Master Specification
Part TUN-ME-DC6

Tunnel Ventilation Equipment

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Contents

TUN-ME-DC6 Tunnel Ventilation Equipment

1 General

a) This Master Specification Part sets out the requirements for the supply and testing of Tunnel ventilation system equipment including:

i) the documentation requirements, as set out in section 2;

ii) the general Tunnel ventilation equipment requirements, as set out in section 3;

iii) the requirements for Tunnel ventilation fans, as set out in section 4;

iv) the requirements for Tunnel ventilation dampers, as set out in section 5;

v) the requirements for Tunnel ventilation attenuators, as set out in section 6;

vi) the reliability, Design Life, and functional safety requirements, as set out in section 7;

vii) the maintainability requirements, as set out in section 8;

viii) the transportation, packing and storage requirements, as set out in section 9;

ix) the Hold Point and Witness Point requirements, as set out in section 10; and

x) the verification and testing requirements, as set out in section 11.

b) For the purposes of this Master Specification Part, Tunnel ventilation equipment includes the following:

i) Tunnel ventilation axial fans;

ii) Tunnel ventilation jet fans;

iii) Tunnel ventilation dampers;

iv) Tunnel ventilation attenuators; and

v) for the equipment listed in sections 1b)i) to 1b)iv), their:

A. mounting frames;

B. spring mounts;

C. associated transition pieces and ductwork; and

D. associated equipment.

c) This Master Specification Part does not apply to the following:

i) the design for the location and arrangement of the Tunnel ventilation equipment;

ii) the control algorithms for operation of the Tunnel ventilation system; or

iii) the design, supply, installation and testing of ventilation for:

A. egress passageways;

B. longitudinal egress passageways;

C. culvert and trafficable service passageways; or

D. any other underground rooms or Tunnel facilities.

d) The supply and testing of Tunnel ventilation equipment must comply with the Reference Documents, including:

i) AS 1055 Acoustics - Description and measurement of environmental noise;

ii) AS 1111 ISO metric hexagon bolts and screws;

iii) AS 1112 ISO metric hexagon nuts;

iv) AS/NZS 1170 Structural design actions;

v) AS/NZS 1252 High-strength steel fastener assemblies for structural engineering - Bolts, nuts and washers;

vi) AS 1397 Continuous hot-dip metallic coated steel sheet and strip - Coatings of zinc and zinc alloyed with aluminium and magnesium;

vii) AS 1530 Methods for fire tests on building materials, components and structures;

viii) AS 1554 Structural steel welding;

ix) AS/NZS 1567 Copper and copper alloys - Wrought rods, bars and sections;

x) AS 1627 Metal finishing - Preparation and pretreatment of surfaces;

xi) AS 1682 Fire, smoke and air dampers;

xii) AS 1851 Routine service of fire protection systems and equipment;

xiii) AS/NZS 2107 Acoustics - Recommended design sound levels and reverberation times for building interiors;

xiv) AS 2207 Non-destructive testing - Ultrasonic testing of fusion welded joints in carbon and low alloy steel;

xv) AS 2312 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings;

xvi) AS/NZS 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules);

xvii) AS/NZS 3013 Electrical installations - Classification of the fire and mechanical performance of wiring system elements;

xviii) AS/NZS 3678 Structural steel - Hot-rolled plates, floorplates and slabs;

xix) AS/NZS 3679 Structural steel;

xx) AS 4024 Safety of machinery;

xxi) AS 4100 Steel structures;

xxii) AS 4254 Ductwork for air-handling systems in buildings;

xxiii) AS 4312 Atmospheric corrosivity zones in Australia;

xxiv) AS 4506 Metal finishing - Thermoset powder coatings;

xxv) AS/NZS 4680 Hot-dip galvanized (zinc) coatings on fabricated ferrous articles;

xxvi) AS 4825 Tunnel fire safety;

xxvii) AS/NZS 5131 Structural steelwork - Fabrication and erection;

xxviii) AS/NZS ISO 9001 Quality management systems - Requirements;

xxix) AS 60034 Rotating electrical machines;

xxx) AS 60529 Degrees of protection provided by enclosures (IP Code);

