.

18.345 Structural plans

- Structural drawings for all load-bearing and interior structures
- Anchoring, fitting and supporting plans for the equipment installations and technical systems
- Plans for structural fire protection measures
- Drainage plans
- Plans for the earthing of the structures
- Work specifications for the structures
- Quantity survey lists, the extensiveness of these to be considered separately in each individual case.

18.346 Plans for technical systems

- Plans for electrical installations consisting of plans for the construction [work] power systems, also including plans for the safety and monitoring systems (monitoring, data transmission, access control, crime reporting and fire alarm installations) as well as any layout arrangements required for the rescue and emergency exit routes (signs, markings and lighting).
- HVAC (heating, plumbing and air-conditioning systems) plans, consisting of the planning of ventilation, water supply, sewerage, fire-fighting, smoke removal and HVAC control systems plus any layout arrangement required for the rescue and emergency exit routes.
- In addition to the above, the planning of safety protection systems must also include the performance of the risk analysis discussed in Section 18.53, the extent of which must be considered separately in each individual case.

18.347 Technical rail track plans

The plan for the rail track geometry must be produced in accordance with RAMO Section 2, "Rail Track Geometry".

The structural design plan for the rail track must be produced in accordance with RAMO Section 3, "Structural Design of Railway Tracks".

The electrification plans and earthing plans must be produced in accordance with the Planning and construction guidelines for electrification, SSR I to III, and in accordance with RAMO Section 5, "Electrified rail tracks". The earthing plans must include all structures, fittings and equipment required.

The safety equipment plans must be produced in accordance with RAMO Section 6, "Safety equipment".

18.348 Work phase plans

- The overall plan for the construction of the railway tunnel and the division thereof into work phases complete with time schedules
- Details of how the electrification of the rail track is taken into account in each phase of the work as set out in Section 18.82.

18.349 Description of the plan

The description of the plan must include the following information:

- A description of the tunnel as specified in Section 18.1
- The planning stage and the initial scenario of the plan, the basis for the planning and design, and the objectives of the plan
- Plus the following with the accuracy required by each planning stage:
  - Operational and risk analyses for the [rail] traffic as well as the environmental effects of the construction work and the traffic, unless these are presented as separate documents
  - Aerodynamic dimensions and design
  - Geotechnical and foundation engineering dimensions
  - Dimensional design of structures and equipment installations
  - Thermic dimensions and design
  - Fire resistance dimensions and design
  - HVAC dimensions and design

- All the background information for planning that cannot be gleaned from the actual plan and which is necessary for the assessment of the solutions presented in the plan as well as for the planning of traffic management, monitoring and maintenance operations and the [layout] arrangements required for the fire-fighting and rescue services.

18.35 Aerodynamic planning and design

18.351 Initial situation

As a train enters a tunnel its front end creates an over-pressure shock wave which advances at the speed of sound to the next tunnel mouth and is then reflected back from there as an under-pressure wave moving at the speed of sound. As the rear end of the train enters the tunnel it creates an under-pressure shock wave which moves forward at the speed of sound to the next tunnel mouth and is then reflected back from there as an over-pressure wave moving at the speed of sound. These pressure waves created by the train then move backwards and forwards in the tunnel at the speed of sound until they are dampened. Along with the train, at the front and the rear ends of the train and between the body of the train and the tunnel surfaces there are pressure waves travelling at the same speed as the train. Any obstacles and changes in the cross-section [of the tunnel] as well as any connecting tunnels and shafts and possible motorized ventilation cause changes to take place in the pressure waves. In the event that there are several trains in the tunnel at the same time, these pressure change phenomena are respectively more complicated.

Maximum effects are caused by superposition where different pressure waves meet up at a single position, thus fortifying one another. The effects are dependent on the speed of the train, on the cross-sections and lengths of both tunnel and train, on the tunnels and shafts connected to the rail tunnel, on the shaping (design) of the train and structures, on the friction coefficients of the tunnel surfaces, on the dampening and acoustic characteristics, on temperature and ventilation, etc. These effects are directed at people's ears, at the tunnel structures and equipment, and at the rolling stock (particularly windows, doors and vents) and they also influence the train's resistance to motion.

The over-pressure wave advancing at the speed of sound bursts out from the tunnel's exit end in the form of a spherical over-pressure wave dispersing into the surrounding area. This pressure wave is usually termed a "micro pressure wave" or a "sonic boom".

The most important planning criterion is the design speed. The effects of pressure variations in the tunnel normally become more significant as the speed of the train exceeds 160 km/h. With speeds below this figure the pressure variation may become a factor to be taken into account in the design if [, for instance,] two trains with large cross-sectional areas meet each other in a double track tunnel. As the speed reaches or exceeds 200 km/h, the burst of the first over-pressure wave from the tunnel's exit end causes a significant noise effect on the surrounding area (sonic boom, cf. supersonic aircraft).

The objective of aerodynamic planning and design is to determine and to optimize the correct cross-sectional size for each rail tunnel, together with the planning and design of pressure equalizing tunnels and shafts; to determine an aerodynamic shape for the tunnel mouths and to plan and design the necessary dampening structures, and to determine the pressure and suction loads for all structures and equipment.

18.352 Basis of planning

Aerodynamic planning is divided into three sub-sections:

1) ***Pressure variations inside the train***

The amplitude of pressure variation (the positive and negative peak values), the pressure change velocity (the time from one peak to another) and the recurrence intervals should be restricted to acceptable values inside the train in order to safeguard passenger comfort and for reasons of the health aspects involved. The most significant of these parameters is the amplitude of pressure variation the extreme values of which should be restricted for the duration of an inspection period of a few seconds to a level where the effects of the pressure variation on people's ears are not too disturbing or harmful to health. The selection of a period of three to five (3 to 5) seconds as the duration of the inspection period is based on the structure of the human ear and on the manner in which it reacts to sudden changes in pressure. The velocity of pressure changes during one (1) second should be examined in cases where the recurrence interval of pressure changes is very short, as a result of connecting tunnels located very close one after another, for example.

The restriction of pressure changes is mostly influenced by the size of the tunnel's cross-sectional area, the layout arrangements of the pressure equalization shafts, the design speed and the dimensions of the rolling stock and the pressure protection measures taken [to protect the rolling stock]. The peak values of pressure changes can also be reduced through the shaping of the tunnel and the tunnel mouths.

2) ***Pressure loads on tunnel structures and equipment***

The structures of a rail tunnel and the tunnel mouths as well as all the equipment installed in the tunnel and the fitment thereof should be selected in such a way that their dimensions are in proportion to the pressure and suction loads caused by the trains. These load values are mostly influenced by speed and by the dimensions of both tunnel and the trains.

3) ***Noise abatement at the tunnel mouths***

For speed categories 2 and 3, the noise effects caused by micro pressure waves in the areas surrounding the rail tunnel mouths should be analyzed and, where necessary, appropriate noise dampening measures should be planned. The noise values are mostly influenced by speed, by the dimensions of both the tunnel and the trains, and by the friction characteristics of the tunnel surfaces, which have an effect on the steepness of the over-pressure wave approaching the tunnel's exit mouth. For instance railway ballast can be used successfully to dampen the sonic boom effect because the friction caused by the ballast reduces the time derivative of the over-pressure wave (i.e. the steepness of the pressure front). Where the attenuation taking place inside the tunnel is not sufficient, the tunnel mouth must be equipped with special dampening structures.

18.353 Dimensional parameters

The aerodynamic dimensions of a rail tunnel must be selected as a function of the following variables:

- Design speed
- The ratio between the cross-sectional areas of the design train and the tunnel
- The ratio between the lengths of the design train and the tunnel
- The pressure equalization shafts and other tunnels connected to the [rail track] tunnel
- The aerodynamic design (shaping) of the rolling stock as well as of the tunnel and the tunnel mouth structures
- The impermeability [to pressure] of the design train and the pressure variations permissible inside the train, in each individual case
- The likelihood of several trains going through the tunnel one after another and the pressure variations permissible inside the trains in such cases
- For double track tunnels, in addition to the above-mentioned variables, the likelihood of trains meeting or running side by side [in the tunnel], and the pressure variations permissible inside the trains in such cases
- The resistance to motion permissible for each type of train and the extra traction power required by this and/or the permissible reduction in speed
- The pressure and suction loads acting on the rolling stock as well as on the tunnel structures and equipment.

18.354 Dimensional criteria

The extreme values of the pressure variations and the pressure change velocities permissible inside the train must be defined separately for each tunnel and for each type of train both for the driver's cab and for the passenger carriages. The values, which are acceptable, are dependent on the recurrence interval of such pressure variations during a single journey (length, number and frequency of the tunnels, traffic density and the likelihood of trains meeting inside the tunnel, the frequency of pressure changes, whether the same passengers travel [on the train] on a daily basis, etc.).

Unless a more detailed analysis is performed, the following maximum values apply until further notice:

- Max P 4 s = 3.0 kPa in the case of frequently recurrent pressure changes
- Max P 4 s = 4.0 kPa in the case of infrequently recurrent pressure changes
- The pressure change velocity should be restricted to a maximum value of 500 Pa/s in cases where the frequency of pressure changes is very high (very frequently recurrent / intermittent).

However, these maximum values given should be updated at the planning stage of each tunnel project because new data is continually obtained from international research, from test runs in tunnels and the related measurements, as well as from pressure-proofing measures carried out on rolling stock.

18.355 Dimensions of cross-sectional areas and pressure equalizing shafts

The dimensions of rail tunnel cross-sectional areas must be selected on the design grounds set out in Sections 18.351-4 and in accordance with the manuals referred to in documents /15 to 20/ and in

accordance with the design guidelines provided by documents /21, 22/. The summary /30/ of these references and the design programs [developed] by the research laboratories quoted in these references may be used as design aids. However, these design guidelines should be updated at the planning stage of each tunnel project because international research work on design parameters and development work on design methods is being carried out on a continual basis.

In the event that the criteria set out in Section 18.354 require the size of the rail tunnel's cross-sectional area to be enlarged beyond the size of the normal cross-sections shown in Appendices 1 to 4, the enlargement of the cross-sections and the increase in the number of pressure equalization shafts must be optimized.

It is not possible to influence the amplitudes of individual pressure waves by means of pressure equalization shafts but these can significantly reduce the pressure peak values caused by superposition. The number and locations of the shafts depends to a greatest degree on the length of the tunnel as well as on train lengths. The selection of dimensions must be made separately for each tunnel in each individual case. Also, the dimensions of the cross-section of a pressure equalization shaft must be selected because a shaft, which is too small, is ineffective and if it is too large it may cause the entire pressure wave to be reflected. Design guidelines are provided in reference documents /19, 20/.

Existing tunnels should be inspected separately in each individual case in the event that the cross-sectional sizes of the rolling stock increase or if speeds are increased. Where, for technical and/or financial reasons, enlargement of the tunnel's cross-sectional area cannot be taken into consideration, the situation can be significantly improved by constructing further pressure equalization shafts. The ability of structures and equipment to withstand pressure loads should always be ascertained. Speed restrictions should be imposed if this is deemed necessary.

18.356 Pressure load dimensions and design of structures and equipment

The term pressure load may refer to either a positive pressure load (over-pressure in the tunnel) or a negative pressure load (under-pressure in the tunnel, or "suction load").

Reference documents /23 to 30/ set out pressure load values measured in the course of test runs in tunnels. A pressure load is commensurate with the train speed squared and in direct proportion to the ratio between the cross-sectional area of trains and the tunnel's free cross-sectional area (A_{trains} / (A_{tunnel} - A_{trains})). By applying these ratios to the pressure load values obtained by measurement, we obtain pressure load values such as those set out in reference document /30/, for example. The negative values of the loads acting on the cladding structures of the tunnel's wall and ceiling surfaces

(i.e. suction loads) normally have absolute values that are higher than the positive values.

The pressure load values measured in the course of test runs are rather unreliable owing to the fact that the point where the measurements are taken is probably not exactly at the point where the different pressure waves meet, whereby it has not been possible to take the effect of superposition into account. Consequently, the measurement values probably do not represent the peak pressure values. For this reason it is recommended that the design pressure loads be calculated separately in each individual case, using the calculation formulae set out in reference document /22/.

