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1 Purpose

- 1.1 The purpose of this Tunnel and Public Area Cooling and Ventilation (TPACV) Standard is to define the environmental conditions for tunnel and public areas, and to specify the performance requirements for cooling and ventilation systems that serve these areas.

2 Scope

- 2.1 This standard applies to all London Underground (LU) enclosed sub-surface locations to which the public have access, and to all non public LU tunnels and shafts.
- 2.2 The Tunnel and Public Areas shall be provided with:
- a) Draught relief to avoid excessive air velocities and pressures induced within public areas by train movements that could otherwise compromise the safety of passengers and staff;
 - b) Sufficient quantities of air to meet the physiological needs of passengers and staff;
 - c) New cooling systems to mitigate additional heat generated by upgrades to the operational railway.
 - d) New tunnel ventilation systems to serve new infrastructure, which shall reduce the risks associated with a fire event, through the provision of smoke control and smoke extraction to achieve the status As Low As Reasonably Practicable (ALARP).
- 2.3 This standard covers alterations of, extensions to and new tunnel and public area cooling assets.
- 2.4 This standard covers alterations of, extensions to and new tunnel and public area ventilation assets.

3 Requirements

3.1 Environmental Conditions

- 3.1.1 Key maximum and minimum environmental conditions for internal tunnel and public areas shall be taken from Table 1 below.

Table 1: Environmental conditions for Tunnel and Public Areas

Environmental parameter	Operational Mode	Areas	Condition
Air Temperature	Traffic - normal	All	$\geq -4^{\circ}\text{C}$
Air Temperature	Traffic - normal	All	$\leq +30^{\circ}\text{C}$
Relative Humidity	Traffic - normal	All	35 - 70%
Air velocity	Traffic - normal	All (except retail areas)	$\leq 5 \text{ m/s}$
Air velocity	Traffic - normal	Retail areas	$\leq 3 \text{ m/s}$
Air velocity	Engineering Hours - normal	All	$\leq 5 \text{ m/s}$
Air velocity	Emergency	All	$\leq 11.1 \text{ m/s}$
Air velocity	All	Internal air terminals (i.e. grilles, louvers, openings, etc)	$\leq 5 \text{ m/s}$
Air velocity	All	External air terminals (i.e. grilles, louvers, openings, etc)	$\leq 5 \text{ m/s}$
Pressure Transients	Traffic - normal	Sub surface station platforms	$\leq 300\text{Pa}$
Instantaneous air velocity	Traffic - normal – (less than 2 seconds duration)	Stairways, escalators and passenger conveyors	$\leq 8 \text{ m/s}$
Instantaneous air velocity	As above	Sub surface station platforms	$\leq 10 \text{ m/s}$
Instantaneous air velocity	As above	All other areas of sub surface stations	$\leq 10 \text{ m/s}$
Instantaneous air velocity	As above	Non public tunnel shafts	$\leq 10 \text{ m/s}$
Instantaneous air velocity	As above	Non public tunnel cross passages	$\leq 15 \text{ m/s}$
Instantaneous air velocity	As above	Non public tunnel adits	$\leq 15 \text{ m/s}$
Noise level (LAeq)	All	Platforms and station public areas (measured at a height of 1.8m from floor level).	$\leq 65\text{dB(A)}$
Noise level (LAeq) 8 hour average	All	Tunnel connections to the TPAV shaft (measured at 1m from the connection)	$\leq 80\text{dB(A)}$

- 3.1.2 The temperatures specified in Table 1 are for the average individual platform temperatures as measured over a week, recorded at the evening peak time during the summer season.