xxxi) AS/NZS IEC 60947.8 Low-voltage switchgear and controlgear, Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines;

xxxii) BS 476-20 Fire Tests on Building Materials and Structures - Part 20: Method for Determination of the Fire Resistance of Elements of Construction (General Principles);

xxxiii) EN 1751 Ventilation for buildings - Air terminal devices - Aerodynamic testing of damper and valves;

xxxiv) EN 1993-1 Design of steel structures;

xxxv) EN 12101-3 Smoke and heat control systems, Part 3: Specifications for powered smoke and heat control ventilators (Fans);

xxxvi) EN 12681-1 Founding - Radiographic testing, Part 1: Film techniques;

xxxvii) EN 12681-2 Founding - Radiographic testing, Part 2: Techniques with digital detectors;

xxxviii) ISO 281 Rolling bearings - Dynamic load ratings and rating life;

xxxix) ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods;

xl) ISO 1996-1 Acoustics - Description, measurement and assessment of environmental noise, Part 1: Basic quantities and assessment procedures;

xli) ISO 1996-2 Acoustics - Description, measurement and assessment of environmental noise, Part 2: Determination of sound pressure levels;

xlii) ISO 3744 Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane;

xliii) ISO 5136 Acoustics - Determination of sound power radiated into a duct by fans and other air-moving devices - In-duct method;

xliv) ISO 5801 Industrial fans - Performance testing using standardised airways;

xlv) ISO 5802 Industrial fans - Performance testing in situ;

xlvi) ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air-terminal units - Insertion loss, flow noise and total pressure loss;

xlvii) ISO 10816-3 Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts, Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ;

xlviii) ISO 12944 Paints and varnishes - Corrosion protection of steel structures by protective paint systems;

xlix) ISO 13347-1 Industrial fans - Determination of fan sound power levels under standardized laboratory conditions, Part 1: General overview;

l) ISO 13347-3 Industrial fans - Determination of fan sound power levels under standardized laboratory conditions, Part 3: Enveloping surface methods;

li) ISO 13348 Industrial fans - Tolerances, methods of conversion and technical data presentation;

lii) ISO 13350 Fans - Performance testing of jet fans;

liii) ISO 14694 Industrial fans - Specifications for balance quality and vibration levels;

liv) ISO 14713 Zinc coatings - Guidelines and recommendations for the protection against corrosion of iron and steel in structures;

lv) ISO 15614 Specification and qualification of welding procedures for metallic materials - Welding procedure test;

lvi) ISO 21927-3 Smoke and heat control systems, Part 3: Specification for powered smoke and heat exhaust ventilators;

lvii) ISO 21940-11 Mechanical vibration - Rotor balancing, Part 11: Procedures and tolerances for rotors with rigid behaviour;

lviii) NEMA MG 1 Motors and Generators;

lix) UL 555 Fire dampers; and

lx) UL 555S Smoke dampers.

2 Documentation

2.1 Design Documentation

In addition to the requirements of PC-EDM1 “Design Management”, the Design Documentation must include:

a) equipment schedule and technical data sheets specific to the proposed Tunnel ventilation equipment;

b) calculations of structural integrity for all Tunnel ventilation equipment supports, frames, and fixings;

c) calculations of structural integrity for the high temperature rating requirements;

d) evidence that materials selected and the Tunnel ventilation equipment will comply with the Design Life requirements;

e) lifting point capacity calculations and certification;

f) Tunnel ventilation equipment loads and footing reactions for supporting structure;

g) control and monitoring input/output lists specific to the supplied Tunnel ventilation equipment;

h) evidence that the manufacturer has at least 10 years of recent experience in the manufacture of the supplied Tunnel ventilation equipment;

i) evidence, including referees and their contact information, that comparable Tunnel ventilation equipment has been in satisfactory operation for a minimum of 5 years in at least 3 road Tunnel projects;

j) general arrangement drawings showing assembly, installation details, set-out dimensions, mounting dimensions, overall dimensions, weights, and construction materials;

k) evidence that the equipment will achieve the high temperature rating required by section 3.4 including type test certification (where applicable) and design calculations to support structural integrity requirements;

