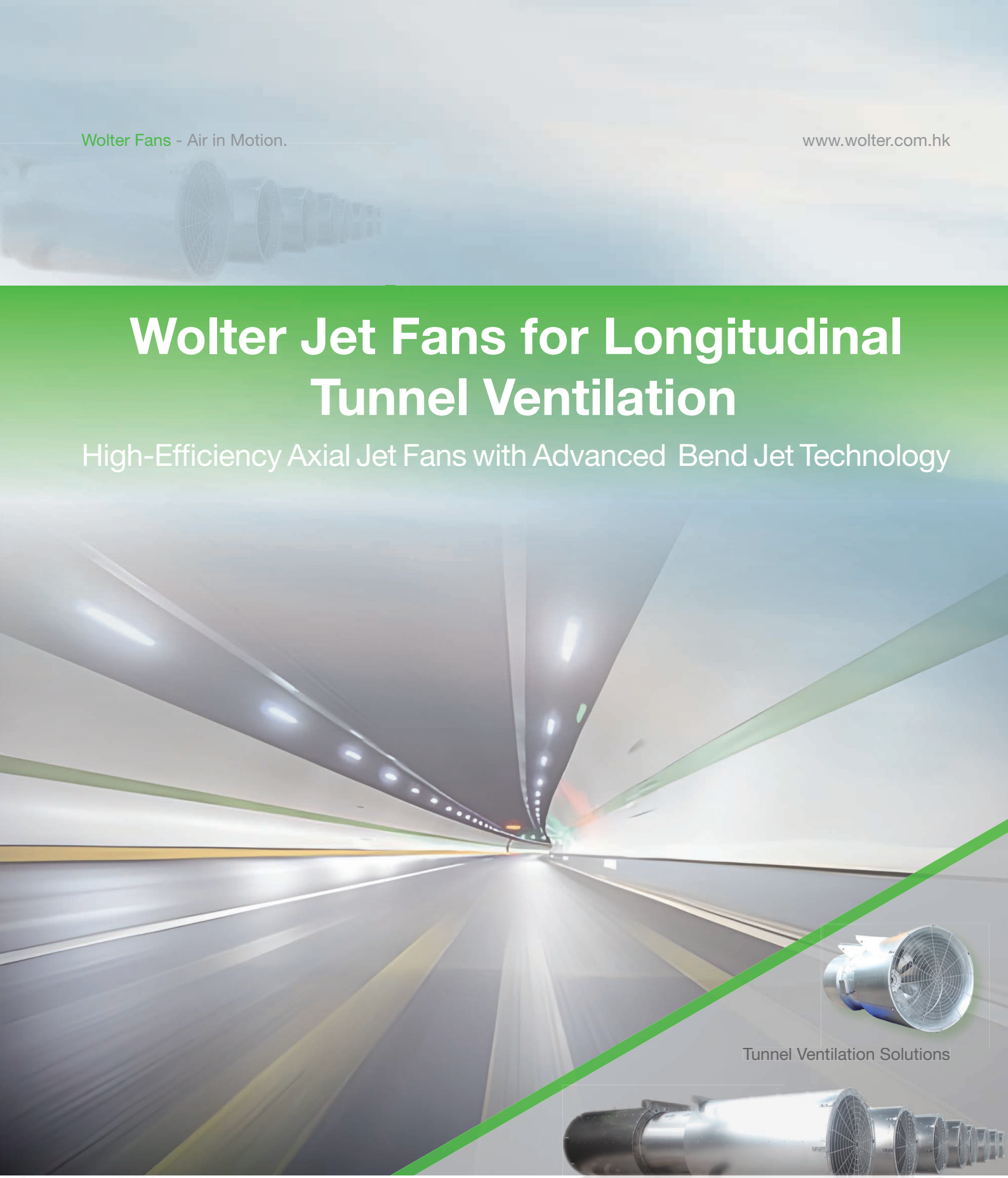
Wolter Jet Fans for Longitudinal Tunnel Ventilation

