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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Managing active electronics in the outside plant

Recommendation ITU-T L.70

ITU-T

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Managing active electronics in the outside plant

Summary

Recommendation ITU-T L.70 refers to the application of active electronics in outdoor environments. It covers mechanical and environmental protection as well as electrical powering and cooling. It also pays attention to maintenance, security and environmental aspects.

Source

Recommendation ITU-T L.70 was approved on 6 November 2007 by ITU-T Study Group 6 (2005-2008) under Recommendation ITU-T A.8 procedure.

FOREWORD

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Introduction

In order to obtain maximum reliability at a minimal cost, network electronics are generally centralized in locations with controlled environments. This is also typical for the initial lay out of copper networks for plain old telephone service (POTS). However, with the increasing demand for connections and bandwidth, operators often face the need to apply active electronics at remote locations. These active nodes cannot always be located inside buildings. This Recommendation focuses on the aspects of active electronics, located at outside plant locations.

Active network nodes in outside plant have a number of characteristics that make their design and maintenance more complex than that of passive nodes:

– active nodes perform a transformation between input and output signal;

– active nodes require electrical powering;

– active nodes dissipate heat.

Recommendation ITU-T L.70

Managing active electronics in the outside plant

1 Scope

This Recommendation lists the elements to consider when applying network electronics in outside plant locations (both in above ground and in underground applications):

– mechanical and environmental protection and related sealing requirements;

– thermal management;

– electrical powering;

– safety and environmental aspects;

– maintenance aspects.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.34] Recommendation ITU-T K.34 (2003), *Classification of electromagnetic environmental conditions for telecommunication equipment – Basic EMC Recommendation*.

[ITU-T K.35] Recommendation ITU-T K.35 (1996), *Bonding configurations and earthing at remote electronic sites*.

[ITU-T K.44] Recommendation ITU-T K.44 (2008), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation*.

[ITU-T K.45] Recommendation ITU-T K.45 (2008), *Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents*.

[ITU-T K.48] Recommendation ITU-T K.48 (2006), *EMC requirements for telecommunication equipment – Product family Recommendation*.

[ITU-T K.50] Recommendation ITU-T K.50 (2000), *Safe limits of operating voltages and currents for telecommunication systems powered over the network*.

[ITU-T K.51] Recommendation ITU-T K.51 (2000), *Safety criteria for telecommunication equipment*.

[ITU-T K.55] Recommendation ITU-T K.55 (2002), *Overvoltage and overcurrent requirements for insulation displacement connectors (IDC) terminations*.

[ITU-T K.64] Recommendation ITU-T K.64 (2004), *Safe working practices for outside equipment installed in particular environments*.

[ITU-T K.65] Recommendation ITU-T K.65 (2004), *Overvoltage and overcurrent requirements for termination modules with contacts for test ports or SPDs*.

[ITU-T K.69] Recommendation ITU-T K.69 (2006), *Maintenance of protective measures*.

[ITU-T L.51] Recommendation ITU-T L.51 (2003), *Passive node elements for fibre optic networks – General principles and definitions for characterization and performance evaluation*.

[IEC 60529] IEC 60529 (2001), *Degrees of protection provided by enclosures (IP Code)* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/026766>.

[IEC 60950-1] IEC 60950-1 (2005), *Information technology equipment – Safety – Part 1: General requirements*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/035320>

[IEC 60950-21] IEC 60950-21 (2002), *Information technology equipment – Safety – Part 21: Remote power feeding*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/029602>

[IEC 62262] IEC 62262 (2002), *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/028473>

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 IP 55 [IEC 60529]: Enclosures protected against dust and resistant to jets of water.

3.1.2 IP 68 [IEC 60529]: Enclosures suitable for permanent submersion.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 active electronics: Electronics requiring a source of electricity (other than the actual signal) in order to execute its function.

3.2.2 active node: Network node, including active electronics as well as the packaging required to protect it sufficiently from external influences as they occur in the environment in which it resides.

3.2.3 temperature-hardened equipment: Electronic equipment that has been designed or adapted to operate in outdoor temperature conditions (e.g., from –40°C to +65°C).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DSLAM	Digital Subscriber Line Access Multiplexer
EMC	Electromagnetic Compatibility
IDC	Insulation Displacement Connector
IP	Ingress Protection (rating)
OA	Outdoor Above ground level (aerial)
OG	Outdoor Ground level
OS	Outdoor Below ground level (subterranean)
SPD	Surge Protective Device

5 Packaging for environmental and mechanical protection

Any node in the outside plant needs to be packaged properly to protect its content from the influences of the environment.

5.1 Environments

Active nodes in outside plant may be located in three typical locations:

– OA: Outdoor above ground level (aerial), mounted on a wall or pole or hanging from an aerial cable.

– OG: Outdoor at ground level, stored in a cabinet or pedestal, standing on the ground, with a base that may reside partially underground.

– OS: Outdoor below ground level (subterranean), stored in an underground man-hole, hand-hole or directly buried.

The typical properties of these environments can be found in Annex A.

Compared to passive network nodes (e.g., as described in [ITU-T L.51] on passive optical nodes), a certain amount of heat is generated inside the enclosure by the electronics. Hence, a more detailed approach concerning operating temperatures is required. This is covered in more detail in clause 6 and in Appendices I and II.

5.2 Sealing against ingress of solids and fluids

For nodes above or at ground level (OA and OG), the minimum recommended protection level against ingress of objects and water is IP 55 according to [IEC 60529] (protected against dust and resistant to jets of water).

For nodes at ground level (OG), it is recommended to provide a separation plate with cable entrance seals to avoid intrusion of dirt, water, rodents or insects via the bottom.

For nodes below ground level (OS), the recommended sealing level is IP 68 according to [IEC 60529] (suitable for permanent submersion). Required submersion depth should be at least 1 m above the top of the enclosure, but may be more if applied in deep manholes (in this case, the maximum required submersion depth is to be agreed explicitly between user and supplier in order to obtain proper sealing performance and structural strength).

5.3 Resistance to aggressive agents

The enclosure containing the electronics should be resistant to the most common aggressive agents as they may occur in the outdoor environments.

For all outdoor environments (OA, OG and OS):

– all materials (metals) should be resistant to corrosion;

– all materials should be resistant to micro organisms (fungi/bacteria).

For nodes above or at ground level (OA and OG):

– all external (polymeric) materials, including surface coatings, should be resistant to UV radiation.

For underground nodes (OS):

– all external materials should be resistant to accidental exposure chemical agents that may occur in underground along side roads, such as oil, diesel, kerosene, acids, bases and surfactants (detergents).

5.4 Mechanical protection

The enclosure should be resistant to the mechanical loads and influences that it may encounter in the outdoor environment.

For nodes above or at ground level (OA and OG):

– a minimum recommended protection level against impact of IK 10 according to [IEC 62262];

– the enclosures, including fixation system, should resist loads induced by wind.

For underground nodes (OS):

– Enclosure should be resistant to accidental impact from above.

– Enclosure should be resistant to a static load on top equivalent to the weight of at least one installer.

– Node should be resistant to vibration and shock.

– Cables must be properly attached to resist axial tension, flexure and torsion loads that may occur during typical installation and maintenance.

6 Thermal management

The temperature inside the enclosure (T_{inside}) must be kept within the operational temperature range of the electronics.