l) proposed factory testing, inspection and commissioning for each type of Tunnel ventilation equipment to be supplied, including where the Contractor proposes that current type test certificates replace Factory Acceptance Testing, in accordance with section 11.2a);

m) Tunnel ventilation fan motor specific documentation comprising:

  i) motor ratings and operational parameters;

  ii) variable speed drives (VSDs) or soft starter requirements (as applicable);

  iii) calculations to demonstrate that the VSDs comply with the motor insulation capability;

  iv) motor bearing manufacturers technical data;

  v) motor resistance temperature detectors (RTDs) technical data; and

  vi) motor electrical characteristics (including power factor);

n) Tunnel ventilation fan impellor blade non-destructive examination methods as required by section 4.5f);

o) Tunnel ventilation axial fan specific documentation comprising:

  i) performance curves in the forward flow direction at all duty points;

ii) performance curves in the reverse flow direction at all duty points (if applicable);

iii) aerodynamic efficiencies in the forward flow direction at all duty points;

iv) aerodynamic efficiencies in the reverse flow direction at all duty points (if applicable); and

v) sound power spectrum at all duty points;

p) Tunnel ventilation jet fan specific documentation comprising:

i) catalogue thrust rating;

ii) estimated installed thrust;

iii) insertion loss for each silencer type;

iv) sound power spectrum in the forward direction; and

v) sound power spectrum in the reverse direction (if reversible);

q) Tunnel ventilation damper and actuator specific documentation comprising:

i) self-generated sound power levels as a function of face velocity;

ii) the pressure losses across the damper for given flow rates when fully open;

iii) pressure loss coefficient as a function of blade angle for modulating dampers;

iv) the additional pressure loss due to any actuators positioned across the damper face;

v) calculations for structural adequacy under specified design pressure loadings; and

vi) design calculations for the stress and fatigue of frames, shafts, and welds;

r) Tunnel ventilation attenuator specific documentation comprising:

i) pressure losses for given flow rates;

ii) structural adequacy for the peak velocity requirements;

iii) insertion loss for each Tunnel ventilation attenuator; and

iv) self-generated sound power levels; and

s) the documentation listed in section 2.1a) to 2.1r) for each required airflow direction.

2.2 Construction Documentation

In addition to the requirements of PC-CN3 “Construction Management”, the Construction Documentation must include:

a) Shop Drawings showing the materials of each component, characteristics of finished surfaces, tolerances, and applicable standards;

b) motor and actuator schematics with termination details and voltage and current ratings;

c) sensor schematics with terminal arrangement schematics;

d) manufacturing standards;

e) proposed material selections;

f) proposed welding procedure;

g) proposed surface treatment procedures;

h) equipment lifting provisions and lifting methodologies;

i) non-destructive examination results and documentation for Tunnel ventilation equipment, as required by section 11.3f); and

j) Tunnel ventilation fan balancing certification as required by section 11.4c).

2.3 Quality Management Records

In addition to the requirements of PC-QA1 “Quality Management Requirements” or PC-QA2 “Quality Management Requirements for Major Projects” (as applicable), the Quality Management Records must include:

a) the Tunnel ventilation fan impellor blade non-destructive examination records required by section 4.5g)ii);

b) Tunnel ventilation fan balancing certification;

c) certified performance curves to demonstrate compliance to this Master Specification Part;

d) type test certifications as required by this Master Specification Part;

e) manufacturer’s routine operations and maintenance procedures;

f) welders’ qualifications and weld records for all welded equipment;

g) surface treatment records;

h) non-destructive examination records;

i) fan motor stator winding insulation resistance at manufacture; and

j) equipment component records that are uniquely identifiable and traceable from manufacture through to all elements of testing, transport, storage, and installation.

3 General requirements

3.1 Performance

Tunnel ventilation equipment must be:

a) designed based on an air density of 1.2 kg/m³; and

b) designed for maximum aerodynamic efficiency in the forward flow direction.

3.2 Ingress protection

Tunnel ventilation equipment must be rated IP65 in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code), including:

a) fan motors;

b) cable terminal boxes;

c) control and monitoring instrumentation;

d) instrumentation terminal boxes; and

e) actuators.