High-Efficiency Axial Jet Fans with Advanced Bend Jet Technology



Tunnel Ventilation Solutions

T14.23

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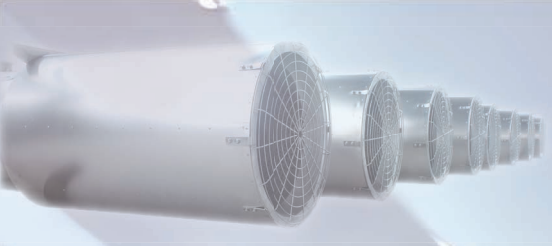
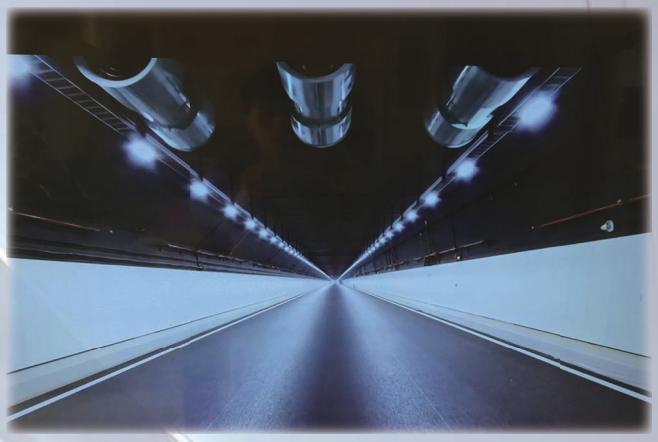


Longitudinal Tunnel Ventilation - Principle and Advantages



Longitudinal ventilation is a duct-free system in which the entire required air volume moves through the tunnel at a controlled velocity from one portal to the other. For tunnels longer than approximately 200 m or subject to significant rush-hour congestion, axial jet fans provide the most practical and economical means of generating positive longitudinal airflow.

Jet fans are purpose-designed with open inlets and outlets optimised for maximum impulse transfer to the tunnel air mass rather than for operation against high external pressure. They are normally mounted in the clearance zone between the traffic envelope and the tunnel roof, spaced at intervals of roughly 100 m (exact spacing depends on tunnel geometry, required thrust and fan performance). Under normal conditions fans operate in the direction of traffic flow (usually uni-directional), but all models are fully reversible for emergency smoke management.

This configuration is especially well suited to cut-and-cover and over tunnels with flat roofs, where a transverse row of parallel jet fans can deliver the necessary thrust with minimal headroom and power demand. Because the tunnel itself serves as the airway, longitudinal systems offer outstanding economy in both first cost and energy consumption. However, air velocity and volume flow increase proportionally with tunnel length; practical limits are typically around 1 km for heavily trafficked roads, corresponding to average air velocities of approximately 8 m/s.

Design Input Data Required for Accurate Ventilation Calculations

Before detailed calculations can be performed, the following project-specific data must be established (many parameters are dictated by regional or national regulations):.

- CO concentration in outdoor air and the maximum permissible in-tunnel CO concentration
- Traffic composition – total vehicles, proportion of passenger cars versus trucks / heavy goods vehicles
- Average CO emission rate per vehicle type (cm^3/s per vehicle)
- Permissible visibility reduction caused by diesel smoke (extinction coefficient or mg/m^3)
- Average and peak traffic density (vehicles per hour per lane)
- Tunnel altitude, length, longitudinal gradient and cross-sectional profile (including hydraulic diameter)
- Number of lanes and traffic direction (uni-directional or bi-directional)

- Design traffic speed and whether congested-flow conditions must be considered
- Requirement for smoke extraction in fire emergency, including design fire curve (temperature and duration)
- Meteorological boundary conditions - wind pressure, temperature difference and barometric pressure difference between portals

Wolter's engineering team routinely assists clients with the compilation and validation of these input parameters.

Airflow and Pollutant Dilution Calculations

The required ventilation volume flow is determined from mass-balance equations that account for vehicle emissions of CO and diesel particulates, permissible concentration limits, tunnel geometry and the need for smoke control in emergency mode. Calculations must follow recognised international or local standards (PIARC, EN, NFPA, local authority guidelines, etc.). Typical governing parameters include:

For CO Emission: $$Cg = \frac{Ce * L * n}{V}$$

For Diesel Smoke: $$Dg = \frac{De * L * n}{V}$$

Cg = permissible CO concentration (ppm)
Ce = CO emission rate of vehicles ($cm^3/s/m$)
Dg = permissible diesel smoke concentration (mg/m^3)
De = diesel smoke emission rate (mg/s/m)
L = tunnel length (m)
n = number of lanes
V = required exhaust volume flow of polluted air (m^3/s)

Project-specific calculations, including allowance for congested traffic and fire scenarios, are prepared by Wolter engineers on request. CFD modelling can be provided for complex geometries or critical projects.