Unless these pressure loads are determined by calculating them separately in each individual case, the following values of design pressure loads are applicable until further notice:

Single-track tunnels:

Speed category	***P_{max} [kPa]***	***P_{min} [kPa]***
1	+2.5	-3.5
2	+4.0	-6.0
3	+7.5	-10.5

Double track tunnels:

Speed category	***P_{max} [kPa]***	***P_{min} [kPa]***
1	+4.0	-6.0

The design pressure loads given are based on the normal tunnel cross-sectional areas as set out in Appendices 1 to 4, on the largest rolling stock in use and on the highest speed in each speed category. The values of the pressure loads may be reduced if the tunnel's cross-sectional area is larger or if the rolling stock is smaller or the speed lower.

The checking process regarding these numerical values provided should be a continual one, and the progress and results of the on-going international research and standardization work a well as the measurements carried out in connection with the test runs should also be constantly monitored.

The load values quoted are absolute loads, which should be multiplied with the appropriate partial safety coefficient in each dimensional design situation. The loads should be treated as variable, mobile, stressful (causing fatigue) and dynamic.

18.357 Air flow velocity

The tunnel system and its ventilation arrangements should be planned and designed in such a way that the air flow velocity will not, in any normal situation, exceed the value 5 m/s in any areas where passengers or outsiders may spend their time or to which they may have ave access. The air flow velocity may only be allowed to increase to the limiting value of 10 m/s in very rare cases or in

emergency situations or in areas solely intended for the use of maintenance personnel.

18.358 Aerodynamic design of structures, damping structures

By means of aerodynamic shaping of the structures at tunnel mouths (see Fig. 18.3:1) it is possible to reduce the peak pressure values inside tunnels. For this reduction to be a significant one it is required that the length of the shaped tunnel mouth structure be several times the largest diameter of the rail tunnel cross-section.

It is also possible to reduce the peak pressure values by means of side tunnels and cavities made into the

walls of rail tunnels. Planning and design guidelines for these are provided in reference document /18/.

By means of dampening structures and constructions installed at tunnel mouths (see Figs. 18.3:2 and 3) it is possible to significantly reduce the noise disturbances caused to the environment by the pressure waves.

Planning and design guidelines for dampening structures are provided in reference documents /15 to 20/.

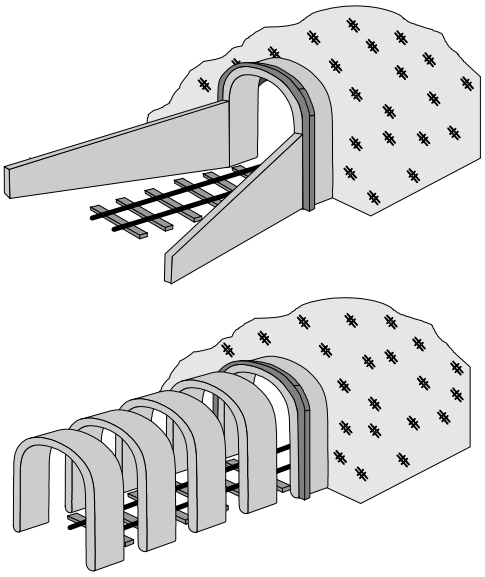


Figure 18.3:1 Examples of aerodynamically shaped tunnel mouth structures

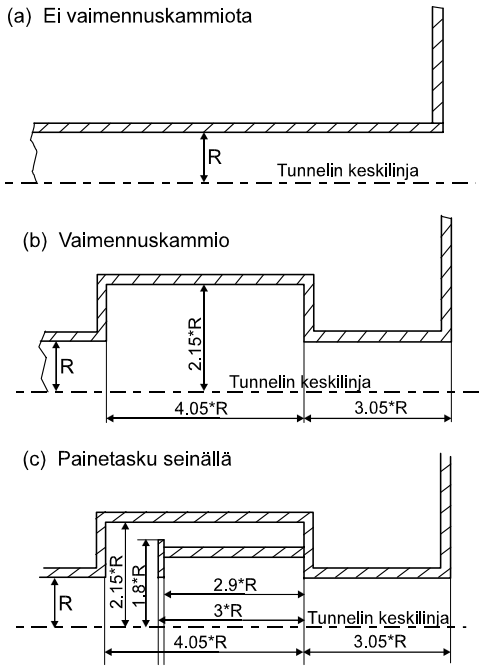


Figure 18.3:2 An example of the operating principle of tunnel mouth dampening structures provided with air flow vents

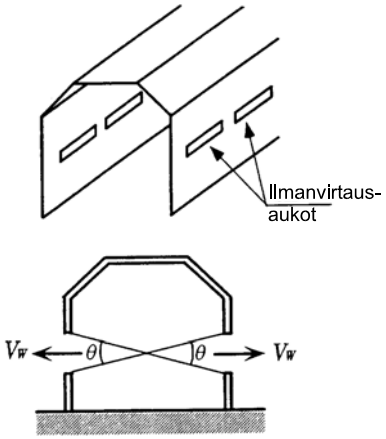


Figure 18.3:3 Examples of dampening chambers used in tunnel mouth construction

(a) No dampening chambers
Tunnel centre line

(b) Dampening chamber
Tunnel centre line

(c) Pressure pocket on the wall

Tunnel centre line

(d) Pressure pockets on the wall
Tunnel centre line

(e) Pressure pocket on the ceiling

18.36 Tunnel cross-section

18.361 Normal cross-section

The dimensions of a normal cross-section of a single-track rail tunnel and the space reservations for structures and equipment included in these are set out in Appendices 1 and 2. The corresponding cross-sectional configurations for double track rail tunnels are set out in Appendices 3 and 4. The substructure alternatives are discussed in RAMO Section 3, "Construction of rail tracks", and in RMYTL Section 6, "Rock construction work". Examples of various substructure alternatives are shown in Appendices 7 and 8.

The surfacing materials used for walkways should be non-flammable and they should be selected so that the surfaces will be sufficiently smooth and that the air flows caused by trains will not cause dust to lift off the ground. The surfacing materials should be such, subject to consideration in each individual case, that the surfaces can be cleaned with suction cleaners (in the case of wood chip transports, for example). The extent of suction cleanable surfaces must be determined separately in the case of each individual tunnel.

The height measurement in the cross-section of a single-track tunnel must be linked to the rail track height level ('line'). In determining the height dimension it must be taken into account that the rail track may have to be raised by 200 mm in connection with maintenance operations. The width measurement must be tied to the rail track's vertical centre line. Note that the cross-section need not be symmetrical in relation to the rail track's centre line. Similarly, the cross-sectional dimensions of a double track tunnel must be based on the height level (line) and the vertical centre line of both rail tracks. These dimensional dependencies should be set out in the description of the design plan, even though the dimensions applied to the construction work may be tied to some other measurement line selected.

The normal cross-section is the minimum cross-section, which must be increased, depending on each individual case, in accordance with Sections 18.362 and 18.363.

18.362 Cross-section and rail track geometry

The dimensions of the normal cross-section of a straight rail track must be increased as a function of the radius of curvature and the rail track slope (banking) as required by the change in the ATU.

The normal cross-sections shown in Appendices 1 to 4 already incorporate all the equipment that may be applicable to a rail tunnel. However, not all of them are necessarily required in every rail tunnel. The space reservations made for equipment, which is not required in the tunnel that is being designed,

may be used as part of the additional space required by the banking (slope) of the rail track.

18.363 Cross-section and speed category

The effect of pressure variations must be taken into account in the cross-sectional dimensions of the rail tunnel as follows:

- For speed category 1 the normal cross-section is adequate. For existing rail tunnels with a cross-section smaller than the normal cross-section the situation must be considered separately in each individual case in accordance with Section 18.35.

- For speed categories 2 and 3 the aerodynamic dimensions of the cross-section must be determined in accordance with Section 18.35. The normal cross-section must be increased to the size required by the aerodynamic dimensions.

18.37 Basis of structural design

18.371 Planning and design guidelines and regulations

The structures of a rail tunnel must be planned and designed in accordance with the Finnish Code of Building Regulations (RakMK). In addition to these statutory regulations, the norms, planning and design guidelines and standards for each building material must be complied with /39 to 47/. In the planning and design of structures subjected to train loads, the planning and design guidelines for railway bridges /48/ and, where applicable, RAMO Section 8 "Bridges" must be complied with. In the planning and design of structures subjected to vehicle loads, the bridge planning and design guidelines issued by Tielaitos (The Finnish Public Roads Administration) must be complied with.

In addition to these statutory regulations and guidelines, bridge planning and design guidelines plus norms and standards the above-mentioned complementary regulations and guidelines set out below must be complied with.

18.372 Structural strength design and dimensions

The structural dimensions of rail tunnels must be determined in view of permanent and variable loads in accordance with the structural loading guidelines /44/ and the bridge planning and design guidelines /48/ as well as in view of deformation loads and accident loads. In addition to these, the loads caused by the manufacture, storage, transport and installation of the structures must be taken into account. For the purpose of determining the dimensions the structures are divided into load-bearing structures, interior structures and equipment installations as per Section 18.12. This dimensional requirement also applies to bedrock and ground provided that these function as load-bearing structures or as a part thereof.

All materials must withstand freezing temperatures. The category of concrete with regard to resistance to freezing and thawing must be determined in accordance with the planning and design guidelines. Furthermore, any materials that are used in the open must also be weather resistant.

Loads are divided on the basis of their type and duration of effect into long term and short term, fixed and mobile, and static, dynamic, fatigue and impact loads. The dimensions for each type of load and load combination must be determined at the ultimate breaking limit, at the fatigue failure limit, at the serviceability limit state and at the accident limit state, making use of the appropriate partial safety coefficients.

The traffic loads and other conventional loads, the way in which these are divided into the said groups, the partial safety coefficients and the load combinations are all given in the statutory regulations and guidelines. The dimensions for these loads and load combinations must be determined in accordance with the appropriate statutory guidelines, bridge planning and design guidelines, norms and standards.

The statutory guidelines for the planning and design of structures must be complemented for the following variable loads:

- Pressure loads caused by trains
- Snow and ice loads
- Fall loads
- Equipment loads
- Additional loads.

The statutory guidelines must be complemented for the following accident loads:

- Impact loads
- Explosion loads.

All the numerical load values are absolute load values.

Pressure loads caused by trains

The dimensions of all structures, equipment and fittings must be determined taking into account the pressure loads caused by trains as set out in Section 18.35.

Snow and ice loads

The dimensions of all lining structures must determined for the ice load of 3.0 kPa. The ice load is a variable and mobile load, which acts in a perpendicular direction to the structure.

In cases where it is possible for ice to form in an air pocket between a lining structure and rock or some other load-bearing structural parts as a result of major water leaks, then the dimensions of the structures must be determined for a larger ice load, which must be considered separately in each individual case.

Any loads that may act on a rock tunnels' reinforcement structures as a result of ice pressure possibly generated in cracks in the bedrock should be determined separately in each individual case.

The dimensions of rail tunnels' tunnel mouth structures must be determined for a snow and ice load of 5-0 kPa. At tunnel mouths where snow tends to drift on a large scale, the dimensions of the structures should be determined for a greater snow load, if considered necessary.

Fall loads

All rock surfaces must always be reinforced in such a way that the risk of any loose boulders falling down is eliminated. The structures need not be designed for fall loads provided that the occurrence of any fall loads is prevented with adequate certainty through reinforcement structures.

If there are grounds to suspect that, in the course of the design life span of a rock tunnel, boulders may become loosened from the rock, then the reinforcement and lining structures must be designed for a fall load of 6 kN acting in a perpendicular direction on the structure. In the case of reinforcement structures, which are fixed to the bedrock, the fall load is a static load with an effective range of 0.5 metres x 0.5 metres. In the case of lining structures that are not fixed to the bedrock, the fall load is a variable, mobile and dynamic load the distribution area of which is 0.2 metres x 0.2 metres.

Equipment loads

The equipment loads acting on rail tunnels must be determined separately in each individual case taking into account not only the weight of the equipment but also the pressure loads caused by traffic as well as the dynamic loads caused by equipment and fittings.

The minimum load in the case of integral installations such as cable racks or lighting rails is 1 kN/m.

The loads caused by the hanging of electrification equipment must be determined separately in each individual case.

The dimensions of equipment and related fittings for hanging and anchoring thereof should be determined in such a way that damage to or failure of a single anchoring point will not give rise to the collapse of the entire installation.

Additional loads

In the dimensions and design of tunnel mouth structures and other structures subject to loads caused by earth or water pressures, the possibility of overfilling as well as the lowest and highest possible heights of water levels must be taken into account.

Any increase in earth pressure caused by a structural part being displaced against the ground must be taken into account.

On the ground surface the effect of a variable load must be taken as at least 4 kPa, unless some other effective (imposed) load is greater than this. The effect of this surface load on the earth pressure value must be taken into account.