6.1 Thermal model

The temperature inside an above ground active enclosure will be determined by a number of factors:

– the air temperature of the environment (T_{air}) (as measured in a thermometer hut);

– solar radiation;

– the heat dissipated by the electronics (Q);

– the construction of the enclosure.

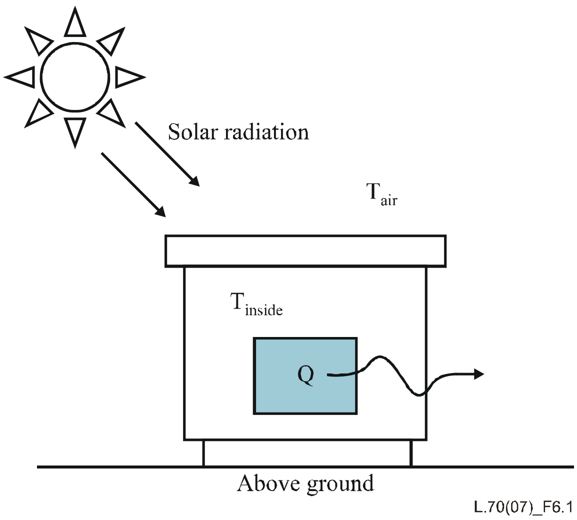

Figure 6-1 – Above ground active node

For underground nodes, a similar model is applicable, however, there will be no direct solar exposure to the enclosure, while the dissipated heat is transferred via the hand-hole and the surrounding soil.

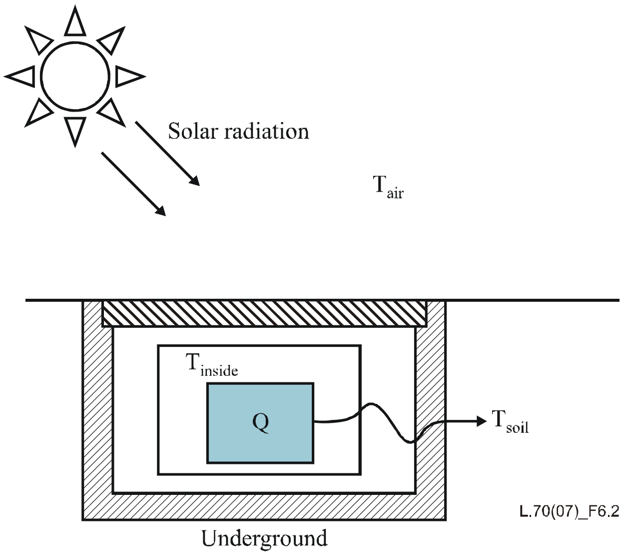

Figure 6-2 – Underground active node

6.2 Operational temperature range of the electronics

Electronic equipment is typically qualified to an operational temperature range of 0°C to +40°C, corresponding to an indoor controlled environment. Applying this type of equipment in outdoor enclosures would require extensive climatic control provisions, increasing initial investment as well as operational cost.

For outdoor applications, it is recommended to use "temperature-hardened equipment" with an operational temperature range of at least –40°C to +65°C, unless there is a different agreement between a manufacturer and a user.

6.3 Enclosure design

The thermal design of the enclosure for active equipment should be selected, taking into account operational temperature, climate and amount of heat to be dissipated as well as economical aspects such as initial investment and operating cost. Therefore, it is recommended to observe the following parameters:

– minimize the effect of solar radiation on internal temperature;

– minimize the extra power required for thermal management;

– consider a modular approach that allows scope to increase cooling capacity when upgrading to more powerful equipment;

– minimize the need for maintenance due to thermal management features.

The most common thermal designs of enclosures for active electronics are described in Appendices I and II.

7 Electrical powering

The electronics of an active node need to be powered with electricity. This can be achieved via different methods.

The required total power budget should take into account:

– net power required to operate the equipment(s);
– efficiency of power converters (losses in transformers, AC/DC or DC/DC converters);
– power required for thermal management of the node (fans, coolers, heaters);
– safety margin for future node expansion.

7.1 Connection to the power grid

In most cases, active nodes are connected to the power grid:

– Metered: power consumption is paid according to actual usage.
– Flat fee: meaning that a fixed yearly amount is paid to the power supplier. In this case, the space for the meter can be saved and meter-reading is not required.

7.2 Remote line powering

Another option is to provide power via the existing copper pairs that are present in the telecommunication network cables. Hereby, powering of the nodes becomes independent of the power grid. It can benefit from the backup power of the central office, by which the use of remote batteries may be avoided.

The principle is shown in Figure 7-1.

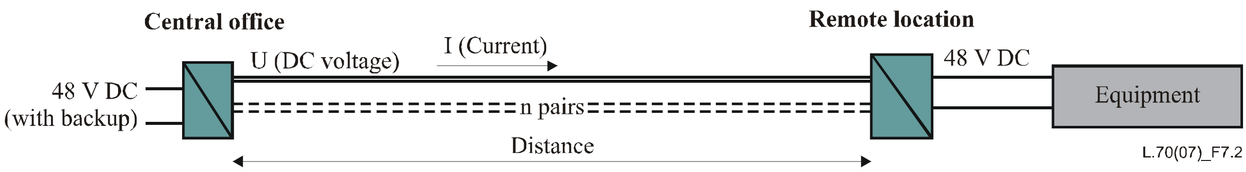

Figure 7-1 – Remote line powering

Power is taken from the DC power system in the central office, converted to a higher voltage and transported via a number of available copper pairs. Hereby power losses in the copper wires can be reduced drastically by decreasing the electrical current in the pairs. At the remote node, the power is converted back to the proper voltage to operate the equipment. This way, electrical power levels up to 500 watts or more can be transported over several kilometres, using a limited number of pairs.

Requirements for equipment using remote line powering are described in [ITU-T K.50], [ITU-T K.51] and in [IEC 60950-21].

7.3 Backup power

For certain applications, it may be necessary to maintain service in case of power outage. Power backup may be obtained by:

– batteries;
– connection to two or more independent electrical feeder loops (redundancy);
– remote line powering (relying on the backup system of the central office).

8 Maintenance aspects

In general, remote active nodes require more maintenance effort than passive outdoor nodes or active equipment in central offices. The main reasons for the more intensive maintenance are:

– limited lifetime of the equipment and moving parts (e.g., fans);

– potential pollution of ventilation systems;
– temperature excursions that have a negative effect on the lifetime of equipment and batteries;
– damage (accidental or intentional; see clause 9).

Compared to centralized electronics, the cost per maintenance intervention will be higher due to the required travel time. In order to minimize the need for maintenance interventions, the following design features and practices are recommended:

– minimum lifetime of fan and equipment should be five years;
– avoid forced ventilation when possible;
– apply multiple fans in parallel (redundancy);
– mount air intake of ventilation systems away from the ground to reduce risk of pollution (e.g., in the "roof" of the enclosure);
– apply air filter types with a minimum need for maintenance or replacement;
– avoid the application of active cooling ("chillers") unless absolutely necessary;
– minimize the need for intervention related to the powering of the node (e.g., resetting of safety switches or fuses, meter reading, battery breakdown, etc.);
– apply a maintenance plan (e.g., annual, bi-annual, etc.) to execute a number of standard activities that will prevent sudden breakdown due to deterioration of the node (e.g., battery replacement, filter replacement, fan replacement, cleaning, etc.);
– apply remote monitoring of critical parameters such as internal temperature, humidity level, fan status, open door contacts, etc.