Calculation of Required Thrust - Overcoming Tunnel Resistance

After the design air velocity (v_T) and volume flow have been established, the total thrust that the jet-fan array must deliver is calculated by summing the individual pressure-loss components and converting the total pressure loss into force:

Total Thruse Required: $$N = \sum P * A_T$$

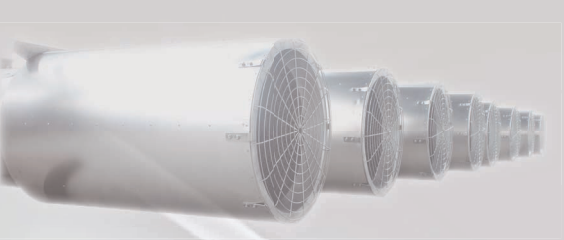
$\sum P$ = sum of pressure losses (Pa);
A_T = tunnel cross-sectional area (m^2).

The four main pressure-loss components are:

1. Portal Entry and Exit Losses
   Generally taken as approximately 1.5 × tunnel velocity pressure ($½ * \rho * v_T^2$).
2. Wall and Fitting Friction Losses

$$\Delta p_s = f * (L / D_H) * (½ * \rho * v_T^2)$$

   Where:
   Δp_s = Pressure loss (Pa); V_T = Tunnel Air Velocity (m/s);
   L = Tunnel Length (m); f = Friction Factor; ρ = Air Density (kg/m^3);
   D_H = Hydraulic diameter of the tunnel (m)
   Typical friction factor f = 0.025 (range 0.02 ~ 0.04 depending on surface roughness and presence of obstructions such as signs, luminaires, etc.).
3. Traffic Drag / Piston Effect
   Aerodynamic interaction between moving vehicles and tunnel air. In uni-directional tunnels, slower-moving or stationary traffic creates additional drag. In bi-directional tunnels, traffic travelling against the ventilation airflow must also be considered.
4. Meteorological Effects
   Wind pressure at portals, thermal buoyancy (stack effect) and barometric pressure differences between entry and exit.



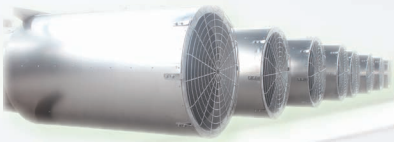
The resulting total thrust is provided by a number of jet fans operating in parallel groups. To avoid mutual aerodynamic interference, fans should be spaced at least 10 tunnel diameters apart in the longitudinal direction;
Alternatively, spacing (m) ≈ fan outlet dynamic pressure (Pa) / 10;
Lateral spacing between parallel fans should ideally exceed 2 × fan diameter. The proximity of the first fan to the entry portal and the last fan to the exit portal also influences overall system efficiency and must be evaluated during detailed design. High-outlet-velocity fans generally experience less thrust reduction due to the induced tunnel airflow, although they often exhibit a lower thrust-to-power ratio (N/kW).

Wolter Jet Fan Range - Performance and Versatility

Wolter supplies a wide range of high-efficiency axial jet fans specifically developed for longitudinal ventilation of road, rail and metro tunnels. Both uni-directional and truly reversible configurations are available.

Key Performance Data

- Diameters: 400 mm ~ 1,600 mm (13 standard sizes; special diameters on request)
- Thrust: up to 3,000 N standard (higher values available)
- Volume flow: up to approximately 256,000 m³/h depending on size and blade angle
- Fire rating: up to 700 °C / 2h in accordance with EN 12101-3 (F200 / F300 / F400 certified versions)
- Impeller materials: corrosion-resistant cast aluminium (standard); cast steel or stainless steel on request
- Casing materials: hot-dip galvanised mild steel (standard); stainless steel on request



Reversibilit

Truly reversible models, featuring symmetrical blade profiles optimised for both flow directions, deliver 100 % of rated thrust in forward and reverse. Conventional uni-directional fans typically achieve 50–60 % of forward thrust when operated in reverse;

Testing & Certification

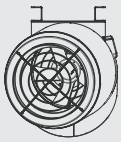
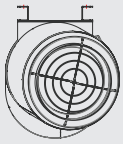
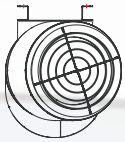
All Wolter jet fans are tested in accordance with ISO 13350 (jet fans) and relevant AMCA 250 standards. Thrust, airflow and sound power levels are measured in both forward and reverse directions. Fire-rated units are additionally tested and certified to EN 12101-3. Every fan undergoes factory acceptance testing before despatch; third-party witnessing is available on request.