All additional loads during the construction stage must be taken into account in the dimensions and design.

Impact loads

All load-bearing structural parts must be designed for impact loads in accordance with the Guidelines for the Loading of Structures /44/ or in accordance with the Guidelines for the design of railway bridges /48/, depending on each individual case. Impact loads refer to accident(al) load situations.

However, the tunnel mouth structures of rail tunnels need not be designed for impact loads provided that these structures do not support any structures, constructions or earth masses the collapsing of which could create a risk situation or block the tunnel.

Explosion loads

All load-bearing structural parts and compartmentalised structures must be designed for explosion pressure loads, which must be determined on the basis of a risk analysis. Explosion pressure loads refer to accident(al) load situations.

18.373 Waterproofing

All tunnel areas must be sealed and equipped with such water-proofing structures that completed tunnels will not run the risk of any damaging water leaks. In areas susceptible to frost and areas above electrification equipment there must not occur any leaks at all. The client for whom the work is carried out should be provided with details of the properties, such as strength, deformation, weather and heat resistance and ageing, of the water-proofing materials.

18.374 Thermic design and dimensions

All ice formation in tunnel areas should be prevented. Any ice formation on the structures and on the various structural layers that could give rise to structural damage or frost action (heaving), or that could hamper the traffic operations, the servicing and maintenance or the equipment itself should be prevented. The freezing of drainage and sewerage systems and equipment should be prevented.

Freezing must be prevented by using substructural layers and thermal insulation materials of adequate thickness and/or electric heating or thermal barriers (such as doors or thermal curtains), or a combination of these. The correct use of ventilation fans and the closing of shafts during the sub-zero season can also reduce the cold content, i.e. extent to which the air inside the tunnel freezes.

The thermal insulations must be designed for cold content F_{50}. If it is possible to prove either by means of measurements or in some other reliable manner that the cold content of the air inside the tunnel is lower than that of the ambient air, then it is possible to use the inside air design cold content F_{50T} /41/ for the design of the thermal insulation.

The thermal insulation must be protected against fire risks. the completed surface on the tunnel side should be able to withstand cleaning with high pressure water.

18.375 Fire resistance design and dimensions

All load-bearing and compartmentalised structures must be designed in accordance with the RakMK (the Finnish Code of Building Regulations) and the norms and standards relating to the material used for the load-bearing structural parts in question /39 to 47/ and according to the fire resistance categories determined on the basis of a risk analysis.

Materials which are flammable or which generate a great deal of smoke or poisonous fumes in a fire situation must not be used for any interior structures without a structural fire protection. The fire protection used must not be the internal chemical fire protection of a flammable material.

Acceptable fire protection for thermal insulation can be reinforced concrete at least 70 mm thick or sprayed concrete with wire mesh reinforcement, provided that the concrete layer on the steel reinforcement is sufficient according to fire resistance requirements. When using other fire protection materials, their fire resistance characteristics and dimensions should be submitted to the client for whom the work is carried out for acceptance. For details of fire protection for the components of the technical systems, see Section 18.7.

18.376 Noise protection

The noise level caused by the equipment of the rail tunnel's technical systems must not exceed 90 dB(A) inside the tunnel.

The noise level should be established separately at each tunnel mouth and shaft opening and the noise caused by the equipment should be restricted to within the limits required by the environment. The noise protection should meet the requirements set out in the environmental programme of the RHK (the Finnish Rail Administration Board).

For speed categories 2 and 3 the noise effects on the environment of the pressure waves bursting out of the rail tunnel's mouth should be analyzed separately in accordance with Section 18.35. Where necessary, the environment must be protected from noise by means of tunnel mouth construction and dampening structures /15 to 20/.

18.377 Vibration isolation

If the vibration caused by the rail traffic and induced to the ground or the bedrock is transmitted as a disturbance to the buildings located in the vicinity of the rail tunnel, then the 'rolling track bedding' should be provided with vibration isolation. The [level of] vibration produced by rail traffic depends on the track's superstructure and substructure as well as on the type and thickness of the soil or rock layers underneath these, on the rolling stock and speeds and from the distance from the buildings in question. Acceptable isolation methods include measures to reinforce the base of the subsoil strata as well as dampening structures and vibration isolation mats.

The need to provide vibration isolation should be analyzed and the vibration isolation measures planned and the dimensions of the structures designed separately in each individual case.

In the event that a rail tunnel is built immediately underneath or on top of a building, which is intended for people to spend time or to work in, then the 'rolling track bedding' should be provided with vibration isolation.

18.38 Fittings and equipment

18.381 Rail track related equipment

Rail tunnels must be provided with all the necessary technical track related equipment in accordance with the appropriate sections of the RAMO regulations. The special requirements set to tunnels by the technical track related equipment and to technical track related equipment by the tunnels are set out in Section 18.4.

18.382 Technical systems

Rail tunnels must be provided with electrical, LVI (heating, plumbing and air-conditioning), lighting, safety and monitoring systems. The level and extensiveness of these systems must be determined separately in the case of each individual tunnel on the basis of the planning and design of tunnel systems as discussed in Section 18.5, and on the basis of functional and risk analyses of the rail traffic. These systems must be implemented in accordance with Section 18.7.

18.383 Other equipment

Both walls of the rail tunnel and one wall of the exit routes and exit tunnels must be fitted with a handrail at the height of 0.9 metres above the ground level. These handrails should be at a minimum distance of 3.1 metres from the centre line of the nearest rail track. The material of the handrails must not be electrically conductive. The handrails must be coated with a fluorescent coating material.

The emergency exit routes and normal exits must be made even and, where necessary, surfaced with non-flammable materials to produce sufficiently even pedestrian walkways.

The tunnel mouths must be fenced off in such a way that any falls by people or animals and access by unauthorized persons to the railway area are prevented.

18.39 Approval of plans and designs

The plans for rail tunnels should be submitted to the client for whom the work is carried out, or to the client's representative for inspection and approval.

18.4 Technical track related requirements

18.41 Rail track geometry

Rail tunnels must, if at all possible, be designed in such a way that they have a longitudinal slope or that they slope towards the tunnel mouths so that a train which has lost its traction power may roll out of the tunnel. Diving type tunnels should be avoided in so far as it is possible.
The rail track geometry must be planned in accordance with RAMO Section 2 "Rail track geometry".

Great longitudinal gradients and minimum radii of curvature as well as the location of railway points inside a tunnel or in the immediate vicinity of a tunnel mouth should be avoided in so far as it is possible.

18.42 Electrification

18.421 Electrification equipment

The electrification equipment used in rail tunnels consist of:

- ***A rail track line***, which is a line consisting of an overhead contact line and a possible return line plus the supporting structures and fittings
- ***Draining transformers*** complete with equipment, if necessary
- ***Earthing***
- ***Tensioning devices*** (weight tensioning, anchoring, centre anchoring).

18.422 Requirements of rail tunnels by electrification

The upper part of the ATU is reserved for the electrification equipment. In addition to this space, the live negative boosting (draining) transformer requires its own area, which is defined in Appendix 5. In the case of medium length and long tunnels, the tensioning equipment requires its own area and this must be established separately in the case of each individual tunnel.

The anchoring and fitment of electrification equipment must be planned and designed separately in each case, taking into account the loads caused by the equipment to act on them as well as the pressure and suction loads defined in Section 18.356.

In tunnel cross-sections the equipment should, in so far as possible, be arranged in such a way that the return and earth conductors are located on a different side from the areas and equipment of the technical and safety protection systems.

Tunnel mouths must, if necessary, be provided with protection against contact (scoop proof protection). These [structures providing] protection against contact must be made in accordance with the regulations relating to protection against contact in the case of bridges, following the electrification design and construction guidelines SSR I to III and RAMO Section 5 "Electrified rail tracks" and Section 8 "Bridges".

All the equipment and structures must be earthed including the reinforcements of concrete structures as well as sprayed concrete layers with wire mesh reinforcements or steel fibre reinforcements. Also sprayed concrete layers with wire mesh or steel fibre reinforcements, which are used during construction work or repair operations, should be earthed.

Provisions must always be made for electrification in the design and construction of rail tunnels, even though the section of rail track in question may not yet be electrified. It is only permitted to omit provisions for electrification if a prior consent has been obtained from the RHK (the Finnish Rail

Administration Board).

18.423 Requirements relating to electrification

It must be possible to cut off the power to the rail track at least for the entire tunnel and, in the case of very long tunnels, even for individual sections of the tunnel as considered necessary. Such details must be defined in connection with the planning and design of the tunnel system, see Section 18.5. The instructions for use must be included in the operating instructions for individual tunnels.

18.43 Safety equipment

18.431 Signals

Location of signals inside tunnels must be avoided wherever possible. The minimum interval between signals may then be increased to at least [sic] 1,600 metres, if necessary.

Where the length of the tunnel or other considerations make it necessary to locate a signal inside a tunnel, then separate pre-signals must be used because a combined main and pre-signal requires a great deal of space. The space reservations for a signal are shown in Fig. 18.4:1.

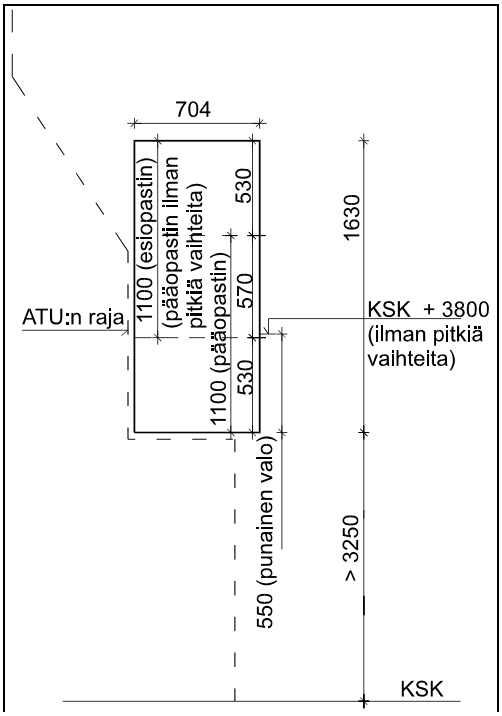
Figure 18.4:1 Space reservations for a signal

ATU limit

KSK + 3800 (without long railway points)

1100 (pre-signal) (main signal without long railway points)

1100 main signal



The signal must be located in accordance with Appendices 1 to 4. At each signal there must be a signal control cabinet located at a maximum distance of five (5) metres from the signal; the space reservations for signal control cabinets are shown in Appendices 1 to 4 (safety equipment and signal control cabinets).

With regard to visibility, RAMO Section 6 "Safety equipment" must be complied with. On a bend, signals may also be located on the left hand side, on the outside of the bend, where necessary (arrow down to the right).

18.432 Rail track free indicators

It is necessary to make a space reservation in the vicinity of signals, and even elsewhere if required, for the equipment which indicates that the track is free. The various alternatives are:

- Rail track circuits with single rail insulation which require a junction box measuring 300 mm x 300 mm x 200 mm, at a maximum distance of 2.5 metres from the rail
- Rail track circuits with double rail insulation which in addition to a junction box require two (2 off) rail chokers measuring 600 mm x 600 mm x 500 mm
- Axle counting devices which require a junction box measuring 400 mm x 400 mm x 300 mm, adjacent to the rail contact at a maximum distance of 2.5 metres.

18.433 Traffic monitoring equipment

The data transmission posts for rail traffic monitoring must be located in the centre of the rail track between sleepers. The control cabinets are either common signal control cabinets or separate control cabinets, for instance at the beginning of a speed restriction.

18.44 Rail track

The rail tracks in rail tunnels must be built as continuous rail tracks over a distance of at least fifty (50) metres on both sides of the tunnel mouth in accordance with RAMO Section 19 "Continuous rail tracks and points".

In the case of medium and long rail tunnels the track components should be given an anti-corrosion treatment in accordance with RAMO Section 15 "Maintenance of rail tracks".

18.5 Planning and design of tunnel systems

18.51 Tunnel systems

When drawing up a general plan for a railway tunnel what one is creating is a tunnel system which is a whole consisting of rail tunnels, of connecting tunnels, work tunnels and service tunnels between these, of shafts, tunnel mouths and open cuts, technical and safety protection areas as well as of all the equipment and technical systems which are installed in the tunnel's premises.