3.3 Design loads

a) Tunnel ventilation equipment, supports and fixings must be designed:

   i) for strength, fatigue, serviceability, and durability;

   ii) with a minimum factor of safety of 1.5 for all loads; and

   iii) with a minimum factor of safety as defined by any applicable standards.

b) Tunnel ventilation equipment static and dynamic design loads must include:

i) self-weight including any lateral components;

ii) thrust, vibration and aerodynamic loads from the ventilation operation;

iii) torque reaction loads during all operational stages;

iv) fan and motor imbalance loads;

v) applicable seismic design standards; and

vi) when in the Tunnel carriageway:

A. loads from traffic induced pressure transients; and

B. thrust, vibration and aerodynamic loads from the in-Tunnel conditions.

3.4 High temperature rating

a) Tunnel ventilation equipment must:

i) be high temperature rated to maintain all operational functionality when exposed to airflow temperatures of 250°C for a minimum of 2 hours;

ii) have the high temperature rating applied to all components and systems that could be exposed to high temperature gases;

iii) withstand the thermal shock due to exposure to a rapid change from ambient air to 250°C and vice versa during system start-up or due to airflow reversals; and

iv) be provided with supports and fixings that maintain structural integrity when exposed to temperature conditions of 450°C for a minimum of 2 hours on any surface of the equipment.

b) Tunnel ventilation dampers must maintain structural integrity when exposed to airflow temperatures of 450°C for a minimum of 2 hours in accordance with BS 476-20 Fire Tests on Building Materials and Structures - Part 20: Method for Determination of the Fire Resistance of Elements of Construction (General Principles) on either damper face.

c) Tunnel ventilation attenuators must:

i) maintain structural integrity when exposed to airflow temperatures of 450°C for a minimum of 2 hours on any surface of the attenuator;

ii) achieve the high temperature rated operation without permanent distortion or buckling for any part of the attenuator;

iii) be designed to allow for thermal expansion of the metal splitters as a result of the high temperature rating requirement; and

iv) have fire hazard properties tested in accordance with AS 1530 Methods for fire tests on building materials, components, and structures to achieve:

A. ignitability index of 0;

B. spread of flame of 0;

C. heat evolved index of 0; and

D. smoke developed of 0.

d) Tunnel ventilation equipment must satisfy any additional high temperature, fire resistance and other requirements of the Tunnel Fire Engineering design.

e) Evidence that the equipment will achieve the high temperature rating required by this section 3.4 including type test certification (where applicable) and design calculations to support structural integrity requirements must be included as part of the Design Documentation.

3.5 Surface treatment

a) Tunnel ventilation equipment must be:

   i) constructed of materials that are suitable for the Tunnel environment and installation conditions;

   ii) constructed of materials which are LSZH;

   iii) constructed of materials which are free of PVC;

   iv) protected from corrosion including the mounting frames, fasteners, connected ductwork and attenuation;

   v) designed to minimum Category 3 in accordance with AS 4312 Atmospheric corrosivity zones in Australia;

   vi) protected to prevent galvanic corrosion of components due to contact between dissimilar metals;

   vii) protected against crevice corrosion by fully welding or otherwise sealing all crevices in metallic components; and

   viii) self-draining to mitigate water pooling via suitably located drain holes, channels and piping as required for the mounting arrangement.

b) Tunnel ventilation equipment components that are galvanized must be:

   i) hot dip galvanised and passivated in accordance the AS 4680 Hot-dip galvanized (zinc) coatings on fabricated ferrous articles;

   ii) hot dip galvanised and passivated prior to other surface treatments; and

   iii) supplied in a jet black finish (RAL 9005).

3.6 Identification

Tunnel ventilation equipment identification plates must be:

a) indelibly marked (stamped);

b) permanently attached to the Tunnel ventilation equipment by the manufacturer;

c) permanently attached to each module of damper and attenuator configurations;

d) clear of any paint applied to the Tunnel ventilation equipment;

e) located to be readily visible in the installed arrangement;

f) provided with the manufacturer name and address;

g) provided with the date of manufacture;

h) provided with the model and serial number of the Tunnel ventilation equipment;

i) provided with the temperature rating of the Tunnel ventilation equipment; and

j) provided with the characteristic performance details of the Tunnel ventilation equipment.