For maintenance of protection components [ITU-T K.69] shall be followed.

9 Safety and environmental aspects

9.1 Electrical safety

[IEC 60950-1] is a basic reference for safety of telecommunications equipment. In all cases, active nodes must comply with locally applicable electrical safety requirements. This may include electrical insulation, grounding, fuses, current loss switches, etc.

If backup batteries are applied, it is recommended to store them in a separate compartment and provide a vent to evacuate hydrogen gas.

In case remote line powering is applied, it should comply with [ITU-T K.50], [ITU-T K.51] and [IEC 60950-21].

The safe working practices described in [ITU-T K.64] shall be followed when work is carried out on outside plant electronic equipment.

9.2 Vandalism and accidental damage

As remote nodes reside in the outside plant, they are exposed to accidental or deliberate damage.

Traffic is the main cause of accidental damage.

For above ground nodes, the design of the enclosure should allow repair or replacement without the need to shut down the node.

The application of underground nodes may decrease the risk of accidental damage by traffic.

For certain locations, extra resistance to vandalism and unauthorized intrusion may be recommended. This can be obtained by applying stronger materials and construction as well as eliminating protruding parts or openings on the outside of the enclosure. The application of a door sensor to monitor access of the enclosure is also recommended.

It is recommended to minimize the risk of blocking the air intake openings (e.g., due to application of stickers or publicity posters) by the design of the enclosure.

9.3 External temperature

The presence of the active equipment should not significantly increase the temperature (e.g., <5°C) of the outer surfaces of above ground enclosures, when compared to the surface temperatures that would occur for these enclosures without an active equipment present.

9.4 Acoustical noise

Especially when fans are applied for thermal management, active nodes may generate a certain level of noise. Maximum noise level should be as low as possible and comply with local regulations.

Fan speed may be reduced when maximum cooling capacity is not required.

9.5 Physical obstruction and visual integration in the environment

Active nodes can be rather large and hence cause physical obstruction when applied above ground.

Above-ground enclosures may also be perceived as visually disturbing.

Therefore, it is recommended to select the location, shape, size and colour of the enclosure to disturb as little as necessary. Underground enclosures may be a good alternative in certain cases.

9.6 Electromagnetic compatibility

9.6.1 Environmental EMC classification

Active nodes should not be a source of undesired electromagnetic emission. Electronic equipment should meet the requirements of [ITU-T K.48]. In any case, all regional or local regulations are to be applied.

The environmental class of active nodes is class 3 (outdoor locations), as defined in [ITU-T K.34]. According to [ITU-T K.34], the enclosure is not assumed to shield against electromagnetic effects. However, in certain conditions it may be recommended to apply enclosures that provide complete electromagnetic shielding (metal). In this case, enclosure doors and covers should be provided with electromagnetic seals.

9.6.2 Earthing and bonding

The bonding conditions and earthing of outside plant electronic nodes shall follow [ITU-T K.35].

9.6.3 Resistibility (overvoltage/overcurrent conditions)

Equipment installed in outside plant electronic nodes shall meet the requirements of [ITU-T K.45]. [ITU-T K.44] describes the resistibility test setups to be used.

If insulation displacement connectors (IDCs) are used inside the electronic enclosure, they shall meet the requirements of [ITU-T K.55]. If protection components such as surge protective devices (SPDs) are used, termination modules shall meet the requirements of [ITU-T K.65].

Annex A

Environmental classification

(This annex forms an integral part of this Recommendation)

For outdoor nodes, three environmental classes cover the majority of the applications around the globe. This annex describes these environmental classes in detail.

This classification is similar to that used for passive nodes [ITU-T L.51] except from a thermal point of view: active electronics will dissipate heat inside the enclosure. Therefore, elements contributing to the temperature of the node are to be considered in more detail.

A.1 Basic outdoor environmental classes

OA (outdoor above ground)

– All outdoor non-sheltered locations, above ground level.

– No external sources of heat or extreme temperatures other than the surrounding air or solar radiation.

– Exposed to contaminants and dust that may occur in the atmosphere in rural, city or industrial areas (e.g., wall-mounted, pole-mounted, strand-mounted nodes).

OG (outdoor ground level)

– Outdoor, standing on the ground, perhaps with a base that resides partially below the ground; this class may also apply to outdoor wall-mounted products which are close to ground level.

– Exposed to contaminants and dust that may occur in the atmosphere in rural, city or industrial areas; the base of the product may be permanently in contact with soil, biological and chemical contaminants that occur at or just below ground or street level (e.g., along roads, pavements and railroads).

OS (outdoor underground)

– Outdoor below ground level.

– Exposed to soil or water-borne contaminants, including organic and inorganic agents related to the presence of roads and traffic (e.g., in manholes, hand-holes or even directly buried).

A.2 Special conditions

Extreme

– Any environment for which at least one of the environmental parameters exceeds the boundaries of the three basic environmental classes as specified above, e.g., more extreme temperature excursions.

– Exact test settings are to be agreed between supplier and customer.

Additional requirements

– In specific cases, extra constraints may be required on top of the conditions of one of the basic environmental classes (e.g., bullet resistance, flooding resistance, etc.). This is not included under the term "extreme" conditions: for these occasions, additional requirements or tests can be added.

Table A.1 – Summary of typical parameters for the outdoor environmental classes

	Outdoor		
	OA	**OG**	**OS**
Exposure ↓	**Above ground**	**Ground level**	**Underground**
T_{air} Min (°C) (Note 3)	–40	–40	–30
T_{air} Max (°C) (Note 3)	+45	+45	+45
Solar radiation	Yes (up to 1120 watt/m²)		No
Relative humidity (max) (%)	100% (occasional/permanent exposure to water possible)		
Precipitation	Rain, snow, etc.	Rain, snow, etc.	NA
Submersion	No	No (Note 2)	Yes
Vibration	5-500 Hz 10 m/s² (~1g) (due to, e.g., traffic, wind, etc.)		
Chemical	Atmospheric (Note 1)	Atmospheric soil (base only) (Note 1)	Soil/waterborne
Biological	Atmospheric	Atmospheric soil (base only)	Soil/waterborne

NOTE 1 – In areas where corrosive atmospheres can be expected (marine and coastal areas, industrial areas, urban pollution), increased corrosion protection may be requested as an additional requirement.

NOTE 2 – If accidental flooding may occur, this is to be added as a conditional requirement. This will also correspond to a higher IP rating according to [IEC 60529].

NOTE 3 – For active nodes, air temperature (as measured in a thermometer hut) is to be considered separate from solar radiation effects. For passive nodes, these effects are generally combined, resulting in a higher maximum temperature for the node.

Appendix I

Thermal design of above ground enclosures

(This appendix does not form an integral part of this Recommendation)

The most typical designs for thermal management of above ground outdoor enclosures are listed in this appendix, with their typical properties. The thermal design of the enclosure is to be chosen as a function of various parameters such as:

– surrounding environment and climate;
– dissipated power level of the equipment;
– maximum operating temperature of the equipment;
– size of the enclosure;
– future expandability;
– power consumption;
– etc.