In the planning and design of a tunnel system the following contributing factors must be optimized and matched to each other:

- Technical requirements relating to the rail traffic, including the most advantageous routing (alignment), horizontal and vertical geometry, plus design speed
- Ground conditions, in particular the foundation engineering conditions as well as the type of bedrock and topography
- Requirements of the environment

- Functional/operational requirements of the rail traffic
- Servicing and maintenance
- Technical areas and technical systems as well as their network connections
- Requirements of safety as well as those of exceptional and accident situations
- The construction and operating costs.

The tunnel system must be planned and designed on the basis of functional/ operational and risk analyses, taking into account the requirements set out in Sections 18.52 to 18.57. The tunnel system must be the subject of a general plan which consists of the general drawings and a description of the plan as well as foundation engineering plans, rock construction plans and technical construction plans and plans relating to the technical systems, all of these with the accuracy required by the ascertaining of viability of the project and by the estimation of costs.

18.52 Functional/operational analysis of rail traffic

For the purposes of the planning and design of the railway tunnel it is necessary to carry out a functional/operational analysis of the rail traffic, and this must include at least the following information:

- Type of traffic
- Volume of traffic
- Design speed
- Details of the rolling stock to be used
- Details of [the likelihood of] several trains travelling at the same time in the railway tunnel in question, and details of speeds to be used by meeting trains, trains travelling one after the other and trains travelling side by side
- Transportation of hazardous substances: types and volumes
- Details of traffic control and monitoring arrangements
- Details of traffic arrangements in case of exceptional situations
- Details of servicing and maintenance arrangements and the arrangements of statutory inspections.

In the functional/operational analysis all the situations to be encountered in normal traffic conditions in the railway tunnel being planned should be examined. The assessments to be made in the various situations include requirements of space arrangements, technical systems, vehicles/rolling stock and equipment and of the cooperation by the train crews, the control centre and the rescue organizations.

18.53 Risk analysis of rail traffic

The tunnel system must also be the subject of a rail traffic risk analysis which is to be carried out on the basis of the functional/operational analysis and draft general drawings; this analysis assesses the

probabilities of conceivable malfunctions and accidents and their consequences as well as their effects on the planning and design of the tunnel system /31 to 39/. This analysis examines the following malfunction and accident situations:

- Stoppage of a train inside the tunnel, under control and out of control
- Breakdown or derailment of a train
- Collision between two trains
- Collision between a train and a service vehicle or an unauthorized person [in the tunnel]
- Fire on a train, with the train either moving or stationary
- Fire in the tunnel
- Accidents arising from the transportation of hazardous substances
- Failure of equipment anchoring devices or failure of a structural component
- Operating fault in the lighting, ventilation or control systems
- Effects of external accidents and events.

The risk analysis includes all the risks affecting the tunnel system in question, and how serious consequences a malfunction or an accident may have and what is the likelihood of this happening. The aim should be to eliminate or diminish such risks by determining adequate measures, which can be undertaken at reasonable cost. The main emphasis should be placed on preventative measures.

A risk analysis should include at least an examination of the types of accidents, which are caused by a fault in the rail track, by a fault in the rolling stock or by a fire. These examinations should take into account the selection and volumes of any hazardous substances transported and as accidents linked to such substances, explosions, emissions or leaks and fires. Similarly, further considerations to be taken into account include the location of the tunnel, particularly when under water, sensitivity of the environment, and the time taken by the emergency services to arrive on the site.

The types of damage to be examined include:

- Personal injuries
- Damage caused by fire
- Material damage.

As a result of this analysis, an indication of the probable number of each type of accident in a year is given. It is possible to make use of aids such as accident and damage statistics compiled by rail operators or similar international statistics. Any acceptable risks must be determined separately in each case.

On the basis of the risk analysis, conclusions must be drawn as to what kind of tunnel and safety area layout arrangements and technical systems will be required and on what kind of scale and at what level these should be implemented. In this context the following needs in particular must be considered:

- Fire and smoke compartmentation of the tunnel system, plus the rescue route, emergency exit route and normal exit layout arrangements and the technical equipment required for these
- Technical and safety protection areas
- Back-up power supply and back-up lighting arrangements
- Sewer system collecting basins and related pipework
- Safety and monitoring systems
- Requirements of the communication and traffic control systems
- Requirements of the operation of the technical systems (automatic/manual operation)
- Requirements of the vehicles/rolling stock and equipment of and cooperation by the train crews, the control centre and the rescue organizations.

The risk analysis is used as a basis for determining the fire loads and explosion loads which are used for the design and dimensions of the structures.

18.54 Functional/operational requirements /31 to 39/ regarding safety as well as exceptional and accident situations

In the planning and design of the arrangements and systems required by safety protection the main emphasis must be placed on preventative measures because it is with such measures that the level of safety can be raised and the costs reduced in the most effective way. In the planning and implementation the following functional/operational requirements, among others, must be taken into account:

- Guidelines for each individual tunnel must be drawn up to cover the action to be taken in exceptional and accident situations. The responsibility for drawing up such guidelines must be defined by the client for whom the work is carried out and separately for each event. The client must make a decision separately for each type of event, on the form, the contents, and of the distribution and on the action diagram used for the action guidelines as well as on the location where these guidelines are to be kept.

- Details of the vehicles/rolling stock and equipment of and cooperation by the train crews, the control centre and the rescue organizations must be established at the time when such action guidelines are drawn up. The personnel must be provided with adequate training and exercises. The design situation to be used is a fire on a train stopped in the tunnel. In such a situation the crucial aspect is the action taken by the train personnel and by the people travelling on the train.

In the planning and design of the tunnel the suitability of the vehicles and appliances used by the local fire and rescue services (authorities) should be taken into account. Access by the rescue vehicles to the tunnels, road links to the tunnel mouths and to the tops of the shafts as well as the parking and

turning areas must be determined in connection with the drawing up of the functional/operational and risk analyses and set out in the general drawings and action guidelines for each individual tunnel.

- The space and equipment requirements of the tunnels and their fittings and those arising from the inspections and servicing of the rolling stock should be taken into account in the planning and design.
- Accidents should be notified quickly to the traffic control, monitoring and rescue organizations.
- Medium length and long rail tunnels must be divided into safety protection sections the lengths of which must be determined on the basis of the functional/operational and risk analyses. The monitoring of traffic (i.e. details of the location of a train within the tunnel) as well as alarm and monitoring indications/notifications must be implemented separately for each safety protection section in such a way that the traffic control centre will be able to locate each incident.
- Any stoppages of trains inside the tunnel should be prevented if at all possible. According to separate considerations in each individual case, arrangements must be made for approach signals for the driver, discontinuation of emergency braking, and guidelines for fast evacuation.
- Double track tunnels, which are connected to the traffic control centre by means of telecommunication links, must be equipped with stopping signals before the tunnel so that the traffic control centre will be able to stop a train before the tunnel in the event of an accident or malfunction situation, which has occurred on the other rail track.
- Exiting must always be advised to be effected against the direction of airflow, unless the proximity of the nearest exit makes it necessary to act otherwise.
- No unnecessary or combustible materials must be used or stored in tunnels.
- The access to a supply of water for fire-fighting purposes must be detailed in the guidelines issued separately for each tunnel.
- The operation of the smoke removal system in a fire situation should always be analyzed separately in each event.
- The access of hazardous substances released in accident situations to the soil, waterways or public sewer network should be prevented to the extent required by YVA (assessment of environmental effects) and the risk analysis, by means of collecting pipe and collecting basin arrangements.
- It must be possible to cut off the power to the rail track at least for the entire tunnel and, in the case of very long tunnels, even for individual sections of the tunnel as considered necessary, in the event that there may be two trains, one behind the other, on the same rail track in the tunnel at the same time. More detailed instructions should be included in the action guidelines.

18.55 Requirements for area layout arrangements /31 to 39/

- The monitoring centre and the equipment enclosures for the technical systems should preferably be located outside the tunnel premises in their immediate vicinity.
- The technical areas should be compartmented to form their own fire compartments.

- Turning areas for rescue vehicles should be built in each tunnel at intervals of approximately one kilometre.
- For medium length and long tunnels, the emergency exit route, normal exit and rescue route layout arrangements and compartmentation should always be detailed separately in each individual case.
- An uncluttered exit route should be arranged on both sides of the rail tunnel. The free width of the exit route should be at least 1,600 mm and the free height at least 2,200 mm. The walk surface of the exit route should be on the 'kv' (road ?) level and sufficiently smooth. The exit route should be provided with a handrail as specified in Section 18.383.
- The maximum distance between compartmented exit routes must be determined separately in each individual case on the basis of the functional/operational and risk analyses. Directions of air flow and the operation of the smoke removal system should be taken into account when deciding on the locations of the exit routes. Regardless of the said analyses, the distances between compartmented exit routes may be a maximum of 1,500 metres for tunnels with mixed traffic and a maximum of 2,000 metres for tunnels with goods rail traffic only.
- The areas for maintenance and servicing activities and the compartmentation of these must be detailed separately in each individual case at the general planning and design stage.

18.56 Requirements for structures, equipment and fittings /31 to 39/

- The fire categories of compartmentation structures must be determined on the basis of the risk analysis. The minimum requirement is REI 60.
- The bushings used in compartmentation structures should be sealed so as to correspond to the fire resistance time of the structures in question.
- The signs for exit routes and emergency telephones must be located in each tunnel at intervals of one hundred (100) metres in the proximity of safety lighting units. The signs should indicate the walking distance to the beginning of the compartmented exit route or to the open air. The signs must be made in accordance with ISO Standard 3864 and the Signalling Systems by the RHK (the Finnish Rail Administration Board) /55*/.
- The need for material stocks for the rescue activities and the need for the acquisition of equipment must be established at the time of drawing up the risk analysis.
- The pressure and suction loads caused by trains as well as the climatic conditions prevailing in the tunnels and shafts must be taken into account when considering the selection of materials for and the durability and fitment of the equipment and fittings.
- Functional diagrams of all the equipment and systems located in the technical areas must be placed in these areas.
- Functional diagrams of all the equipment and systems controlled by the monitoring centre as well as their servicing instructions, action guidelines for exceptional and accident situations and the set of general drawings for the railway tunnel in question must be placed in each monitoring centre.
- A name plate must be placed at each of the tunnel mouths of each rail tunnel, showing the name and length of the railway tunnel in question. The size and location of this name plate must be selected in such a way that the text can be read from a moving train.

18.6 Structural planning and design

18.61 Rock tunnels

18.611 Surveys

In addition to the minimum surveys specified in Section 18.332 at least the following more detailed surveys of the bedrock at the rock tunnel site must be carried out:

The topography of the rock surface must be established in areas where the rock surface is exposed by carrying out 3-D measurements, and in areas where the rock surface is covered by carrying out motorized rock penetration tests and/or soil scanning and/or seismic sounding tests which are complemented with motorized rock penetration tests. The measurement and drilling locations as well as the sounding lines must be specified in the survey programme.

Exposed rock surfaces and open cuts must be the subject of an engineering-geological charting operation during which the types of rock, their disintegration, orientation and fissure formation and their planes of weakness (orientation, fissure formation intervals, gouges) are defined.

The results obtained must be presented on a chart where the location of the proposed tunnel is to be situated as well as all the altitudinal positions of the rock surfaces, which have been established. This chart must also show the various rock type areas as well as the locations and numbers of any planes of weakness and significant fissures.

If necessary, rock sample drillings (54 mm) and seismic soundings must be carried out in order to establish in detail the type/quality of the rock and any variations that may occur in it.
The drill core samples must be subjected to an engineering-geological interpretation and used for establishing the RQD factor, which describes the type of rock in question, over the entire depth of the drill hole; a Q classification must be carried out. Using the same drill holes, water consumption tests must also be carried out in order to establish the need for injection (grouting).

If necessary, the strength and deformation characteristics of the types of rock and the fissures must be established by performing rock stress measurements and laboratory tests (1- and 3-axial tests, fissure shear tests). Where necessary, the stress state of the rock must be established for the purpose of mechanical rock analyses.

18.612 Mechanical rock analyses

Mechanical rock analyses must be performed in order to determine deformation and the need for rock reinforcement and to ascertain stability in cases where the type of rock, the rock stress state or the thickness of the structures make this necessary. The design parameters are defined on the basis of the results obtained in surveys carried out in accordance with Section 18.611 /14/.

18.613 Planning of rock construction work

The plans for quarrying, sealing injection (grouting) and rock reinforcement work include the documents listed in Section 18.344. These plans must be drawn up following the planning principles

set out in Section 18.37 and in accordance with the RMYTL General work specifications and quality requirements for earthworks in railway construction (RMYTL), Section 6, "Rock construction work".