3.7 Normal operating conditions

a) Tunnel ventilation equipment must be designed for continuous operation in a Tunnel environment with Tunnel pollution levels that are defined by the ventilation system designer for the Project.

b) Tunnel ventilation equipment must be designed to:

   i) operate regularly and intermittently as required for the ventilation functionality;

ii) operate in normal temperatures ranging between 0°C and 55°C;

iii) resist attack or nesting by vermin, insects, and birds;

iv) mitigate debris and trash ingress; and

v) mitigate water ingress from seepage.

c) Tunnel ventilation equipment located above the Tunnel carriageway must be designed to:

i) withstand high-pressure washing;

ii) withstand deluge operation; and

iii) accommodate vehicle induced pressure transients.

3.8 Lifting points

a) Tunnel ventilation equipment must be provided with lifting points to enable lifting of heavy equipment or assemblies.

b) Tunnel ventilation equipment lifting points must be:

i) certified to AS 4100 Steel structures;

ii) subjected to non-destructive testing when welded;

iii) provided with any removable eyebolts; and

iv) supplied with a methodology for lifting and removing using the lifting points.

4 Tunnel ventilation fans

4.1 General

The requirements of section 4.2 to section 4.8 are general requirements and must be applied to both Tunnel ventilation axial fans and Tunnel ventilation jet fans.

4.2 Tunnel ventilation fan casings

Tunnel ventilation fan casings must be:

a) manufactured from minimum 6 mm thickness galvanised mild steel;

b) provided complete with spun or continuously welded flange ends;

c) provided with internal radial fan motor mounts continuously welded to the casing; and

d) provided with jacking and lifting or cranage points for safe transport and installation.

4.3 Tunnel ventilation fan motors

a) Tunnel ventilation fan motors must be:

i) mounted integral with the fan casing;

ii) selected for maximum efficiency;

iii) compliant with:

A. AS 60034 Rotating electrical machines; and

B. AS 3000 Electrical installations;

iv) fitted with anti-condensation heaters;

v) able to accelerate from standstill to full speed in 10 seconds or less;

vi) rated for at least 6 starts per hour;

vii) designed for starting using soft starters or variable speed drives;

viii) able to achieve a minimum power factor of 0.9;

ix) rated with a voltage of 400 V or 690 V (3 phase); and

x) rated with a frequency of 50 Hz.

b) Tunnel ventilation fan motors with a frame size of 280 (75 kW) or greater must use insulated bearings on both the drive and non-drive end of the motor.

c) Tunnel ventilation fan motors must utilise soft starters or VSDs.

d) Tunnel ventilation fan motor insulation ratings must be:

i) suitable for the type of starting;

ii) suitable for the high temperature operation defined by section 3.4; and

iii) minimum Class H insulation with maximum Class F temperature rise at rated load.

e) Tunnel ventilation fan motor insulation ratings for VSD controlled fans must be:

i) suitable for the VSD location, the length and type of cabling;

ii) suitable for any overvoltage limiting devices; and

iii) the high temperature operation defined by section 3.4.

f) Tunnel ventilation fan motor cabling must be:

i) compliant to WS52W of AS/NZS 3013 Electrical installations - Classification of the fire and mechanical performance of wiring system elements; and

ii) LSZH.

4.4 Tunnel ventilation fan bearings

a) Tunnel ventilation fan motors must be provided with drive and non-drive end bearings.

b) Tunnel ventilation fan bearings must be:

i) supplied with grease in accordance with the manufacturer’s recommendations; and

ii) designed to avoid permanent damage when the Tunnel ventilation fans are not operated regularly.