I.1 Single wall, natural convection

The most simple enclosure type for housing active electronics would be a single wall box or cabinet, without any specific features for thermal management. Heat is transferred via natural convection along the inside and outside of the enclosure walls.

The outer walls are exposed to solar radiation and a significant amount of solar energy is transferred to the inside of the closure, increasing temperature.

This cooling method does not require extra energy and is maintenance-free.

Internal temperature will rise at least 15-20°C above external air temperature.

NOTE – "At least" means that on a day with intense sunshine, the temperature inside the enclosure will be 15°C or more above the temperature of the surrounding air, even if thermal dissipation inside the enclosure is minimal. E.g., in a passive single wall cabinet, the temperature will rise to about 55°C while the surrounding air is at 40°C.

Due to poor thermal management properties, this design is not recommended for active nodes.

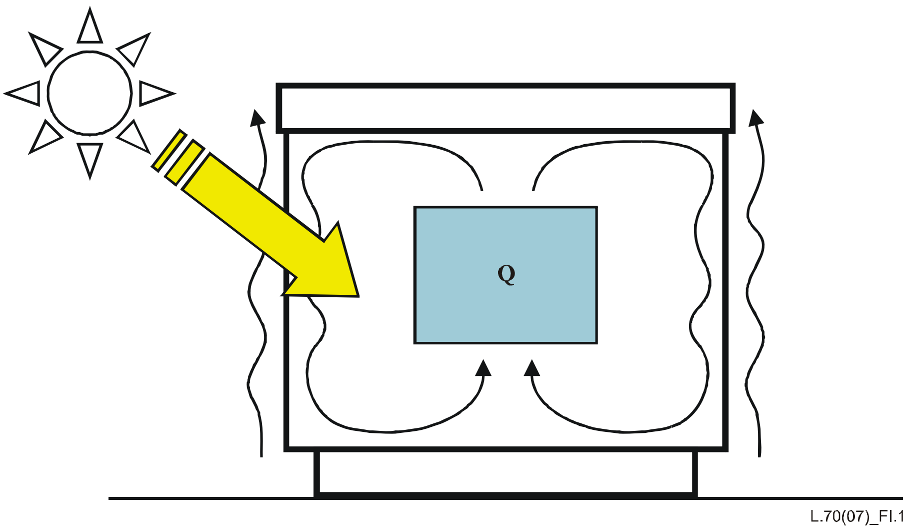

Figure I.1 – Single wall, natural convection

I.2 Vented dual wall, natural convection

By applying a double wall construction, the effect of solar load on internal temperature can be reduced. The space between the inner and outer wall must be vented in order to evacuate both the heat generated by solar radiation as well as by the equipment by natural convection. When properly dimensioned, a "chimney-effect" will be created, increasing effectiveness of the cooling.

This enclosure design combines the advantages of effective thermal management at a low operating expense (no extra energy for cooling and virtually maintenance free).

Internal temperature will be at least 7-8°C above external air temperature.

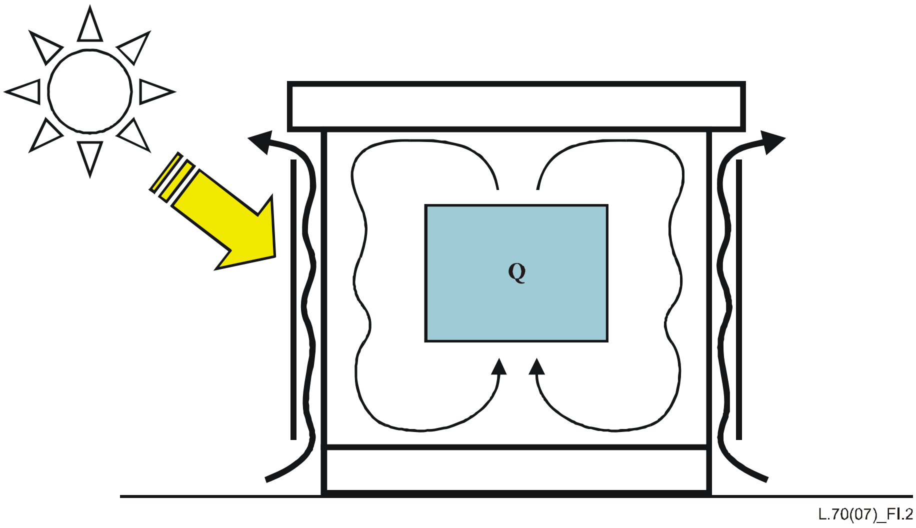

Figure I.2 – Dual wall, natural convection

I.3 Forced convection

Increasing airspeed and airflow will make heat transfer to the environment even more effective.

Inside the enclosure, this may be obtained by fans, separate from or integrated into the electronics units. Outside, air can be forced through the dual wall construction. Preferably, the air is circulated top-down, to avoid aspiration of dirt or sand particles from the ground.

The extra fans in the enclosure will require about 10-20% extra electrical power, on top of the energy to operate the actual equipment.

Recommended fan lifetime is at least five years to minimize fan maintenance.

Fan speed may be regulated as a function of internal temperature. This would increase fan lifetime and decrease power consumption.

Internal temperature will be at least 7-8°C above external air temperature.

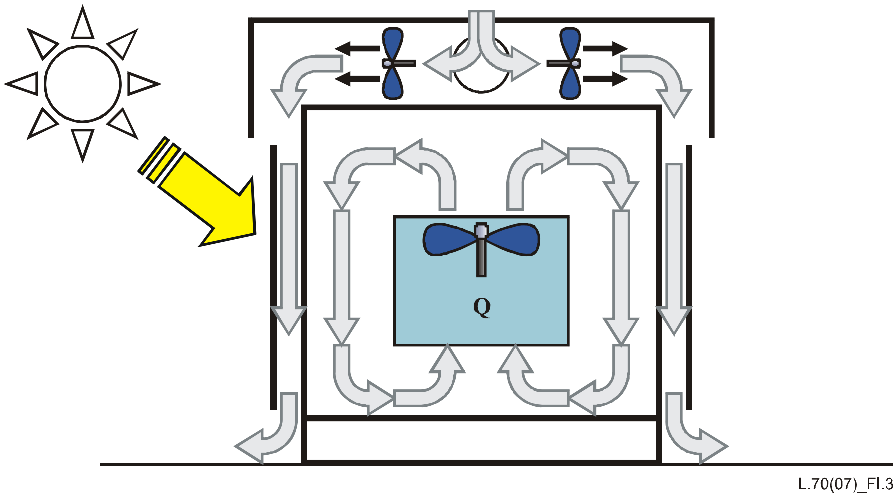

Figure I.3 – Dual wall, forced convection

I.4 Air-to-air heat exchangers

Cooling by forced convection can still be improved by applying heat exchanger elements. Heat exchangers increase the effective contact surface for cooling.

The fans of the heat exchanger will typically require 15-30% extra electrical power for cooling.

Heat exchangers should respect the IP 55 sealing level to avoid exchange of external air and intrusion of dust or moisture into the enclosure. The external circuit of the heat exchanger should be designed to minimize dust or dirt build up, that would result in early deterioration of cooling capacity and the related need for maintenance.