Bend Jet Technology

- Optimised Flow Direction for Superior Effective Thrust

Wolter's standard product range already offers optional bent and twisted casings that provide an adjustable outlet air profile angled to suit specific site conditions. Building on this capability, Wolter has developed the advanced Bend Jet configuration.

The Bend Jet features a carefully engineered curved (arc-contoured) outlet that directs the high-velocity impulse jet slightly towards the longitudinal centreline of the tunnel. This design effectively counters the Coand attachment of the jet to the tunnel ceiling - a phenomenon that creates intense shear, vortices and high frictional losses (commonly quantified by empirical installation loss factors). By directing the jet core into the central portion of the tunnel cross-section, the Bend Jet produces a far more favourable velocity profile: high velocity in the core where it usefully accelerates the bulk airflow, and low velocity near the ceiling where friction losses would otherwise be greatest.

Twist Angle	Twist Left	Twist Right
30 deg		
60 deg		
90 deg		

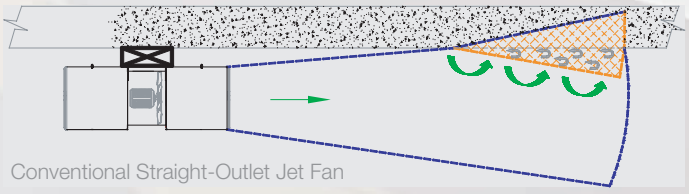
Ideal Applications for Bend Jet

- New tunnel projects where whole-life cost optimisation is a priority
- Refurbishment or capacity-upgrade projects where increasing traffic loads or stricter fire
- Safety requirements must be met without major structural alterations
- Tunnels with challenging geometry or where niche space is limited

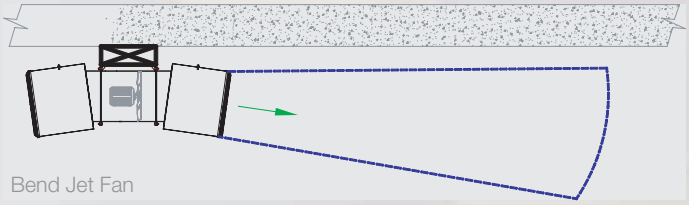
Wolter can supply project-specific selection tables, effective-thrust calculations and comparative performance data demonstrating the Bend Jet advantage for your particular tunnel length, cross-section and design criteria.

Typical Benefits versus Conventional Straight-Outlet Jet Fans of the Same Size and Power

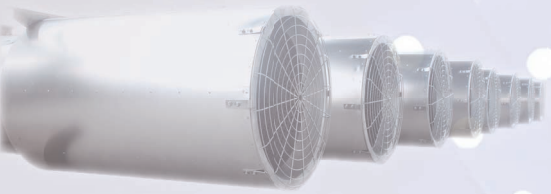
- 20~50 % higher effective thrust delivered to the tunnel air mass
- Dramatically reduced ceiling friction and background velocity losses
- Fewer jet fans required to achieve the specified ventilation or thrust performance
- Lower total installed power and reduced electrical infrastructure (cabling, switchgear, VFDs)
- Smaller and/or shorter niches or recesses
- Significant savings in civil construction cost
- Lower whole-life operating and maintenance costs (fewer units to inspect and service)
- In fire-emergency mode: substantially less disturbance to the stratified hot smoke layer at the ceiling, improving tenability and the effectiveness of any complementary smoke-extraction measures



Conventional Straight-Outlet Jet Fan



Bend Jet Fan



Technical Construction - Engineered for Reliability and Longevity

Impellers

Blades and hubs manufactured from corrosion-resistant cast aluminium as standard, with adjustable pitch angle for fine-tuning on site. X-ray inspection of blades and hub can be performed on request. Cast steel and stainless-steel impellers are available for aggressive environments.