4.5 Tunnel ventilation fan impellors

a) Tunnel ventilation fan impellors must be:

i) provided with true aerofoil blades for unidirectional fans;

ii) provided with symmetrical blades for reversible fans;

iii) designed such that the first critical speed is at least 50% higher than the design maximum operating speed; and

iv) designed to withstand stresses generated by over-speed testing to 125% of the nominal operating speed.

b) Tunnel ventilation fan impellor blades and hubs must be cast from aluminium alloy.

c) Tunnel ventilation fan hubs must be fitted with a cast iron or steel insert, bored and key-wayed to ensure secure mechanical coupling with the drive motor shaft.

d) Tunnel ventilation fan impellor blades must be uniquely and permanently identifiable with traceability to the impellor hub assembly.

e) Tunnel ventilation fan impellor blades must be subject to non-destructive examination for Defects to demonstrate freedom from cracks and imperfections.

f) The Contractor must submit Tunnel ventilation fan impellor blade non-destructive examination methods as part of the Design Documentation.

g) Tunnel ventilation fan impellor blade non-destructive examination records must:

i) be uniquely identifiable and traceable to each blade; and

ii) be provided as part of the Quality Management Records.

4.6 Tunnel ventilation fan terminal boxes

a) Tunnel ventilation fan motor terminal boxes must:

i) utilise LSZH cabling;

ii) consist of an external motor terminal box on the fan casing;

iii) consist of an internal motor terminal box integral to the fan motor;

iv) utilise solid conduit to connect the internal and external terminal boxes;

v) utilise flexible connectors to absorb movement and vibration between terminal boxes;

vi) be sized to accommodate all cabling terminations associated with the fan motor; and

vii) be Readily Accessible for maintenance purposes.

b) Tunnel ventilation fan motor instrumentation terminal boxes must:

i) be separate from the fan motor terminal boxes;

ii) be mounted externally to the fan casing; and

iii) be Readily Accessible for maintenance purposes.

4.7 Tunnel ventilation fan motor RTDs

a) Tunnel ventilation fan motors must be provided with:

i) motor bearing RTDs; and

ii) motor winding RTDs.

b) Tunnel ventilation fan motor RTDs must:

i) be provided by the motor manufacturer as part of the motor assembly;

ii) be provided for both the drive end and non-drive end motor bearings;

iii) be positive temperature coefficient thermistors;

iv) be provided for each motor phase winding;

v) be located in phase winding hot spots as identified by the motor manufacturer;

vi) have a measurement range that that enables suitable warning and alarm setpoints;

vii) be connected to the PMCS to enable over temperature trip protection; and

viii) comply with AS/NZS IEC 60947.8 Low-voltage switchgear and controlgear, Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines.

4.8 Identification

a) Tunnel ventilation fans must be provided with:

i) fan identification plates on the fan casing;

ii) motor identification plates on the motor; and

iii) motor identification plates on the fan casing.

b) Tunnel ventilation fan identification plates must be readily visible when viewed from a position adjacent to the fan casing that is suitable for inspection and maintenance of the fan.

c) Tunnel ventilation fan casing and motor identification plates must include:

i) markings in accordance with AS/NZS IEC 60947.8 Low-voltage switchgear and control gear, Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines;

ii) information in accordance with section 3.6; and

iii) motor speed in revolutions per minute.

d) Tunnel ventilation fan motor identification plates must include:

i) information in accordance with section 3.6;

ii) nominal power rating;

iii) motor power factor; and

iv) electrical characteristics of the motor.

4.9 Condition monitoring

4.9.1 Condition monitoring system

a) Tunnel ventilation fans must be provided with instrumentation in accordance with this Master Specification Part to provide monitoring data to a condition monitoring system.

b) The condition monitoring system required by section 4.9.1a) must utilise industry best-practice condition monitoring software to analyse the monitoring data collected for the purposes of scheduling preventative maintenance and providing early warning of faults and failure.

c) The condition monitoring system must interface with each fan monitoring system including:

i) the vibration monitoring system required by section 4.9.2;

ii) the electrical monitoring system required by section 4.9.3; and

iii) the shock pulse monitoring system required by section 4.10.15 (Tunnel ventilation axial fans only).

d) The condition monitoring software required by section 4.9.1a) must be provided with a secure interface in accordance with RD-ITS-D1 “Design of Intelligent Transport Systems (ITS)” that enables remote monitoring of trend and real-time data, including the setting of condition monitoring system specific analysis parameters, alarms levels and thresholds.