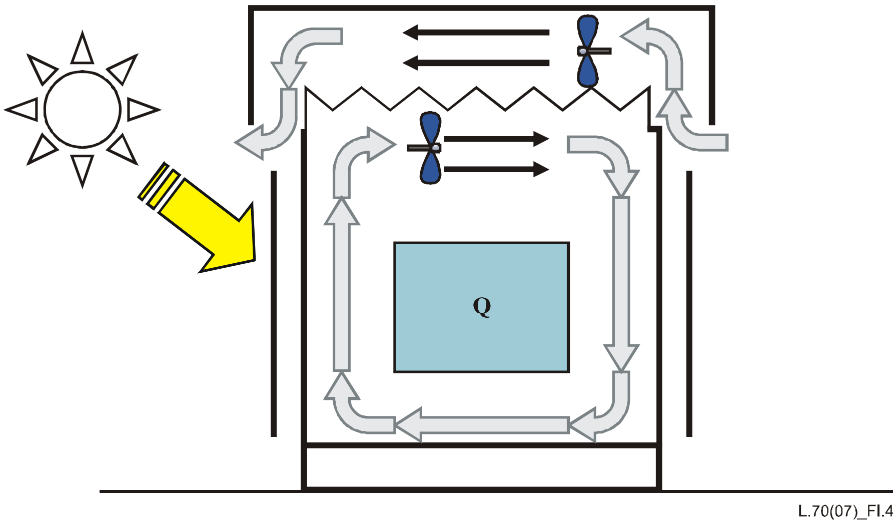

Figure I.4 – Dual wall, heat exchanger

I.5 Natural and forced ventilation

For the cases described in clauses I.1 to I.4, the air is constantly re-circulating inside the enclosure. The heat is transferred from the air inside to the air outside through the walls of the enclosure.

By blowing external air directly into the enclosure, a more effective heat transfer can be achieved, resulting in a smaller temperature difference compared to the external air.

Ventilation by free convection is sometimes applied to improve heat transfer in single wall cabinets; however, it is difficult to achieve a proper sealing level for this method. Adding sealing filters would obstruct the rather weak airflow. Therefore, this layout is not recommended for active nodes.

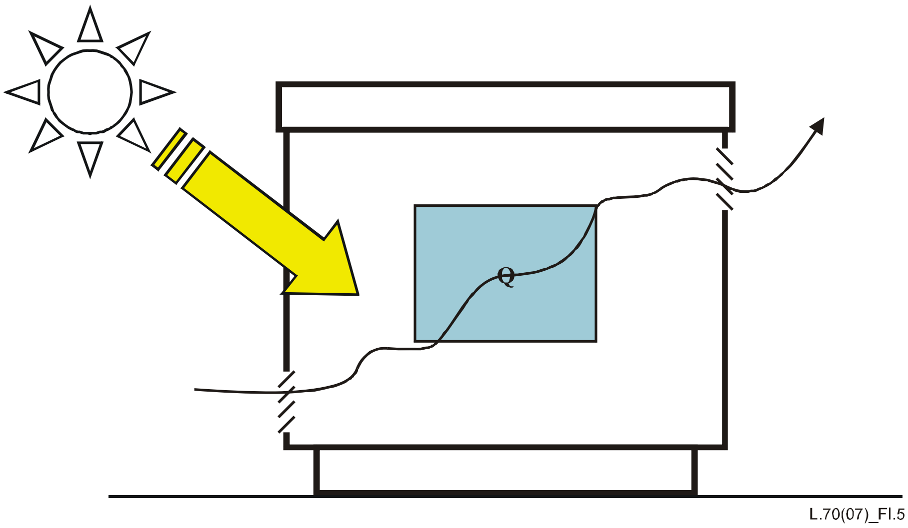

Figure I.5 – Single wall, ventilation by natural convection

The most appropriate method for cooling by ventilation is the use of fans and filters. This is the combination of a fan, driving the external air in and out of the enclosure, with a filter system that prevents intrusion of dust, insects and liquid water. Filter design with minimal need for regular cleaning or replacement is recommended.

Even when applying IP 55 filters, the air flow will contain water vapour.

Sufficient resistance to corrosion of the equipment is also to be considered.

Filter fans will require about 10-30% of extra electrical power for cooling.

Internal temperature will be at least 3-5°C above external air temperature.

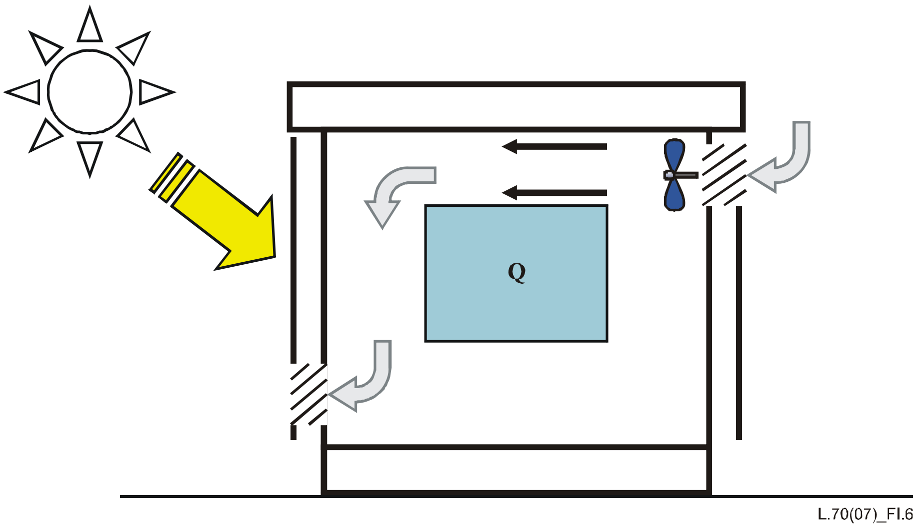

Figure I.6 – Dual wall, forced ventilation (filter fans)

I.6 Active cooling ("chillers")

All above methods move heat from the warmer interior to the cooler environment. The temperature inside the enclosure will always be higher than the surrounding air. For certain types of equipment, e.g., when using indoor equipment, it may be required to maintain operating temperatures below the maximum ambient air temperature. This can only be obtained by applying active cooling devices (chillers). These devices are able to "pump" heat from a cooler to a warmer environment (as in a refrigerator or air conditioner).

About 40-70% of extra electrical power is required to power the cooling unit and its fans. These units will also require more space and more frequent maintenance than the above solutions.

Practically, active cooling is therefore only recommended for specific applications, in extreme conditions or in very large nodes, where the investment and operating expense can be shared over a large number of subscriber lines (operating cost to be compared to a small building).

Internal temperature can be maintained up to 20°C or more below external air temperature.