Motors

Totally enclosed fan-cooled (TEFC), pad-mounted motors complying with IEC 34. Standard winding insulation Class F. Enhanced Class H insulation or special high-temperature windings are available for emergency operation at 250 °C for 60 minutes, F300 or F400 (tested and certified to EN 12101-3). Minimum L10 bearing life is 20,000 hours, corresponding to an average service life of approximately 100,000 hours (calculated per ISO 281).

Casing

Mild steel plate, 3~6 mm thick according to diameter, hot-dip galvanised after fabrication and welding. Straight casings are standard; bent or twisted casings (Bend Jet configuration) are available to optimise the outlet flow angle for specific tunnel profiles. Full stainless-steel casings can be supplied on request. Motor support arms are welded or bolted; the complete assembly is hot-dip galvanised for maximum corrosion protection.

Silencers

External casing in galvanised steel with perforated galvanised-steel inner liner. Bell-mouth inlets formed at both ends for smooth entry and minimum pressure loss. Standard silencer lengths are one or two times the fan diameter. Custom lengths and acoustic designs are available to achieve specific sound-pressure-level requirements.

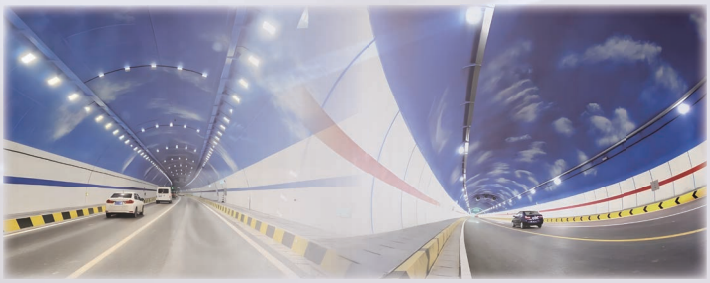
Surface Protection

Three Standard Levels:

1. Standard finish: Hot-dip galvanised steel components + manufacturer's standard motor paint; impeller left unpainted.
2. External epoxy finish: Full epoxy-paint system on all external surfaces (colour to RAL specification).
3. Internal + external epoxy finish: 3-coat epoxy system on casings inside and out; perforated silencer sections executed in stainless steel (unpainted).

Mounting Arrangements

Robust mounting feet suitable for either rigid bolting to the tunnel structure or installation on anti-vibration isolators. Custom base-frame systems engineered to suit different tunnel profiles and geometries. Safety wires (material 1.4401) and protective grilles are available as required.

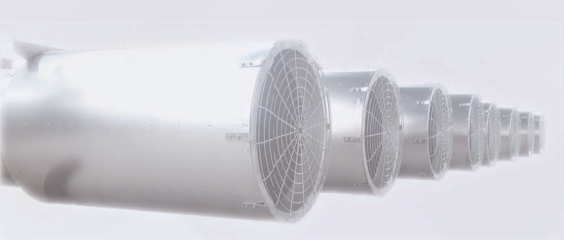


Quality Assurance, Testing and Certification

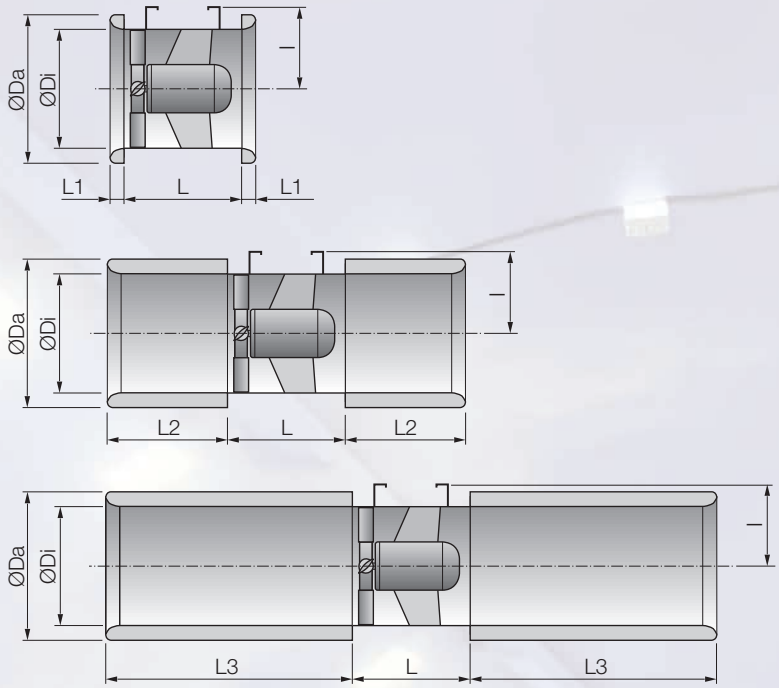
Wolter jet fans are manufactured under rigorous quality-management systems (aligned with ISO 9001 principles). Modern test facilities, including heat-test chambers, enable comprehensive verification of performance and fire rating. All jet fans are tested and certified in accordance with EN 12101-3 (F200 / F300 / F400) as applicable. Thrust and aerodynamic performance testing follows ISO 13350 / AMCA 250; sound-power measurements comply with relevant AMCA 300 or ISO 13347-2 standards. Every unit undergoes factory acceptance testing prior to despatch. Independent third-party inspection and certification (e.g. TÜV, GL) can be arranged.