e) The condition monitoring software required by section 4.9.1a) must retain historical monitoring data for the Design Life of the Tunnel ventilation fan and enable direct access to trend data across all channels and analysis parameters.

f) For each Tunnel ventilation fan, the condition monitoring system must trend data while the fan is both operational and on standby at regular intervals of no longer than 30 minutes.

g) For each Tunnel ventilation fan the condition monitoring system must collect datasets:

i) for the full duration of the start-up and run down of the fan;

ii) for the full duration of any warning and alarm condition; and

iii) at regular intervals of no more than 15 minutes while the fan is energised.

h) The condition monitoring system must interface to the PMCS to enable the PMCS to monitor:

i) the status of the condition monitoring system; and

ii) alarms from the condition monitoring system.

i) All set-points and parameters for the condition monitoring system must be user configurable within the PMCS.

4.9.2 Vibration monitoring system

a) The vibration monitoring system must continuously monitor temperature and vibration levels from Tunnel ventilation fans to provide data to the condition monitoring system required by section 4.9.1.

b) The vibration monitoring system must consist of instrumentation to:

i) monitor vibration and temperature on the non-drive end of the Tunnel ventilation fan motor;

ii) monitor vibration and temperature on the drive end of the Tunnel ventilation fan motor; and

iii) monitor vibration at distributed locations on the Tunnel ventilation fan support structure.

c) Vibration and temperature instrumentation required by section 4.9.1d) must be cabled back to a dedicated junction box mounted on the Tunnel ventilation fan support structure.

d) The vibration monitoring system must use a dedicated condition monitoring controller that:

i) sends overall levels to the PMCS for each instrument required by section 4.9.1d);

ii) sends warning and critical status information to the PMCS;

iii) receives PMCS based warning and critical set-point information from PMCS;

iv) receives Tunnel ventilation fan operating direction from the PMCS (where applicable);

v) receives Tunnel ventilation fan running status (on/off) from PMCS; and

vi) sends data to the condition monitoring software required by section 4.9.1.

e) The instrumentation required by section 4.9.1d) must be provided at sufficient locations to enable the vibration monitoring system to identify, as a minimum, the following:

i) imbalance in the Tunnel ventilation fan;

ii) bearing faults;

iii) anti-vibration mount condition;

iv) equipment deteriorating based on operating parameters; and

v) changes in the mechanical and support structure.

f) The vibration monitoring system must report each of the following for each vibration instrument required by section 4.9.1d):

i) derived peak;

ii) RMS;

iii) true peak; and

iv) high frequency (spectral band).

g) The vibration monitoring system must report each of the following aggregated across all of the vibration instrumentation required by section 4.9.1d):

i) crest factor;

ii) derived peak;

iii) peak to peak;

iv) RMS;

v) true peak; and

vi) high frequency (spectral band).

h) The vibration monitoring system must report each of the following from the temperature instrumentation required by section 4.9.1d):

i) drive end bearing temperature; and

ii) non-drive end bearing temperature.

4.9.3 Electrical monitoring system

a) The electrical monitoring system must continuously monitor electrical parameters from Tunnel ventilation fans to provide data to the condition monitoring system required by section 4.9.1.

b) The electrical monitoring system must be fully integrated with the condition monitoring system required by section 4.9.1.

c) The electrical monitoring system must consist of instrumentation to:

i) measure voltage supply prior to the Tunnel ventilation fan's VSD or soft starter; and

ii) measure current supply after the Tunnel ventilation fan's VSD or soft starter.

d) Electrical instrumentation required by section 4.9.3c) must be provided within MCCs serving the Tunnel ventilation fans.

e) The electrical monitoring system must use a dedicated condition monitoring controller that:

i) sends overall levels to the PMCS for each monitor required by section 4.9.3c);

ii) sends warning and critical status information to the PMCS;

iii) receives warning and critical set-point information from PMCS;

iv) receives fan operating direction from the PMCS (where applicable);

v) receives fan running status (on/off) from PMCS; and

vi) sends data to the condition monitoring software required by section 4.9.1.