The quarrying and reinforcement plans must be drawn up in such a way that all risks to the environment and any deformations are under control, and that all permanent rock structures are sound and stable.

The sealing measures must be planned so that no harmful water leaks will occur in the completed rock areas. There must occur no water leaks at all above the electrification equipment. In the perched water and groundwater conditions there must not occur any changes that could be harmful to the environment. The materials being used for sealing measures together with their product declarations must be presented to the client for approval in writing. The actual used amounts of each material must be documented.

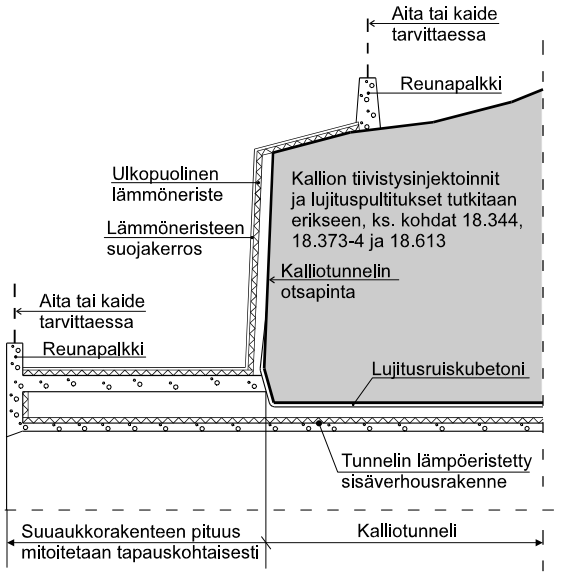
The rock foundations must be built in accordance with the General work specifications and quality requirements for earthworks in railway construction (RMYTL), Section 6, "Rock construction work". The foundations must be treated in such a way that no frost heave will occur. The various alternatives are set out in the RMYTL (General work specifications and quality requirements for earthworks in railway construction), Section 6. Examples are shown in Appendices 7 and 8.

18.614 Structures

The load-bearing and interior structures and the fitment and anchoring of equipment and fittings must be planned and designed following the design principles set out in Section 18.37 as well guidelines for structural planning and design /39 to 51/.

All lining structures as well as fitment and anchoring must be planned so that all water leakage and freezing problems and as the norms, standards and planning and design damage caused by these to structures and equipment can be avoided. Particular attention should be paid to elimination of water leakages and freezing above electrification equipment. The lining structures should be provided with inspection doors to enable a thorough inspection of the rock interstices.

For each tunnel mouth such tunnel mouth structures must be designed that they will prevent any water, snow or ice from the surrounding terrain from draining/falling onto the rail track or from coming into contact with any technical equipment to do with the rail track or any other technical equipment. Particular attention should be paid to the protection of all electrification equipment. The length of the tunnel mouth structure, the heights of the edge beams and flanging beams as well as the extensiveness and thicknesses of thermal insulation must be designed separately in each individual case according to the cold content and the local water, ice and snow conditions. Particular attention should be paid to the elimination of any leakage and freezing problems at the points where the tunnel mouth structures and the rock face are joined together. Lining structures, which are provided with thermal insulation, must be extended from the rock tunnel across the jointing area into the tunnel mouth structure, unless special reasons exist and require a different action to be taken. If necessary, electric heating cables can be used. A basic solution for the tunnel mouth structure of a rail tunnel is shown in Figure 18.6:1.



- Reunapalkkien korkeudet mitoitetaan paikallisten lumi- ja jääolosuhteiden mukaan
- Lämmöneristeet mitoitetaan pakkasmäärän sekä vesiolosuhteiden ja kalliolaadun mukaan

Figure 18.6:1 Basic principle / longitudinal cross-section of the tunnel mouth structure of a rail tunnel

1 Fence or railing where necessary

2 Edge beam

3 External thermal insulation

4 Protective layer of thermal insulation

5 Sealing injections (grouting) and
reinforcement bolting of the rock must be surveyed separately, see Sections 18.344, 18.373-4 and 18.613

6 End face of rock tunnel

7 Sprayed concrete reinforcement

8 Tunnel's interior lining structure with
thermal insulation

9 Rock tunnel

10 Fence or railing where necessary

11 Edge beam

12 Length of tunnel mouth structure must be determined separately in each individual case

- The heights of the edge beams must be determined according to local snow and ice conditions
- The dimensions of the thermal insulation must be determined according to the cold content as well as the water conditions and the type (quality) of the bedrock.

18.615 Drainage system and substructure

The drainage system of a rock tunnel consists of the following parts:

- Shotcreting (concrete spraying) of the rock surfaces and subsoil drainage for the sprayed concrete
- Water-proofing of the lining structures
- Filling [materials] for the substructure; these should be very permeable to water and not susceptible to frost heave
- Subsoil drainage, drainage water sewers and wells located in the substructure
- Pumping plants and their pressure lines
- [Sewer] system connections and discharge pipes leading to the surrounding terrain or waterway system.

The drainage system must be planned in accordance with RMYTL Section 4 "Drainage work". The drainage system must keep the substructure dry to the level of the underside of the insulation layer or to a lower level. The system must be protected against freezing.

The substructures must be planned so that all frost heave problems and damage can be avoided. The treatment of rock foundations in accordance with Section 18.613 and RMYTL Section 6 "Rock construction work" must be taken into account in the planning of substructures.

18.62 Concrete and steel tunnels

18.621 Extent of coverage

RAMO Section 18 "Railway tunnels" does not discuss the so-called ground tunnels, which include tunnels built underground using special methods, and without any open cuts. Neither does it discuss any tunnels built by sinking them in water or by other specialist methods. If necessary, the RHK (the Finnish Rail Administration Board) will issue separate regulations and guidelines for the types of railway tunnel referred to above.

RAMO Section 18 "Railway tunnels" is only concerned with those underground concrete and steel tunnels, which are built as bridge-like structures and using building pits opened from the surface.

18.622 Guidelines for planning and design

The planning and design principles set out in Sections 18.1 to 18.5 must be followed in the planning and design of concrete and steel tunnels. For technical systems, Section 18.7 must be complied with in so far as applicable.

The foundation structures and load-bearing structural parts of concrete and steel tunnels must be planned and designed in accordance with the regulations contained in the RakMk (the Finnish Code of Building Regulations) and, in so far as applicable, the Guidelines for the design of railway bridges /48/, the Bridge planning and design guidelines by Tielaitos (the Finnish Public Roads Administration), RAMO Section 8 "Bridges" and the norms relating to the materials in question.

In so far as earthworks are concerned, the General work specifications and quality requirements for earthworks in railway construction (RMYTL) must be complied with.

In so far as drainage, water-proofing, thermal insulation and lining structures are concerned, the above-mentioned Bridge planning and design guidelines, as well as the regulations and guidelines in Section 18.61 relating to rock tunnels, where applicable, must be complied with.

18.7 Technical systems

18.71 Extensiveness of the systems

The need for and extensiveness of technical systems of railway tunnels must be determined separately for each individual tunnel on the basis of the functional/operational traffic analysis discussed in Section 18.52 and the risk analysis discussed in Section 18.53.

Not all technical systems are necessarily required in all railway tunnels. Depending on the length of the tunnel in question, the extensiveness of the technical systems can, as a general rule, be considered as follows:

- In the case of rail tunnels with a length of < 200 metres no technical systems are required apart from a drainage system.

- In the case of rail tunnels with a length of 200 to 500 metres the technical systems required in addition to a drainage system include at least a lighting system and other equipment necessitated by this.
- In the case of medium length and long rail tunnels the need for and extensiveness of technical systems must be considered separately for each individual tunnel.

The said length definitions are not the only factor determining the level of equipment; all the factors discussed in the functional/operational and risk analyses should be taken into account when considering the equipment required.

18.72 Electrical systems

18.721 Transmission and distribution of electric energy

The tunnel system must be connected to the distribution network operator's low voltage network. The number of connections to the local electricity company's energy network depends on the length of the tunnel and the type of traffic. In the event that the tunnel system requires several network connections, these should be supplied from different transformer circuits if at all possible.

The distribution system for the electrification of the construction stage must be implemented by means of a TN-S system (5-conductor system).

In the transmission and distribution of electric energy the following documents and regulations, among others, must be complied with:

- TUKES/SETI A1-93 Electrical safety regulations (StM)
- TUKES/SETI A2-94 Electrical installations in buildings (RaSM)
- The Finnish Code of Building Regulations E1
- SL4/RM Location of transforming stations with regard to fire safety
- SFS Standards (e.g. areas reserved for distribution boards and telecommunications as well as cable routes)
- Safety instructions for work involving and areas used for electrical, telecommunications and safety equipment, Oy VR-Rata Ab, 1996.

Substances which are used at transformer stations (distribution substations) and which could constitute a danger to people or the environment should be approved and they must be listed on a plate attached to the door of the transformer station.

The installation conditions and area classifications should be taken into account when considering installation techniques and selection of equipment.

The low voltage network serves all technical systems and equipment, which require electric energy. In addition to these, each service point must be provided with socket outlets; the technical requirements for and the number and location of these must be determined in the electrical plan.

18.722 Main and group distribution centres

The structural and testing standards that should be used for the [distribution] centre areas are the European EN 60439 series Standards (SFS-EN...), taking into account national supplementary guidelines and the conditions prevailing in the tunnel system.

Motor drives (> 5 kW) must be provided with compensation, cos 0.9.

The main equipotential bonding rail must be located in the main [distribution] centre area.

18.723 Back-up power supply

The need for back-up power supply must be established in the risk analysis.

The need for back-up power supply is determined primarily by the power and operating requirements of the smoke exhaust fans and pumps, and by the number of installation supply [points] in the back-up lighting and the safety and monitoring systems.

The back-up power supply may be implemented using either a fixed back-up power unit (diesel aggregate) for each tunnel or using portable back-up power units of the rescue service units (equipment outside the tunnel).

The time when the back-up power is put into service or switched on must be determined in the risk analysis.

18.724 Cable routes

For reasons of fire protection the cable installations should be carried out primarily as subterranean cable installations, using cable conduits or cable tubing. From the cable conduits the cables must be routed up, via tubing, to cable racks and then further to the actual installation point. Cable racks should be used for shorter cable runs, taking fire and other protection requirements into account. A cable with a PE sheath, for example, requires fire protection in the case of rack installations exceeding 50 metres in length.

When selecting the routes for cable runs, routing the cables through areas with a fire risk should be avoided, as well as places where there is a risk of mechanical damage being caused to the cabling. The cable installations must be provided with fire protection, unless the requisite protection can be provided through the selection of [safe] cable routes or by the use of special cabling.

Power cabling and control/alarm cabling should be kept apart from one another in so far as fire protection is concerned. Lighting and other such secondary cabling may be installed as cable rack installations. Fire protection must, nevertheless, be taken into account.

In the event that safety devices outside the tunnel premises, such as traffic signs, receive their power supply from the tunnel areas, such supply cable must be provided with fire protection.

Area and enclosure classification must be taken into account when selecting cable routing materials.

18.73 HVAC (heating, plumbing and air-conditioning) systems

18.731 Ventilation

In normal situations a train travelling in a rail tunnel at the design speed causes pressure variations, which generate adequate ventilation.

Pressure variations and air flows can easily become excessive, and therefore the rail tunnel must be provided at proper intervals with pressure equalizing shafts or with other types of connection leading to the atmosphere in order to reduce the pressure and to restrict sudden pressure shocks. Depending on the design speed, pressure equalization may be necessary in medium length and long rail tunnels. In the case of double [track] tunnels pressure equalization is assisted with connecting tunnels between the rail tunnels and special pressure equalization ducts located between the rail tunnels.

The connecting tunnels should be able to be closed as separate fire protection compartments if they act as emergency exits or normal exit routes.

The distance between shafts or other links to the atmosphere and their cross-sections should be selected, on the basis of calculations, in such a way that the pressure change velocities and absolute extreme values specified in Section 18.35 will not be exceeded.

The need for the rail tunnel to be provided with motorized ventilation should be checked separately for each individual tunnel in cases where the tunnel is used by diesel locomotives or where, in connection with maintenance and repair work, appliance like diesel vehicles or welding equipment which generate a great deal of impurities are used.

Motorized ventilation is effected with the use of axial fans, without ducting, designed for longitudinal ventilation of tunnels and supplied complete with silencers and installation kits. The outside diameter of such fans in a rail tunnel must not exceed 1,200 mm, and they must be located in the rail tunnel in the manner specified in Appendices 1 to 4.