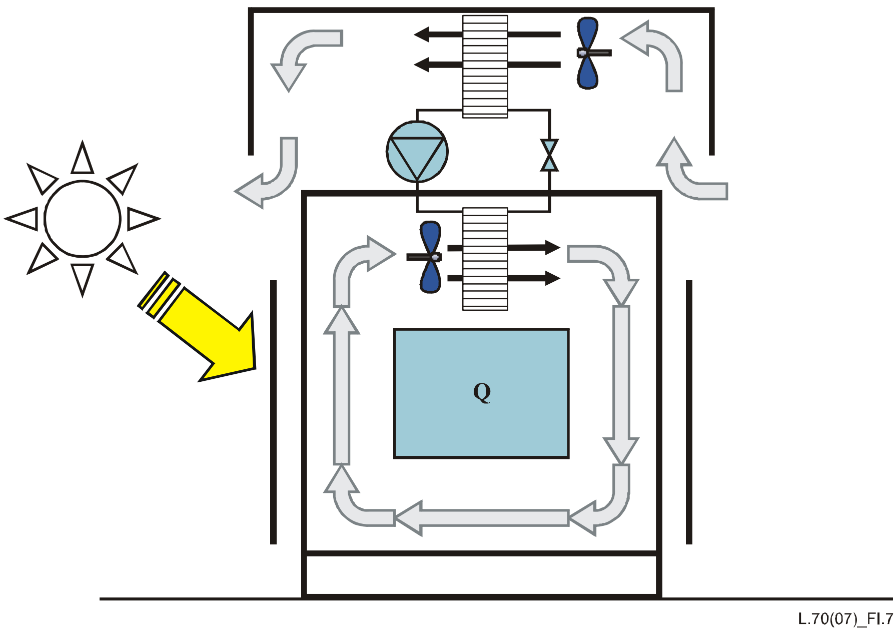

Figure I.7 – Active cooling

I.7 Heaters

In some cases, it is recommended not only to manage the maximum temperature but also the minimum temperature range inside an enclosure:

– maintain minimum operating temperature of the equipment (operating temperature ranges for equipment starting at 0°C are still very common);
– obtain minimum temperature before (cold) start of the equipment;
– avoid condensation inside the enclosure.

Appendix II

Thermal properties of underground enclosures

(This appendix does not form an integral part of this Recommendation)

This appendix lists the most typical designs for thermal management of underground outdoor enclosures, with their typical properties. Here, only designs are considered that have no above ground elements.

II.1 Free or forced convection inside

The most simple design for an underground active node is to store the node in a single wall, sealed enclosure inside a hand- or manhole. Air inside the enclosure will circulate due to natural or forced convection. Fans are often an integrated feature of the electronic equipment.

The heat is transferred through the walls of the enclosure to the air inside the manhole, and then further to the walls of the hand-hole into the surrounding soil.

In case the manhole fills up with water (partially or completely), the heat will be transferred through convection in the water. In this mode, heat transfer is more effective than in a dry manhole.

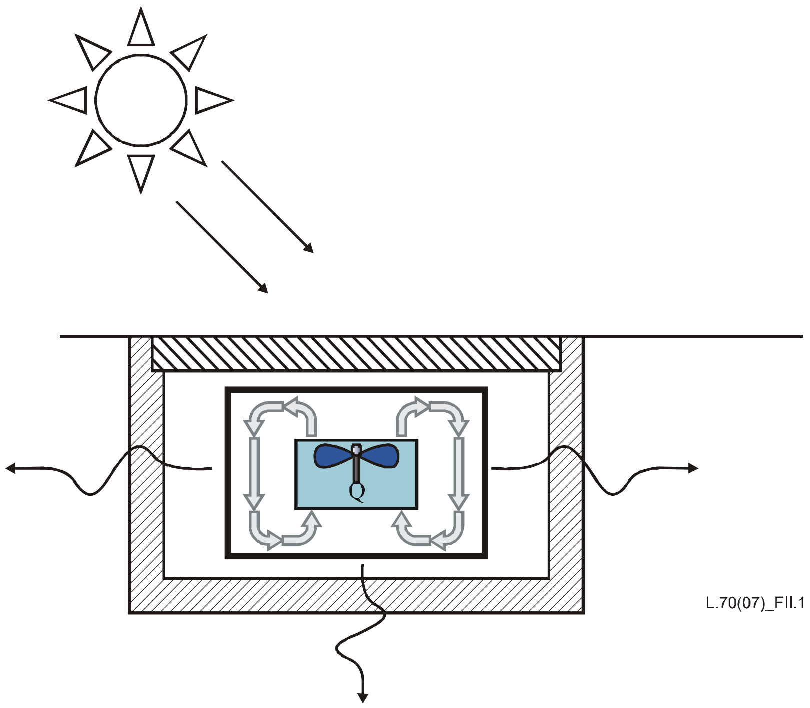

Figure II.1 – Forced convection inside

II.2 Heat exchanger

If more or better heat transfer is desired, a heat exchanger may be added. More effective heat transfer is obtained by higher airspeeds and increased contact surface area. The forced convection on the outside of the enclosure will also increase airspeeds in the hand-hole, with a positive effect on heat transfer. The heat exchanger design should maintain the IP 68 sealing level of the enclosure. External fans should be protected or even shut down when the hand-hole fills with water.

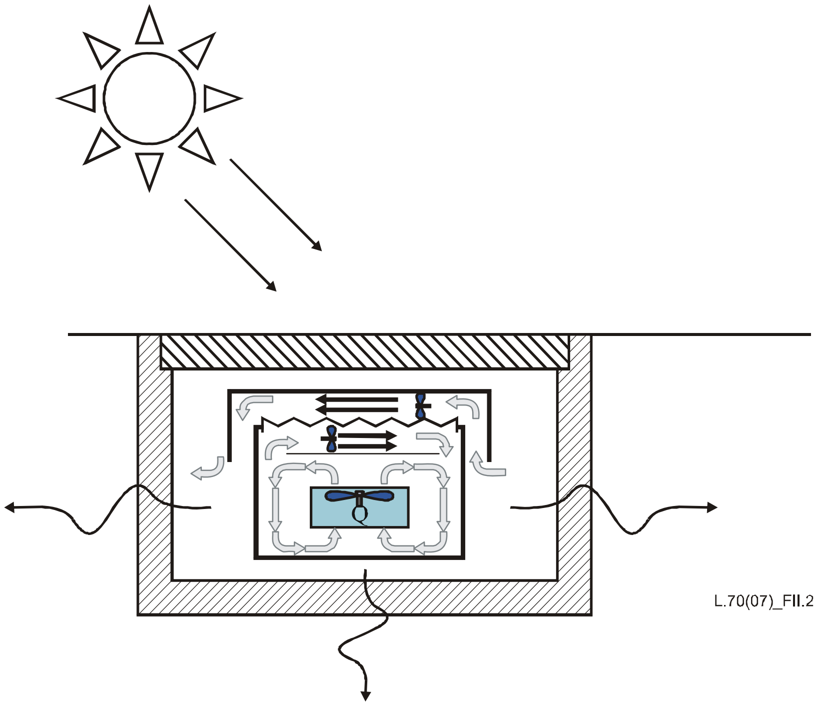

Figure II.2 – Heat exchanger

Appendix III

Example of performance specification for active street cabinets (ground level and above ground, OG and OA)

(This appendix does not form an integral part of this Recommendation)

III.1 Evaluation criteria

Performance criteria	Method and conditions		International standard/reference	Requirements
Performance criteria references				
Visual examination	Examination of the product with the unaided eye		[b-IEC 61300-3-1]	No defects which would adversely affect product performance Coating shall not disbond or show cracks
Tightness	Test temperature:	(23 ± 3)°C	[IEC 60529] Test condition for second numeral 5	No visual water ingress in splice compartment and equipment
	Internal diameter of nozzle:	6.3 mm		
	Spray medium:	Tap water		
	Flow rate:	12.5 l/min ± 5%		
	Water pressure:	Adjusted to achieve specified flow rate.		
	Core size of stream:	40 mm diameter at 2.5 m from nozzle		
	Distance to sample:	between 2.5 m and 3 m		
	Sample position:	as installed in use		
	Duration:	One minute per square metre of cabinet surface, but not less than 3 minutes in total		