- 3.1.3 For platforms, the average temperature shall be established from the mean of three location specific averages taken 30m from the headwall and tail wall and at the centre of the platform, at 1.8m above finished floor level.
- 3.1.4 The internal noise levels specified in Table 1 are those generated by the TPACV system only.
- 3.1.5 The internal noise levels generated by the TPACV system shall not compromise the audibility of the public address system.
- 3.1.6 Internal noise levels generated by existing TPACV systems at boundary wall locations shall not be exceeded following modifications to or replacement of the TPACV system.
- 3.1.7 Higher continuous noise levels (i.e. above 80dB(A)) at tunnel connections to the TPAV shaft (measured at 1m from the connection) shall be acceptable provided average exposure over 8 hours is assessed in accordance with HSE L108 Guidance on the Control of Noise of Work Regulations.
- 3.1.8 Higher continuous noise levels at tunnel connections to the TPAV shaft shall not exceed 92 dB(A).
- 3.1.9 If the continuous noise level at the tunnel connection exceeds 80dB(A), where maintenance work is required within the vicinity of a tunnel connection to the TPAV, when possible, the TPAV shall be switched off for the duration of the maintenance works.
- 3.1.10 If the continuous noise level at the tunnel connection exceeds 80dB(A), and the TPAV must remain operational, any person working within the vicinity of the tunnel connection to the TPAV (e.g. track maintainers) shall be required to wear personal protective hearing protection equipment.
- 3.1.11 If the continuous noise level at the tunnel connection exceeds 80dB(A), any person within the vicinity of the tunnel connection to the TPAV (e.g. passengers being evacuated from a train) who are not wearing personal protective hearing protection equipment, shall not be permitted to stay within the area for longer than 30 minutes.
- 3.1.12 TVM shall determine the impact of the introduction of new rolling stock or train operations on the existing environmental conditions.
- 3.1.13 TVM shall determine the resultant system temperature following implementation of a TPAC system.
- 3.1.14 London Underground's Ventilation, Cooling and Power (VCP) Performance Team shall quantify the maximum cooling capacity required at each location.
- 3.1.15 London Underground's VCP Performance Team shall provide the location specific daily cooling load profile.
- 3.1.16 London Underground's VCP Performance Team shall quantify the change to the thermal ambience benefits associated with the introduction of new rolling stock or train operations.

- 3.1.17 London Underground's VCP Performance Team shall quantify the change to the heat strain risk status associated with the introduction of new rolling stock or train operations.
- 3.1.18 London Underground's VCP Performance Team shall assess benefits realisation to ensure that the TPACV system has met requirements.
- 3.1.19 If the introduction of new rolling stock or train operations results in a negative impact on the existing environmental conditions appropriate mitigating measures shall be implemented to meet compliance with the requirements in Table 1.
- 3.1.20 The TPACV system elements may be subjected to transient vibration induced by the operation of the railway, and the magnitude of the vibration forces shall be based on a location-specific analysis and/or survey.
- 3.1.21 The TPACV system elements may be subjected to transient pressure fluctuations induced by the train piston effect, and the magnitude of the pressure fluctuations shall be based on a location-specific TVM analysis and/or survey.
- 3.1.22 Evaporative cooling systems shall not be employed within the subsurface internal tunnel and public areas as any increase in the existing relative humidity increases heat strain risk.
- 3.1.23 For design purposes, key maximum and minimum environmental conditions for external atmosphere shall be taken from Table 2 below.

Table 2: Design environmental conditions for external atmosphere

Environmental parameter	Value
Altitude	0 – 1400m
Low Air Temperature	- 4 °C
Relative Humidity at Low Air Temperature	100%
High Air Temperature	+ 29°C
Relative Humidity at High Air Temperature	54%

- 3.1.24 The designer shall use as the basis of design, the climate predictions from UKCP09 for a 2050s P50 medium emissions scenario.
- 3.1.25 The sensitivity of the TPACV system design to this input shall be provided by means of a parametric sensitivity analysis during the TVM analysis done during the design development phase.
- 3.1.26 The UKCP09 data is relative to the 1961 and 1990 baseline and some of the predicted climate change has already occurred. The table below shows the predicted changes and the changes over and above the current 2030s medium assumption being adopted.

Table 3: Design environmental conditions for external atmosphere

Case	Change from 2006 (°C)	2006 Evening Peak Temperature (°C)	CP09 Predicted Evening Peak Temperature (°C)
2030 Med P50	0.440	26.86	27.3
2055 Med P50	1.211	26.86	28.1
2055 Med P90	3.093	26.86	30.0
2055 High P50	1.564	26.86	28.4
2055 High P90	3.683	26.86	30.5
2085 Med P50	2.367	26.86	29.2
2085 Med P90	4.893	26.86	31.8
2085 High P50	3.380	26.86	30.2
2085 High P90	6.533	26.86	33.4