Fans, which are used for longitudinal ventilation of tunnels, should be high thrust fans, which are designed specially for the ventilation of tunnels. They should be reversible with regard to direction of thrust and their thrust must be equal in both directions. The heat resistance of the fans should be +250°C for one hour.

The fan manufacturers should have in operation an acceptable quality control system, ISO 9001 for example.

The tunnels and shafts of the tunnel system must be used as the paths of the motorized ventilation. If the tunnel is equipped with smoke exhaust fans, then these should also be able to be used for ventilation purposes.

Appropriate fans complete with all necessary other equipment must be used in the technical areas which form part of the tunnel system.

The ventilation required by infrequent maintenance and repair operations may also be affected by using temporary fan installations, unless motorized ventilation is required for some other reason.

Motorized ventilation should only be used if and when necessary.

Any unnecessary running of fans should be prevented in an appropriate manner.

In the case of urban areas as well as leisure and conservation areas the need for the shafts to be equipped with noise attenuators should be checked.

18.732 Sewerage

In order to remove any water that may collect in rail tunnels and other tunnels, sewage pipes and drainage pits must be installed at the bottom of these tunnels where water coming from subsoil drainage pipes and elsewhere is collected. The principle of installing such pipes in a rail tunnel is shown in Appendices 1 to 4 and 5. With the help of the sewage pipes the waters are then directed either by gravity or through pumping stations to the outside soil, waterways or sewage network.

Pumping stations should, if at all possible, be located at the lowest points of the tunnels and as close as possible to ground surface connections. Pumping stations are normally built with concrete and the pumps of the immersed type, complete with back-up pumps.

Where provisions are made for also collecting fire-fighting water and dangerous substances resulting from an accident situation in the sewage network of the tunnel, then this sewage network must be equipped with collecting basins. Such collecting basins are either rock or concrete basins. Where pumping stations are required, the collecting basins must be located in the vicinity of such pumping stations. The dimensions of the collecting basins must be determined in such a way that their capacity is adequate for at least one day's (24 hours') drainage water, unless such water is led out of the tunnel separately, as well as any other water and any dangerous substances that may possibly leak into the tunnel. In the case of underwater tunnels the dimensions of the basins regarding drainage water must always be checked separately.

The flow of any harmful or dangerous substances accumulated in the collecting basins from the basins to the soil, waterways or sewage network must be prevented by means of a reliable locking device.

The collecting basins or pumping stations must be equipped with oil separators if considered necessary. In the event that
a neutralization or other such treatment of dangerous substances in the collecting basins is not possible, a provision must be made for disposal by removing them separately.

18.733 HVAC monitoring system

For the purposes of the control, monitoring and alarms of the technical systems the tunnel system must be equipped with an HVAC (heating, plumbing and air-conditioning) system in accordance with the functional/operational and risk analyses.

In the case of tunnels or tunnel systems where the quantity of technical equipment is very small, functions relating to measurements, adjustments and controls can be managed from the unmanned sub-stations of the system in question which are located in the vicinity of the technical areas or the power distribution centres which serve the technical systems. In such cases only crucial alarms are transmitted to a manned monitoring point deemed suitable for that purpose.

It must be considered separately in each individual case when it would be necessary to use a centralised property monitoring system and a related technical monitoring centre where all the data relating to the technical systems would be directed.

18.74 Lighting

The lighting arrangements (i.e. lighting, sign illumination and safety lighting) should be implemented in such a way that it is possible in all situations to move in the tunnel areas with safety. The lighting systems must be realized tunnel section by tunnel section as required by the functional/ operational and risk analyses.

18.741 Normal lighting

The use of and the maintenance and repair operations in each tunnel must be taken into account when taking a decision on the lighting systems.
The requirements regarding the level of lighting are as follows:

- In rail tunnels at least 10 lx on the walkway level

- In other tunnel areas 20 lx on the walkway level.

If necessary, the minimum level of lighting in rail tunnels should be increased if so required by the volume of traffic, dazzle prevention, the servicing and maintenance operations, and the location of emergency exits or by some other considerations. The lighting units should be located at an adequate distance from the train signals so that there is no risk of dazzle or a wrong interpretation.

With regard to the lighting installation techniques, the instructions provided by the ST card file must be followed. Mounting trays should be used for equipment installations. The lighting units should withstand the special conditions, which prevail in the tunnel, e.g. the effects of pressure shocks.

In normal circumstances the lighting is switched on from the traffic control centre and, in addition to that, from the tunnel mouths and shaft tops of the tunnel system as required by the functional/operational and risk analyses. The lighting of normal exits and rescue routes should always be able to be switched on at either end of the normal exits and rescue routes. The lighting must not be kept permanently switched on, unless this is required for special reasons.

In addition to normal lighting, the tunnel areas must also be equipped with sign illumination and safety lighting systems in accordance with Section 18.758 and, if necessary, with a back-up lighting system connected to a back-up power supply, see Section 18.742.

18.742 Back-up lighting

Back-up lighting must be arranged in cases where this is required by the functional/ operational and risk analyses. Power supply to the back-up lighting system must be effected either with a permanent back-up power plant for each individual tunnel or with portable emergency power plants belonging to the maintenance or rescue organizations.

In cases where uninterrupted lighting is required for the safety of persons, the back-up power supply must be realized using the so-called 'No break' equipment. Because of the long time it takes to transport portable machinery by the servicing and maintenance organizations (duration of power cut in excess of thirty (30) minutes), it is required that personal safety in so far as lighting is concerned be ensured by the use of safety lighting and sign illumination (SFS 4640), see Section 18.758.

18.75 Safety and monitoring systems

18.751 Fire annunciator systems

A fire annunciator system must be realized in accordance with the risk analysis. Technical areas are usually equipped with a fire annunciator system. Rail tunnels are usually not equipped with a fire annunciator system.

A fire annunciator system should be realized in accordance with the EN-54 Standard (SISM 2812/701/79).
In addition to the actual equipment, an automatic fire annunciator system must incorporate a message transmission system.

The system should be an addressable one (i.e. it must be able to locate the position of a fire in the tunnel, for example) and guaranteed uninterrupted by a network back-up. Selection of fire annunciators must be based on the needs of each particular location. In the location of fire annunciators the conditions to be particularly taken into account include electrotechnical and other such states, which might cause a fire in the tunnel.

The peripheral functions of the system can be utilized for the control of IV [?] equipment and fire safety locks.

The transmission of the message regarding a fire situation should be directed to the local monitoring and rescue organization.

18.752 Fire extinguishing systems

The fire extinguishing system and its extensiveness is defined in the risk analysis.

Fire extinguishing is affected by using water hydrants in the tunnels and manual extinguishers in the technical areas.

The system should incorporate a safety device, which ensures that power supply to the rail track is switched off before extinguishing water is fed into the pipework.

The supply of water for fire-fighting purposes must be ensured in the eventuality of a fire, either in the rail tunnel itself or in the vicinity, outside the tunnel. Appropriate methods include the following:

- For extinguishing a fire from outside the tunnel, water may be obtained from a near-by waterway by using the fire-fighting service's own appliances, or brought in a tanker vehicle or taken from an extinguishing water post constructed in the vicinity of the tunnel mouth.

- When a train on fire has stopped inside the tunnel or there is some other fire in the tunnel and the fire is such that it is possible to enter ('assail') the tunnel, water for the tunnel can be obtained from the extinguishing water pipework installed in the tunnel and from the water hydrants as well as from the drainage and extinguishing water basins constructed.

The extinguishing water pipework can be supplied, using the fire service's own pumps, from the supply connections located outside the tunnel, from separate extinguishing water basins using permanently installed pumps at the basins, or from a municipal water supply network. In view of the risk of freezing it is recommended that a dry extinguishing water pipework be used. If a pressurised wet pipework is used for fire-fighting purposes, then the extinguishing water pipes should be provided with protection against freezing. Wet pipes must be located in protective tubes in the same way as when laying them underneath a railway track.

Extinguishing water pipes forming part of a fire extinguishing system should be corrosion-proof and fire resistant and they must not be electrically conductive. Where plastic tubing is used, extinguishing water pipes should be installed in the tunnel substructure and protected from fire.

Extinguishing water pipework may be omitted provided that it is possible to use fire-fighting vehicles which are driven into the tunnel and each of which is capable of transporting at least 10 m^3 (10,000 litres) of extinguishing water.

The detailed dimensions of the fire extinguishing system should be determined in cooperation with the local fire-fighting authorities.

All technical areas must be equipped with manual fire extinguishers.

18.753 Smoke removal systems

The smoke removal system must be designed on the basis of the risk analysis.

In a tunnel fire, smoke spreads very quickly into the various tunnel areas and will hamper fire-fighting efforts as well as rescue operations.

In the case of short tunnels it may be assumed that the smoke dissipates without the assistance of motorized smoke removal.

For tunnels with a length of 500 to 1,000 metres it can generally be assumed that the smoke will dissipate without the assistance of motorized smoke removal, provided that the tunnel is horizontal or slopes in the longitudinal direction. In the case of diving tunnels or tunnels which slope from inside towards the tunnel mouths, the necessity of motorized smoke removal should be checked. Any motorized smoke removal that may be required must be arranged by means of tunnel fans through the tunnel mouths.

In the case of tunnels measuring between 1,000 and 2,000 metres, motorized smoke removal must be arranged primarily with the help of tunnel fans through the tunnel mouths. All other connections to atmosphere in the tunnel, such as the pressure equalization shafts, may be of assistance in smoke removal operations.

In the case of long tunnels, motorized smoke removal must be arranged either with the help of tunnel fans or by means of separate smoke removal fans located in the vicinity of the pressure equalization shafts. If it is necessary to employ tunnel fans for ventilation purposes, then it is recommended that also smoke removal be arranged using tunnel fans.

Where motorized smoke removal is required, special axial fans designed for smoke removal must be employed. The above-mentioned fans designed for ventilation purposes can then be used for moving smoke along in tunnels.

The dimensions of fans used for motorized removal of smoke must be determined in such a way that a flow velocity of at least 2 m/s is achieved at the tunnel's cross-sectional area.

The smoke removal fans should be officially tested and their heat resistance should be 350°C for one (1) hour. The dimensions of the fans should be determined in such a way that the fans are also able to function when the smoke is cold or the exhaust air smokeless, in other words that they can also be used for ventilation purposes.

The smoke removal fans should be able to be controlled from outside the tunnel.

In order to be able to choose the appropriate emergency exit and rescue route direction, long tunnels must be equipped with devices indicating the direction of air flow.

18.754 Aerial systems

The extensiveness of the aerial system of a railway tunnel must be specified in the functional/ operational and risk analyses.

The aerial link to be constructed from the railway tunnel to the [tunnel] users' cable TV system (video monitoring) must be realized in accordance with the SFS guidelines taking into account the regulations issued by the Telecommunications Administration Agency (Telehallintokeskus) (applications THK 21A/94M and THK 23A/93M).

The tunnel system must be connected to the telephone network of the Public Telecommunications Operator (Telelaitos) and equipped with aerial connections to the NMT, GSM and VIRVE indoor aerial systems in accordance with the functional/ operational and risk analyses. The types of aerial that can be used include the so-called 'leaky cable' or base station aerials. The system equipment (such as amplifiers) is supplied by the operator in question.

The aerial system of a train radio must be realized in accordance with the guidelines issued by the RHK (the Finnish Rail Administration Board).

18.755 Emergency telephone systems

A railway tunnel must be equipped with an emergency telephone system in accordance with the risk analysis. The emergency telephone links are established from the distribution centres to the traffic control centre, to the nearest station as well as to the emergency centre and to the electricity board.

The emergency telephones must be installed in each rail tunnel at maximum intervals of 300 metres. In addition to this emergency telephones must be installed at the tunnel mouths and at both ends of the exit routes as specified in the risk analysis.

The functioning of the emergency telephone system should be provided with a back-up system and be guaranteed to provide an uninterrupted service during possible power cuts.

18.756 Video monitoring systems

The need for a video monitoring system in a railway tunnel must be determined separately in each individual case on the basis of the functional/ operational and risk analyses.

The video monitoring system must be connected to the monitoring system specified in the risk analysis. The number and location of cameras must be planned separately for each individual tunnel. The camera equipment must be provided with IR control. The system should be provided with an operating link to the compulsory public address system of the traffic control centre.

The video signal transmission system should be compatible with the main system technology.