Why Partner with Wolter for Your Tunnel Ventilation Project?

- More than five decades of specialist ventilation engineering experience within the Wolter Group
- Complete project capability - from conceptual design support and equipment selection through to installation supervision, commissioning, operator training and long-term service & maintenance
- Extensive international reference list covering major road, rail and metro tunnel projects
- Innovative Bend Jet technology delivering measurably superior effective thrust, lower whole-life cost and enhanced fire-mode performance
- Flexible manufacturing - standard products plus project-specific adaptations (bent casings, special materials, custom finishes, etc.)
- Full compliance with international standards (EN, ISO, AMCA) and ability to satisfy stringent local fire-safety and performance requirements
- Competitive commercial offering combined with high reliability and low maintenance burden.



Dimensions



Model Size	Di [mm]	Da [mm]	* Da [mm]	l [mm]	L [mm]	L1 [mm]	[kg]	L2 [mm]	[kg]	L3 [mm]	[kg]
400	401	501	551	250	400	60	110	460	150	860	200
450	450	550	600	280	400	60	140	510	185	960	250
500	504	600	654	315	400	80	180	580	230	1080	310
560	565	715	765	345	700	80	225	640	290	1200	390
630	634	784	834	400	700	80	250	710	340	1340	450
710	711	861	911	450	700	100	400	810	495	1520	690
800	797	997	1047	500	700	100	320	900	430	1700	640
900	894	1094	1144	580	700	120	380	1020	525	1920	790
1000	1003	1203	1303	630	780	140	620	1140	860	2140	1170
1120	1125	1325	1425	690	816	160	740	1280	920	2400	1340
1250	1250	1450	1550	750	816	160	830	1410	1100	2660	1550
1400	1405	1645	1755	830	1000	180	930	1580	1300	2980	1780
1600	1605	1845	1955	930	1000	180	1050	1780	1530	3380	2040

Note: * More silent version for option.
We reserve the right to alter drawings / measurements without notice in case of technical improvements.

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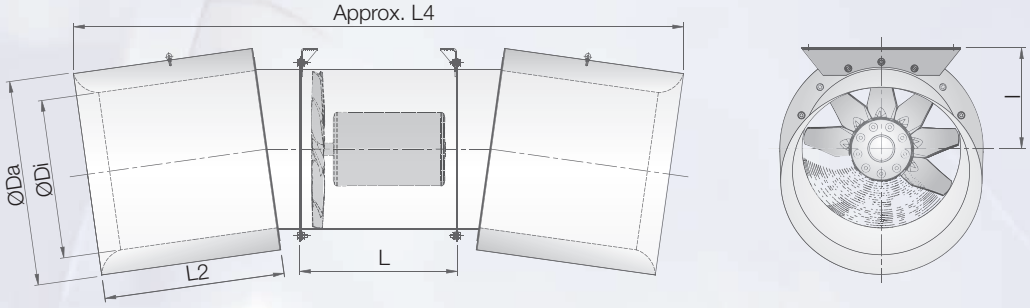

Model Size	Di [mm]	Da [mm]	* Da [mm]	I [mm]	L [mm]	L2 [mm]	L4 [mm]	[kg]
400	401	501	551	250	400	460	1730	160
450	450	550	600	280	400	510	1830	210
500	504	604	654	315	400	580	1940	250
560	565	715	765	345	700	640	2400	330
630	634	784	834	400	700	710	2520	420
710	711	861	911	450	700	810	2730	530
800	797	997	1047	500	700	900	2960	540
900	894	1094	1144	580	700	1020	3240	660
1000	1003	1203	1303	630	780	1140	3580	880
1120	1125	1325	1425	690	816	1280	3910	1060
1250	1250	1450	1550	750	816	1410	4160	1310
1400	1405	1645	1755	830	1000	1580	4800	1480
1600	1605	1845	1955	930	1000	1780	5220	1800