- 3.1.27 System components exposed to solar radiation operate against the maximum possible solar gain in addition to, and coincident with the maximum specified ambient air temperatures.
- 3.1.28 The external noise level generated by a TPACV system with no tonality shall not exceed LA90 minus 10dB at the nearest noise sensitive receptor.
- 3.1.29 The external noise level generated by a TPACV system with tonality shall not exceed LA90 minus 15dB at the nearest noise sensitive receptor.
- 3.1.30 The location of the nearest noise sensitive receptor shall be agreed with the Local Authority.
- 3.1.31 The background noise level shall be established in accordance with the procedure detailed in British Standard BS 4142.
- 3.1.32 Where existing TPACV systems are the predominant noise source at a given location, the background noise level shall be measured with the existing TPACV system operational.
- 3.1.33 Where an existing TPACV system is the predominant noise source at a given location, and they are to be shut down for a period of refurbishment during which the background noise levels will reduce, the background noise level measured with the existing TPACV system operational shall be agreed as the baseline design LA90 criteria with the Local Authority.
- 3.1.34 Equipment shall meet the performance criteria specified by Department of Energy and Climate Change in the 'Enhanced Capital Allowance (ECA) Scheme for Energy Efficient Technologies - Energy Technology Criteria List'.
- 3.1.35 Before use Suppliers shall arrange listing of qualifying equipment that is not on the Energy Technology List.

3.2 Tunnel and Public Area Cooling

3.2.1 This section covers cooling systems that serve tunnel and public areas which includes, but is not limited to, the following:

- Chilled water systems
- Borehole cooling water systems
- Seepage cooling water systems
- Cooling coils within ventilation systems supplying cooled air into the network
- Cooling pipes within tunnel invert
- Tunnel Energy Segments (embedded cooling pipe work in segmental lined tunnels)

3.2.2 Tunnel and Public Area Cooling (TPAC) infrastructure removes heat from the London Underground network and either discharges it to atmosphere or exports it to be utilised by an external stakeholder.

3.2.3 Additional heat is mainly generated on the London Underground network by:

- Increased energy used by the increased speed limits and frequency of the service.
- Increased energy due to modified train performance.
- Increased energy usage by train auxiliary systems. e.g. saloon cooling
- Increase passenger demand
- Waste heat from equipment rooms
- Climate change

3.2.4 Cooling capacity shall be calculated based on, but not limited to, the following factors:

- Service patterns
- Train performance
- Traction energy efficiency
- Driver speed distance profiles
- Infrastructure geometry and properties

3.2.5 Where the average summer evening peak platform temperatures are predicted by the TVM to exceed 30°C, TPAC infrastructure shall be provided to remove the additional heat generated by line upgrades and other service capacity projects.

3.2.6 Annual cooling load profile shall be based upon the following cooling demand:

- 100% of the peak summer demand for the three summer months (June, July August);
- 80% of the peak summer demand for May;
- 80% of the peak summer demand for September and October.

3.2.7 Waste heat recovery functionality shall be incorporated into new TPAC systems.

3.2.8 External stakeholders located within the vicinity of the TPAC systems, which could utilise the waste heat, shall be identified during the feasibility design stage.

3.2.9 Following completion of the feasibility design of the TPAC system, a preliminary waste heat recovery business case assessment shall be completed by the project team.

3.2.10 Following completion of the detail design of the TPAC system, the detailed design waste heat recovery business case assessment shall be completed by the project team.

3.2.11 Following completion of the detailed design waste heat recovery business case assessment, if there is a positive net financial effect or if the benefit cost ratio (BCR) meets the minimum business target, then the waste heat recovery system shall be implemented.

3.3 Tunnel and Public Area Ventilation

3.3.1 This section covers ventilation systems that serve tunnel and public areas which includes, but is not limited to, the following:

- Mid tunnel exhaust / supply ventilation systems
- Station based ventilation exhaust / supply systems that serve the tunnels and platforms only
- Over platform exhaust / supply ventilation systems
- Under platform exhaust / supply ventilation systems
- Draught relief shafts

3.3.2 Tunnel and Public Area Ventilation (TPAV) systems are located within shafts that either connects to the running tunnels or to the station platform tunnels.

3.3.3 The TPAV system's primary function is to either exhaust air from the network to atmosphere, or to supply outside air into the network.

3.3.4 Draught relief shafts passively ventilate the network by providing a low resistance air path connection to atmosphere which reduces the magnitude of the train induced piston pressures.