The remote control functions and output equipment of the monitoring TV system are determined in accordance with the risk analysis. System links should be arranged to the traffic monitoring and crime reporting systems. The network back-up system must be guaranteed to provide an uninterrupted service.

18.757 Crime reporting systems

The need for a crime reporting system in a railway tunnel must be determined separately in each individual case on the basis of the functional/ operational and risk analyses.

A crime reporting system must include addressable area and location cover. It should also be possible to connect data from other traffic monitoring sources to this system. The aim of the system is to prevent the presence of unauthorized persons within the monitored areas or premises and to report any such presence.

The network back-up system must be guaranteed to provide an uninterrupted service.
The system operating data should be passed on to the proper authorities.

18.758 Safety lighting and sign illumination systems

A safety lighting and sign illumination system as well as emergency exit signs should be located in railway tunnels to ensure that people can get out and to safeguard rescue operations (1 to 3 h). The power supply to the system must be affected with sets of batteries. The system must be realized in accordance with the set of guidelines 147/01/87 issued by the Rescue Department of the Ministry of the Interior, and [the Standards] SFS 4640/1985-06-03 and SFS EN-60598-2-22.

The illumination of signs must be switched on permanently during the traffic period. The lighting level of the safety lighting on the walkway level must be at least 1 lx in the rail tunnel and at least 2 lx in areas difficult to negotiate, such as staircases. Arrangements must be made for external control of the safety lighting and for the monitoring of the battery sets.

The operating principles of the system should be selected separately for each individual location (lighting unit/central accumulator system).

18.759 Sound reproduction systems

The sound reproduction system of a railway tunnel must be determined on the basis of the functional/ operational and risk analyses.

The sound reproduction system should incorporate the sound reproduction system for the compulsory public address system. The system must transmit radio announcements as well as traffic management, passenger and emergency announcements.

The power supplies to the equipment included in this system must be guaranteed to provide an uninterrupted service.

18.76 Monitoring centres

The monitoring centre for technical systems must be provided with all the equipment required for the control and monitoring of the HVAC (heating, plumbing and air-conditioning) system and other technical systems and with safety-related equipment.

The monitoring system must be realized with a single unit of software-based computer hardware, which includes a central processing unit, PC controllers, reporting equipment and an alarm indication board.

The monitoring centre must also house an emergency telephone switchboard, equipment for radio communications and for the crime reporting system as well as the local equipment for video surveillance (monitors, among other things).

The functional diagrams of all the technical equipment and systems must also be located in the monitoring centre.

18.8 Construction of tunnels

18.81 Scheduling of construction

The client for whom the work is carried out draws up a railway tunnel construction programme, or a contractual programme, or has one drawn up, in which at least the following matters must be presented:

- The construction project and details of the construction site and of the way in which an electrified rail track has been taken into account
- The contractual parties in the construction project and the obligations and limits of responsibility for each
- The documents to be complied with and their mutual order of competence
- The scope of each contract, the contractual limits, the contractual delivery times and consequences of possible delays
- Types of contract, prices and terms of payment
- Warranties, securities and insurance
- Responsibility for quality assurance, quality assurance plan and quality assurance measures
- Regulations regarding the labour force, the management and surveillance of work/labour
- Requirements regarding tender documentation and details of the way the tenders are dealt with
- Plans/designs, surveys and documents that the constructors are assumed to have.

The construction of a railway tunnel must be carried out in compliance with the documents and plans drawn up at the planning stage. Plans/designs and work specifications, which relate to particular items of work take priority over any general documents and work specifications.

Each constructor should draw up and submit to the client for approval the overall plan for the work prior to commencing any work. The overall plan should include a construction area development plan, the order of work operations, a mass utilization plan, supply and installation plans, details of matching up the various part operations, and a time schedule.

Work plans for each part operation should be drawn up and submitted to the client for approval prior to commencing any of the part operation in question.

18.82 Taking electrified railway track into account

When working in the vicinity of an electrified rail track, which is being used by traffic, the railway traffic and the electrification should be taken into account in accordance with the documents listed in Section 18.822. In the following there is a summary of the matters to be taken into account.

18.821 Responsibility

It is the client's responsibility to ensure that all the restrictions and safety regulations regarding the electrified rail track are made known, extensively enough, to those who perform the work.

It is the responsibility of those who perform the work to ensure that all the restrictions and safety regulations regarding the electrified rail track are complied with. The railway traffic must not be disturbed nor endangered.

Those who perform the work should find out sufficiently about the rail traffic at the construction site by studying in advance the timetables and the conditions prevailing at the site.

18.822 General documentation

In the performance of work and in the planning thereof the following general documents relating to the electrified rail track, in addition to the other contractual documents, must be complied with:

- Train safety regulations (Jt)
- Technical regulations and guidelines relating to the Train safety regulations (Jtt)
- Technical rail track regulations and guidelines, RAMO Section 5 "Electrified rail tracks"
- Regulations on electrified rail tracks, VR 3554
- Qualificational requirements for railway workers, RHK (the Finnish Rail Administration Board)
- Safety guidelines for work carried out in railway areas, VR 5243
- Protection of workers during rail track maintenance work carried out on rail tracks used by traffic, VR 5223
- "Like a Beast", safety guidelines when working on electrified rail tracks, VR 5206
- "Beware power lines", a guide for drivers of construction machinery, Electrotechnical Inspectorate (SETI)
- Resolution by the Council of State on the regulations for blasting and quarrying operations (410/86) and the safety regulations on blasting and quarrying operations ratified by the Ministry of Labour, 16:0

It is the responsibility of all performers of work to ensure that they have the above-mentioned general documents relating to electrified railway tracks at their disposal and to make sure that the latest version of each document is being used.

It is the responsibility of each performer of work to ensure that the documents listed above are complied with throughout their entire scope. Herein, only matters, which have a most essential bearing on the performance of work, have been chosen from these documents.

18.823 Electrification and safe distances

All the wires, return wires and rails forming part of the track conducting wire as well as the hinged cantilevers which support these components, complete with insulators, are live.
The rail track conducting wire carries a 25 kV voltage that has the frequency of 50 Hz.

The distance of a working person and that of all the tools and accessories handled, from the live parts of the electrified rail track must always be at least 2.0 metres. This also applies to the live parts of the rolling stock (trolley arm).

No construction machinery or any part of it must not reach closer than the following distances to any of the live parts of the electrified rail track:
- 3.0 metres in the lateral direction

- 2.0 metres underneath, without a lift-restricting device

- 1.5 metres underneath, for a construction machine moving on solid ground and equipped with a lift-restricting device

- 1.0 metres underneath, for a construction machine moving on rails and equipped with a lift-restricting device

More detailed regulations are given in the Regulations on electrified rail tracks, VR 3554.

Working above live components is prohibited without the protective structures referred to in RAMO Section 5 "Electrified rail tracks".

If the distance of a working person, a construction machine, tools or accessories from the live parts of the electrified rail track is less than the above-mentioned minimum distances, then the rail track conducting wire must be de-energized by means of a voltage ceiling for the duration of the performance of the work in question.

18.824 Railway work zone (reach)

The term 'railway work zone' (or 'reach') is defined in the document entitled Qualificational requirements for railway workers.

Those performing the work or the construction machinery and equipment they use must not enter the railway work zone nor go any closer than 3.1 metres to the centre line of a rail track which is used by rail traffic, without special permission obtained from the client for whom the work is carried out and without making the requisite safety arrangements. The measures required by the safety arrangements are set out in the general documents listed in Section 18.822.

If in order to carry out the construction work it is necessary to work temporarily at a distance of less than 3.1 metres from the centre line of a rail track, which is used by rail traffic, a special security man must be placed near-by to ensure the safety of the rail traffic and those performing the work. This security man must not have any other duties apart from the above-mentioned security task.

Whenever work is actually carried out within the railway work zone, the rail track in question must be reserved for the exclusive use of the construction site, whereby it must be closed for traffic for a period to be agreed separately.

18.825 Rail track reservations and voltage interruptions

The rail traffic operator must take care of any restrictions concerning the railway traffic in the manner specified in the documents relating to each type of work.

During a rail track reservation the rail track is in an operational condition but closed to traffic. The rail track reservation applies to a single rail track at a time. A rail track reservation does not involve any interruption in the voltage supply.

An interruption in the voltage supply means that the live parts of the electrified rail track are made dead for a pre-determined period of time. The electrification equipment stays
in position for the duration of the interruption in the voltage supply, unless it has been agreed separately that it should be removed. An interruption in the voltage supply applies to a single rail track at a time. An interruption in the voltage supply does not mean that the rail track is reserved. The effective working time is shorter than the duration of the interruption in the voltage supply owing to the earthing and other operations required by the interruption and owing to the necessary traffic arrangements.

The foreman responsible for the work performance in question must make a written agreement on each interruption in the voltage supply with the person (installer) responsible for the temporary earth of the electrified rail track. An interruption in the voltage supply must not be construed as starting at any given time notified. The interruption in the voltage supply begins and the work may be commenced [only] when the installer of the temporary earth hands over the agreement form relating to the interruption in the voltage supply to the foreman responsible for the work. Once the work has been completed, the foreman responsible for the work signs and hands over the agreement form to the person who will dismantle the temporary earth as an indication that the work has been completed. The voltage must not be reconnected prior to receiving this notification.

The performer of the work must make the request for a rail track reservation or an interruption in the voltage supply in the manner specified in the documents relating to each type of work.

18.826 Earthing

Construction machinery and equipment must always be earthed in the circumstances where any part of it extends closer than 5.0 metres from the live components of an electrified rail track. The earthing of construction machinery and equipment must be carried out by a person who has received the appropriate training for this task. The performer of the work must agree on the earthing work with the local electricity board at least two working days prior to the time of earthing.

Any earthing work involving permanent structures and possibly safety structures must be carried out by the performer of the work in accordance with the plans/designs and RAMO Part 5 "Electrified rail track", except for the connection to the earth rail which must be performed by a person who has received the appropriate training for this task. It must be noted in particular that any structures, which

are installed during an interruption in the voltage supply, must also be earthed during the same interruption in the voltage supply. Connections to the earth rail must be agreed upon at least two working days prior to the time of earthing.

18.827 Effects of electrification on measuring instruments

It is possible that disturbing electrical currents are induced from the live parts of the electrified rail track or from the subterranean cables to the cables of the measuring instruments and any effects by these on the measurements obtained must be prevented by a correct layout arrangement of the measurement cables and equipment.

18.828 Safety training

The performer of the work must agree with the client for whom the work is being carried out on the training to be given on electrical safety aspects. On this safety training occasion information must be given on the risk factors related to rail traffic and electrical safety training provided for the entire personnel taking part in the work prior to starting the work. All those taking part in the work on the construction project in question must attend the training session before a single person or machine may have access to the vicinity of the electrified rail track.

18.83 Structural engineering work

The structural engineering work must be performed in accordance with the plans and in compliance with the documents listed in the construction schedule.

The plans for rock construction work should take into account the results of the surveys and analyses referred to in Sections 18.33 and 18.61 as well as any interpretations of these. The rock construction work must be carried out in accordance with the plans, the work specifications for each work performance and plans made during the work performance as well as the RMYTL General work specifications and quality requirements for earthworks in railway construction, Part 6 "Rock construction work".

The earthworks and foundation engineering work must be carried out in accordance with the plans and foundation engineering guidelines /1 to 6/ as well as the RMYTL General work specifications and quality requirements for earthworks in railway construction, Section 6 "Rock construction work".

The concrete and steel structures must be built in accordance with the plans and the appropriate material norms /39 to 47/.

For the building of bridge-like structures, the General work specifications and quality requirements in bridge construction /50/ as well as RAMO Section 8 "Bridges" must be complied with.
For all interior structures it is required that element manufacturing, transport and installation plans be

drawn up and submitted to the client for whom the work is carried out for approval prior to the commencement of manufacture.

Each performer of work should draw up written documents in respect of any solutions that differ from or complement the plans as well as all the as-built drawings specified in these documents, and these must then be documented in accordance with Section 18.10.

18.84 HVAC work

Each performer of HVAC work should take part in the drawing up of the overall plan for all the work performances referred to in Section 18.81 and draw up a work schedule to cover their own work performances which must be submitted to the client for whom the work is carried out for approval.

The HVAC work must be carried out in accordance with the plans and in compliance with the documents listed in the construction schedule and in the work specifications. In addition to these, the documents to be complied with include the LVI-RYL and ST card files.

Each equipment supplier and installation firm should draw up written documents and as-built drawings in respect of any solutions that differ from or complement the plans as well as functional diagrams and servicing and maintenance instructions for all the equipment they have supplied and installed, which must then be compiled into a continuous manual and documented in accordance with Section 18.10.