III.2 Test program

Test	Method and conditions		International standard/ reference	Performance criteria
Mechanical tests				
Wind resistance	Force: Point of application: Direction: Duration:	F = 0.15 × W (cm) × H (cm) Most extreme point located away from fixation points In the axis that will generate the highest couple, performed in both directions. 5 seconds	None	No overturning of cabinet
Shock	Severity: Duration: Wave form: Number of shocks: Axes:	10 g (100 m/s²) 11 milliseconds Half sine 3 up and 3 down 3 mutually perpendicular	[b-IEC 60068-2-27] Test Ea	Visual examination Tightness
Vibration	Sweep range: Cross-over frequency: Amplitude <9 Hz: Acceleration >9 Hz: Axes: Duration: Configuration:	(5-500) Hz at 1 octave/minute 9 Hz 3.5 mm 10 m/s² (~ 1 g) 3 mutually perpendicular 10 cycles/axis Completely filled	[b-IEC 60068-2-6] Test Fc	Visual examination Tightness
Resistance to shotgun blast	Distance: Calibre: Lead pellets:	20 m 12/70 Size number 5 (3 mm)	[b-IEC 60794-1-2] Method E13	Visual examination: no intrusion of pellets; deformation of outer shell allowed

Test	Method and conditions		International standard/ reference	Performance criteria
Climatic tests				
Temperature – humidity cycling	Lowest temperature: Highest temperature: Dwell time: Transition: Humidity: Cycle duration: Number of cycles:	(–40 ± 2)°C (+65 ± 2)°C 3 hrs 1°C/minute 85% RH ± 5% RH at the maximum temperature 8 hrs 20	[b-IEC 61300-2-48]	Tightness Visual examination: – no dripping of condensed water allowed onto electronic equipment and on splicing or patch panel trays – coating shall not disbond or show cracks
Salt spray	Test temperature: Medium: Test duration: Test sample:	(+35 ± 2)°C 5% NaCl in water 5 days Sample with reduced size may be used, having identical sealing, electrical connection and protection features and materials as the actual enclosure	[b-IEC 60068-2-11] Test Ka	Visual examination: Coating shall not disbond or show cracks No signs of corrosion on electromagnetic shielding and grounding connections inside the cabinet No signs of corrosion of metals
Solar radiation – Thermal management	Ambient temperature: Sun load (IR radiation) Maximum air speed in the climatic chamber: Power dissipation: Duration:	(45 ± 2)°C (Note 3) 1120 W/m² 0.1 m/s X watt (Note 1) Until temperature equilibrium	[b-IEC 60068-2-5] Test Sa	Temperature at air intake of electronic equipment in cabinet remains below Y°C (Note 2)
NOTE 1 – Power level X for testing is to be set at the maximum intended dissipated heat for the enclosure. Equipment can be simulated by resistors and fans in a configuration similar to the equipment frame. NOTE 2 – Maximum air temperature Y inside the enclosure should correspond to the maximum operating temperature of the enclosure. For temperature-hardened equipment, this should be a maximum of 65°C. NOTE 3 – For moderate climates, an ambient temperature of 40°C may be applied; to be agreed between customer and supplier.				

Appendix IV

Example of performance specification for underground level (OS)

(This appendix does not form an integral part of this Recommendation)

IV.1 Evaluation criteria

Performance criteria	Method and conditions		International standard/ reference	Requirements
Performance criteria references				
Appearance	Examination with the unaided eye		[b-IEC 61300-3-1]	No defects which will adversely affect product performance
Pressure loss during test	Temperature: Internal pressure: Elapsed time: Pressure measurement	At test temperature (20 ± 2) kPa <12 hrs Before and after test	[b-IEC 61300-2-38] Method B	Difference in pressure before and after the test: ≤ 2 kPa at the same atmospheric conditions
Tightness	Internal pressure: Test time: Depth:	(20 ± 2) kPa 15 minutes Just below water surface	[b-IEC 60068-2-17] Test Qc	No continuous emission of bubbles

IV.2 Test program

Test	Method and conditions		International standard/ reference	Performance criteria to be checked
Mechanical tests (tightness evaluation)				
Axial tension cable	Test pressure: Load/cable: Test time:	(20 ± 2) kPa D/45 ×1000 N (max. 1000 N) 1 hour each cable	[b-IEC 61300-2-4]	Pressure loss during test Displacement ≤ 3 mm Tightness
Cable flexure	Test temperatures: Test pressure: Force: Force application: No. of cycles:	(–15 ± 2)°C and (+45 ± 2)°C (20 ± 2) kPa 30° bending or max. 500 N force 400 mm from end of cable seal 5 per cable	[b-IEC 61300-2-37]	Pressure loss during test Appearance Tightness

Test	Method and conditions		International standard/ reference	Performance criteria to be checked
Impact	Test temperatures: Test pressure: Impact tool: Weight: Drop height: Locations: Number of impacts:	(–15 ± 2)°C and (+45 ± 2)°C (20 ± 2) kPa Steel ball 1 kg 2 m In the centre of the cover (top) 1	[b-IEC 61300-2-12] Method B	Pressure loss during test Appearance Tightness
Re-entries	Number: Aging between each re-entry: Temperature range: Dwell time: Transition: Test pressure:	10 minimum 1 cycle –30°C/+60°C 4 hrs 2 hrs (20 ± 2) kPa regulated	[b-IEC 61300-2-33]	Tightness
Static load	Test temperatures: Test pressure: Load/surface area Time: Position:	(–15 ± 2)°C and (+45 ± 2)°C (20 ± 2) kPa 1000 N/25 cm² 10 min On cover	[b-IEC 61300-2-10]	Pressure loss during test Appearance Tightness
Cable Torsion	Test temperatures: Test pressure: Torque Torque application: No. of cycles:	(–15 ± 2)°C and (+45 ± 2)°C (20 ± 2) kPa Max. 50 Nm or max. 90° rotation 400 mm from end of cable seal 5 per cable	[b-IEC 61300-2-5]	Pressure loss during test Appearance Tightness
Cable Vibration	Test pressure: Frequency: Amplitude: Cable clamping: Duration:	(20 ± 2) kPa regulated (10 ± 1) Hz sinusoidal 3 mm 500 mm from end of cable seal 10 days	[b-IEC 61300-2-1] [b-IEC 60068-2-6] Test Fc	Tightness Appearance

Test	Method and conditions		International standard/ reference	Performance criteria to be checked
Environmental tests (tightness evaluation)				
Resistance to aggressive media	Media:	pH 2, pH 12 Kerosene (lamp oil) Petroleum jelly Diesel fuel for cars	[b-IEC 61300-2-34]	Appearance
	Test time:	5 days	[b-EN 590]	
	Sample configuration:	Sample with reduced size may be applied, having identical sealing, electrical connection, protection features and materials as the actual enclosure		
Resistance to stress cracking	Test temperature:	(+50 ± 2)°C	[b-IEC 61300-2-34]	Appearance No visible cracking
	Medium:	10% Igepal		
	Test time:	5 days		
	Sample configuration:	Sample with reduced size may be applied, having identical sealing, electrical connection, protection features and materials as the actual enclosure		