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Air in Motion

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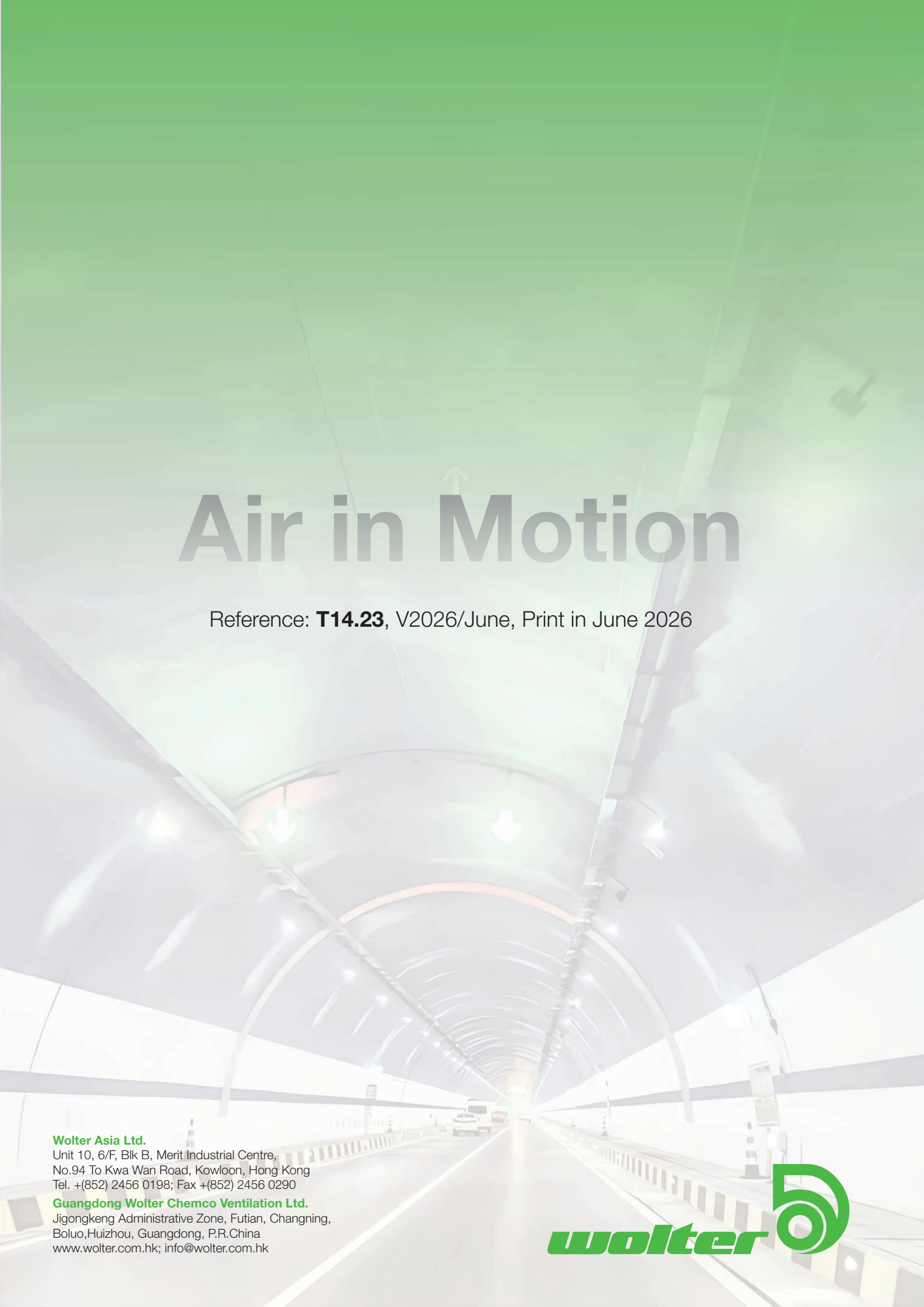

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