18.85 Rail track engineering work

The rail track superstructure as well as the electrification and safety equipment work must be carried out in accordance with RAMO's appropriate sections and the Planning and Construction Guidelines for Electrification, I to III.

The performers of work should take part in the drawing up of the overall plan for the work and adapt their own supplies and work performances so as to suit the overall schedule.

18.86 Overhaul work on existing tunnels

18.861 Need for overhaul

The condition of existing rail tunnels and their equipment must be monitored through inspection measures, which are set out in Section 18.9. The need for overhaul work must be determined on the basis of these inspections. A rail tunnel must be overhauled in the following cases:

1) The tunnel structures and/or equipment require repair and renewal measures in excess of normal maintenance operations.
2) An increase in the size or weight of the rolling stock and/ or increased speeds require measures to be taken.
3) The track section is to be provided with electrification.

18.862 Inspections and surveys

Whenever any of the reasons listed above in Section 18.861 requires overhaul measures to be carried out in the rail tunnel, then a main inspection and any necessary special inspections should be carried out in the tunnel as specified in Section 18.9. On the basis of these inspections, a survey programme covering the entire tunnel and all its structures and equipment must be drawn up and the surveys specified in the programme must be performed.

Apart from any visual needs for overhaul measures and those found during the inspections, the surveys should also pay attention to [possible] equipment faults and structural damage, which are not obvious on visual inspection or in equipment tests. These could include, among other things, problems and damage caused by freezing as well as the loosening of stones/ rocks or sprayed concrete from the ceilings and walls of rock tunnels, and these must be surveyed, if necessary, by carrying out test drilling or using specialist procedures such as photography or sounding methods.

18.863 Planning of overhaul work

All overhaul work should always be the subject of individual plans for each tunnel, based on thorough inspections and surveys where all structures, equipment, installations and fittings as well as any need for additional space must be taken into account. These plans must be drawn up complying with the provisions in Sections 18.1 to 18.7 in so far as these are applicable.

An increase in the size of the rolling stock, increased speeds as well as provisions for changes in rail track construction and electrification should always be taken into account when drawing up an overhaul plan. Unless the tunnel's cross-sectional area is enlarged, the possibility of increasing the number of pressure equalization shafts should be considered in order to reduce the problems caused by pressure variations, see Section 18.35.

18.864 Overhaul work

The overhaul work must be carried out in accordance with plans relating to individual work performances. Also, in so far as these are applicable, Sections 18.1 to 18.10, references /1 to 55/ and RAMO's other Parts as well as structural repair guidelines must be complied with.

18.87 Quality assurance

18.871 Quality systems

Each performer of work is required to have a functional quality system, which is approved by the client for whom the work is carried out.

The organization which is having the railway tunnel built and those responsible for monitoring the work are required to have a functional quality system which is approved by the client for whom the work is carried out and sufficient competence for having the construction work referred to in Section 18.31 built.

18.872 Responsibility, plans and measures

Responsibility for quality assurance, drawing up plans for quality assurance and quality assurance measures must be set out in the construction schedule and in work specifications relating to individual work performances. In addition to these general work specifications and quality requirements relating to each individual work performance /39 to 52/ must be complied with. With regard to HVAC work, the documents to be complied with also include the LVI-RYL and the ST card files.

Each performer of work should draw up and submit to the client for whom the work is carried out a quality assurance plan as the work is commenced.

18.873 Verification of compliance

Each performer of work should at their own expense obtain all the certificates and test results mentioned in the contractual documentation, which are necessary to verify the compliance of the completed work with all the requirements. These must be compiled in the form of a compliance document which must be presented to the client for whom the work is carried out not later than on the occasion of the acceptance inspection.

In addition to the test results and certificates it is required that all the information relating to the building materials and equipment and the performance of work that may be of importance later on when establishing the properties of the structures, be entered, work phase by work phase, in the compliance document.

The quality assurance plan and reports on the implementation thereof must be attached to the compliance document.

18.88 Taking into account environmental requirements

The environmental effects of the construction work must be taken into account by complying with the provisions of the following documents:

- The Environmental Program by the RHK (the Finnish Rail Administration Board)
- Possible requirements and restrictions imposed on the construction measures in connection with the assessment of environmental effects (YVA)
- The regulations and guidelines given in the survey result analyses and plans for the treatment and protection of perch water and groundwater as well as of various types of soil
- The environmental risk analysis in respect of rock construction work
- Work specifications for each work performance in rock construction plus the RMYTL General work specifications and quality requirements for earthworks in railway construction
- The Safety at Work document.

The performer of the work should carry out the environmental inspections, measurements and protective measures and draw up the reports required by the above-mentioned documents.

18.9 Maintenance of tunnels

The maintenance of railway tunnels is divided into *basic maintenance* and *repair operations*.

The *overhauling* of railway tunnels is a construction operation and it is discussed separately in Section 18.8.

18.91 Basic maintenance

18.911 Objectives of and responsibility for maintenance

The objectives of railway tunnel maintenance are:

- Awareness of the condition of the tunnels and documentation of this
- To ensure the operating condition of the tunnels and the safety of traffic
- Prevention of dilapidation.

The maintenance contractor should draw up a basic maintenance guide separately for each tunnel. This guide must consist of the following documents:

- Contact particulars of the maintenance contractor and persons with responsibility
- A set of general drawings and specialized drawings of the railway tunnel, to the extent that these are required
- The final list of drawings and work specifications for all individual work performances included in all the plans
- Description of the plan as specified in Section 18.349
- Functional diagrams and technical data for the tunnel's equipment and installations
- Action plans for exceptional situations
- Operating, servicing, maintenance and inspection instructions for the tunnel's equipment and installations as well as regular maintenance cards which should specify the servicing intervals and maintenance operations required
- The compliance document.

The maintenance contractor should keep a management system, which should include not only the above-mentioned information but also details of the condition, continuously updated, and suggestions for measures to be taken. It should be possible to output from this register all the data required for the monitoring of the condition of the railway tunnels and for anticipating the measures that will need to be taken. The data held in this register is the property of the RHK (the Finnish Rail Administration

Board).

18.912 Inspections

The basic maintenance includes the following inspections:

1) Walk-about inspection

During the walk-about inspection of the rail track, a visual inspection of the tunnel structures, equipment and fittings must be carried out.

2) Annual inspection

The annual inspection must be carried out at least once a year. The annual inspection must include all the inspection measures listed in Sections 18.913 and 18.914. The inspector should draw up an inspection report on the annual inspection. The check lists included in Appendices 9 and 10 should be used as an aid.

Where necessary, the annual inspection must be carried out twice a year: one inspection in the summer, preferably after a period of plenty of rainfall in order to discover possible water leaks, and another inspection in the winter after a period of freezing temperatures in order to discover possible snow and freezing problems as well as possible frost damage.

3) Main inspection

The main inspections of railway tunnels must be carried out at intervals of seven (7) years.

The main inspection must be carried out by a skilled tunnel designer with the aid of the necessary specialist designers. The person performing the inspection must draw up an inspection report.

The main inspection must be carried out during rail track reservations and interruptions in the voltage supply, using the necessary technical accessories and measuring instruments.

The chief inspector must define the inspection equipment to be used, separately in each case. All the structures, equipment and fittings of the railway tunnel as well as the operation of the technical systems must be inspected.

A report must be drawn up on the main inspection, which must be forwarded to the RHK (the Finnish Rail Administration Board) and to the maintenance contractor. The report must include details of any faults and defects discovered as well as proposals for measures that need to be taken, together with estimates of urgency and cost. The report must include a statement detailing the condition of the structures and technical systems of the railway tunnel and a prognosis of the future development regarding the tunnel's condition and the future need for renovation. The check lists included in Appendices 9 and 10 should be used as an aid. The report should also include a statement as to whether the basic maintenance has been carried out properly or not.

18.913 Structural inspection measures

With regard to structural parts the inspection must cover:

- Cleanliness and need for cleaning
- Stability, deformations, ruptures, cleavages, fissures and fissure widths
- Condition of water-proofing seals and water leaks
- Condition of thermal insulation and frost damage as well as problems caused by snow and freezing
- Damage to coatings and corrosion
- In the case of tunnels with lining structures, rock interstices and rock surfaces, reinforcement structures and lining structures on the interstice side
- Condition and geometry of the rail track and corrosion on the rail track components.

For the inspections of tunnel mouth structures and other bridge-like structures, RAMO's Section 8 "Bridges" must be complied with.

In addition to filling in the check list in Appendix 9, Inspection form for railway tunnels - structures, a report must be drawn up on the inspection, and where necessary, the report must be accompanied by Appendices in which a report on the results of the inspection, more detailed than the check lists, can be given. In addition to a verbal description of the inspection, photography may be employed as extensively as necessary to complement the report.

18.914 Equipment and fitment inspection measures

With regard to equipment and fittings the inspection must cover:

- Fitment and supporting structures of equipment, in particular any corrosion found on them
- Operation of fans, fire and gate slides (dampers) and control devices
- Distribution boards, rising cables, transformer stations and back-up power supply equipment
- LVIS monitoring equipment, in particular the operation and transmission of alarms
- Lighting units and control of lighting units
- Telecommunication equipment
- Drainage and sewage systems and pumping stations: operation, corrosion, leaks, sealing of valves, operational tests for pumps, sand and oil separators.

In addition to the servicing, maintenance and inspection guideline manual, the inspections must comply with the regulations and guidelines contained in the LVI-RYL and the ST card file.

The procedures and timings of electrotechnical inspections are specified in The Ministry for Trade and Industry resolution KTM 517/1996 as well as in the various regulations issued by Telehallintokeskus (the Telecommunications Administration Agency).

18.915 Basic maintenance measures

The basic maintenance measures include the measures to be taken between repairs or overhaul work and which must be determined on the basis of inspections. The basic maintenance measures ensure that the operating condition of structures and equipment is maintained and that an adequate level of safety is assured. The maintenance routines should be methodical and both technically and economically on a correct level.

The structures must be cleaned with the frequency and as extensively as required on the basis of inspections. The tunnels must be washed during rail track reservations and interruptions in the voltage supply using high-pressure water and at intervals specified on inspection. Plans should be drawn up separately in each case for any other structural maintenance measures as well as for any repairs and overhaul operations to be undertaken.

The equipment must be serviced and overhauled in accordance with the overhauling guidelines. The equipment servicing [and maintenance] operations include, among other things, the following:

- Checking the operation of the emergency telephone
- Servicing of the manual fire extinguishers
- Calibration of measurement [instruments]
- Servicing and testing of fans
- Cleaning of ventilation ducting
- Cleaning of signals and lighting units
- Replacement of lighting units and filters
- Cleaning and servicing of drainage and sewage systems and equipment.

The maintenance contractor should ensure that the necessary monitoring and security operations are carried out.

18.92 Repairs

18.921 Special inspections

A special inspection of some part, equipment or system of the tunnel must be carried out when, during the inspections specified in Section 18.912, it is discovered that there are grounds for carrying out an inspection, which requires special expertise or specialist equipment. A special inspection must also be carried out after each occurrence of a malfunction or an accident. The special inspection must be carried out and a report thereupon to be drawn up by a suitably equipped expert to be appointed separately in each individual case.

18.922 Measures to be taken

Each repair operation must be carried out in accordance with a plan to be drawn up by the expert

separately for each case.

18.10 Documentation

18.101 Documentation of surveys and ADP instructions

The results of the surveys must be handed over to the client for whom the work is carried out, in both written (hard copy) and digital forms. The client must specify the format and the number of the hard copy sets. The digital documentation should be in the format specified by the client.

For all surveys and measurements carried out, the coordinate and altitude (height) systems used must be indicated.

18.102 Documentation of plans/designs and as-built drawings and ADP instructions

The plans, any amendments and addenda made to them, and the as-built drawings must be handed over to the client for whom the work is carried out, not later than at the time of the acceptance inspection, in both written (hard copy) and digital forms. The client must specify the format and the number of the hard copy sets. The format of the digital documentation should be agreed with the client separately in each case.

18.103 Documentation of documents and ADP instructions

The documents must be handed over to the client for whom the work is carried out, in both written (hard copy) and digital forms. The text must be typed using the word processing software specified by the client and in accordance with the typing instructions provided separately by the client.

The compliance document as well as the servicing, maintenance and inspection instruction manual for the equipment must be handed over to the client in the format to be agreed separately in each case.

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