Functional tightness requirements (continued)[1]

Test	Method and conditions		International standard/ reference	Performance criteria
Environmental tests (tightness evaluation)				
Salt fog	Test temperature Test pressure: Medium: Test time:	(+35 ± 2)°C (20 ± 2) kPa 5% NaCl in water 5 days	[b-IEC 60068-2-11] Test Ka	Tightness Appearance
Temperature cycling	Lowest temperature: Highest temperature: Dwell/transition time: Internal pressure: Number of cycles:	(–30 ± 2)°C (+60 ± 2)°C 4 hrs/2 hrs (20 ± 2) kPa regulated 20	[b-IEC 60068-2-14] Test Nb	Tightness Appearance
Thermal management	Ambient temperature: Sun load: Location: Duration: Power dissipation:	(40 ± 2)°C 1120 W/m² Dry hand-hole 1 week X watt (Note 1)	None	Temperature in closure remains below Y°C (Note 2)
Water head	Column height: Test pressure at RT: Duration:	1 m (or more if required for the application) above cover 0 kPa sealed 7 days	[b-IEC 61300-2-23] Method 2	No water ingress
NOTE 1 – Power level X for testing is to be set at the maximum intended dissipated heat for the enclosure. Equipment can be simulated by resistors and fans in a configuration similar to the equipment frame. NOTE 2 – Maximum air temperature Y inside the enclosure should correspond to the maximum operating temperature of the enclosure. For temperature-hardened equipment this should be a maximum of 65°C.				

[1] All testing is at room temperature unless otherwise stated. RT: Room temperature.

Functional optical requirements

NOTE – The test program below is only applicable if optical cables are terminated in the enclosure.

Performance criteria	Method and conditions		International standard/ reference	Requirements
Performance criteria references (optical evaluation)				
Appearance	Examination of product with the unaided eye		[b-IEC 61300-3-1]	No defects which would adversely affect product performance
Change in attenuation	Source wavelength:	1310 nm and 1550 nm	[b-IEC 61300-3-3]	δIL ≤ 0.3 dB per incoming fibre during the test δIL ≤ 0.2 dB per incoming fibre after the test

Test	Method and conditions		International standard/ reference	Performance criteria to be checked
Mechanical tests (optical evaluation)				
Cable flexure	Force: Force application: No. of cycles:	30° bending or max. 500 N force 400 mm from end of cable seal 5 per cable	[b-IEC 61300-2-37]	Appearance Change in attenuation after the test (residual loss)
ODF handling	Raise ODF Raise MDF		None	Appearance Change in attenuation after the test (residual loss)
Shock	Severity: Duration: Wave form: Number of shocks: Axes:	15 g (150 m/s²) 11 milliseconds Half sine 3 up and 3 down 3 mutually perpendicular	[b-IEC 61300-2-9] [b-IEC 60068-2-27] Test Ea	Appearance Change in attenuation after the test (residual loss)
Cable torsion	Torque: Torque application: No. of cycles:	Max. 50 Nm or max. 90° rotation 400 mm from end of cable seal 5 per cable	[b-IEC 61300-2-5]	Appearance Change in attenuation after the test (residual loss)

Test	Method and conditions		International standard/ reference	Performance criteria to be checked
Vibration	Sweep range: Cross-over frequency: Severity <9 Hz: Severity >9 Hz: Axes: Duration:	(5-500) Hz at 1 octave/minute 9 Hz 3.5 mm 10 m/s² (~ 1 g) 3 mutually perpendicular 10 cycles/axis	[b-IEC 61300-2-1] [b-IEC 60068-2-6] Test Fc	Appearance Change in attenuation after the test (residual loss)
Environmental tests (optical evaluation)				
Temperature cycling	Lowest temperature: Highest temperature: Dwell/transition time: Number of cycles:	(–30 ± 2)°C (+60 ± 2)°C 4 hrs/2 hrs 20	[b-IEC 61300-2-22] [b-IEC 60068-2-14] Test Nb	Appearance Change in attenuation

Bibliography

[b-EN 590] SS-EN 590 (2004), *Automotive fuels. Diesel. Requirements and test methods*. <http://webstore.ansi.org/RecordDetail.aspx?sku=SS-EN+590%3A2004>

[b-IEC 60068-2-5] IEC 60068-2-5 (1975), *Environmental testing – Part 2-5: Tests – Test Sa: Simulated solar radiation at ground level*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/000534>

[b-IEC 60068-2-6] IEC 60068-2-6 (2007), *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/038736>

[b-IEC 60068-2-11] IEC 60068-2-11 (1981), *Environmental testing – Part 2-11: Tests – Test Ka: Salt mist*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/018467>

[b-IEC 60068-2-14] IEC 60068-2-14 (1984), *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/018469>

[b-IEC 60068-2-17] IEC 60068-2-17 (1994), *Environmental testing – Part 2-17: Tests – Test Q: Sealing*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/018471>

[b-IEC 60068-2-27] IEC 60068-2-27 (2008), *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/039106>

[b-IEC 60794-1-2] IEC 60794-1-2 (2003), *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/030610>

[b-IEC 61300-2-1] IEC 61300-2-1 (2003), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-1: Tests – Vibration (sinusoidal)*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/031611>

[b-IEC 61300-2-4] IEC 61300-2-4 (1995), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-4: Tests – Fibre/cable retention*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/019447>

[b-IEC 61300-2-5] IEC 61300-2-5 (2002), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-5: Tests – Torsion/Twist*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/032846>

[b-IEC 61300-2-9] IEC 61300-2-9 (1995), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-9: Tests – Shock*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/019452>

[b-IEC 61300-2-10] IEC 61300-2-10 (1995), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-10: Tests – Crush resistance*. (Withdrawn in 2002) [b-IEC 61300-2-12] IEC 61300-2-12 (2005), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-12: Tests – Impact*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/034517>

[b-IEC 61300-2-22] IEC 61300-2-22 (2007), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-22: Tests – Change of temperature*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/037705>

[b-IEC 61300-2-23] IEC 61300-2-23 (1995), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-23: Tests – Sealing for non-pressurized closures of fibre optic devices*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/019465>

[b-IEC 61300-2-33] IEC 61300-2-33 (2006), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-33: Tests – Assembly and disassembly of fibre optic closures*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/036857>

[b-IEC 61300-2-34] IEC 61300-2-34 (1995), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-34: Tests – Resistance to solvents and contaming fluids*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/019475>

[b-IEC 61300-2-37] IEC 61300-2-37 (2006), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-37: Tests – Cable bending for fibre optic closures*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/037068>

[b-IEC 61300-2-38] IEC 61300-2-38 (2006), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-38: Tests – Sealing for pressurized fibre optic closures*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/036856>

[b-IEC 61300-2-48] IEC 61300-2-48 (2003), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-48: Tests – Temperature-humidity cycling*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/033526>

[b-IEC 61300-3-1] IEC 61300-3-1 (2005), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-1: Examinations and measurements – Visual examination*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/034902>

[b-IEC 61300-3-3] IEC 61300-3-3 (2005), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-3: Examinations and measurements – Active monitoring of changes in attenuation and return loss.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/033593>

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