f) The instrumentation required by section 4.9.3c) must be provided and configured such that the system is capable of identifying, as a minimum, the following:

i) unusual voltages in the Tunnel ventilation fan supply;

ii) voltage and current imbalance;

iii) voltage and current total harmonic;

iv) rotor eccentricity; and

v) rotor bar faults.

g) The electrical monitoring system must report the following for each Tunnel ventilation fan:

i) total input active power of the motor;

ii) motor efficiency;

iii) line frequency of the voltage bus;

iv) output load of the motor;

v) RMS values of voltage or current waveforms;

vi) motor rotational speed;

vii) maximum RMS for motor start-up currents as a percentage of the nameplate full load;

viii) motor load in percentage of the full load on the motor nameplate;

ix) magnitude of the fundamental phasor of voltage or current waveforms;

x) phase of the fundamental phasor of voltage or current waveforms;

xi) power factor of the motor;

xii) maximum magnitude of rotor bar sideband harmonics;

xiii) maximum instantaneous peak value of start-up motor currents;

xiv) time duration for the motor to remain in start-up state; and

xv) unbalance of 3-phase voltage buses or 3-phase motor currents in compliance with NEMA MG 1 Motors and Generators.

4.10 Tunnel ventilation axial fans

4.10.1 Tunnel ventilation axial fan performance

a) Tunnel ventilation axial fans must be designed for maximum aerodynamic efficiency at the design duty point and flow rate in the forward flow direction.

b) Tunnel ventilation axial fans that are single duty must have an aerodynamic efficiency in the forward flow direction of at least 70%.

c) Tunnel ventilation axial fans that have multiple duty points by VSD operation, must have maximum aerodynamic efficiency for the most frequently used duty point.

4.10.2 Arrangement

Tunnel ventilation axial fans must be:

a) suitable for horizontal or vertical mounting as required by the ventilation design; and

b) able to be operated individually or as part of a set arranged in parallel.

4.10.3 Reversibility

Tunnel ventilation axial fans that are reversible must:

a) have an aerodynamic efficiency in the reverse flow direction of at least 90% of the forward flow direction;

b) reverse from full flow in one direction to full flow in the opposing direction in 90 seconds or less;

c) change from full flow in one direction to full flow in the opposing direction with a de-energised period of 30 seconds or less; and

d) be rated for 6 starts per hour in either direction, including at least 3 reversals within 20 minutes.

4.10.4 Stalling

Tunnel ventilation axial fans must be:

a) able to be operated at all required duty points without stalling;

b) able to be started and increase speed continuously to the maximum operational design pressure without stalling; and

c) fitted with anti-stall devices as required to protect the fan against stall conditions.

4.10.5 Casing

In addition to the requirements of section 4.2, Tunnel ventilation axial fan casings must be:

a) fitted with a bushing that is normally closed by a secure plug that can be removed to enable testing using an anemometer or pitot-static probe; and

b) fitted with inspection hatches to enable access to the fan impellor and motor for inspection, commissioning, and maintenance.

4.10.6 Motors

In addition to the requirements of section 4.3, Tunnel ventilation axial fan motors must be:

a) selected for the range of pitch angles required; and

b) of the “totally enclosed, air over” or “totally enclosed, fan cooled” type.

4.10.7 Bearings

In addition to the requirements of section 4.4, Tunnel ventilation axial fan bearings must be:

a) provided with greasing points with removable covers for dust and water protection;

b) fitted with remote greasing facilities; and

c) supplied by greasing lines brought out of the fan and securely mounted to the casing.

4.10.8 Adjustable pitch blades

a) Tunnel ventilation axial fans must be fitted with adjustable pitch blades.

b) Tunnel ventilation axial fan adjustable pitch blades must:

i) be adjustable in their installed position when the fan is stationary via inspection hatches;

ii) be adjustable without the need to remove the hub;

iii) have index marks or a template that indicates the design operation blade setting;

iv) have a minimum of 3 adjustment increments above and below the design point;

v) be provided with blade stops to prevent angles that will overload the motor; and

vi) not seize over the Design Life of the Tunnel ventilation axial fan.

4.10.9 Mounting frame

a) Tunnel ventilation axial fans must be supplied complete with mounting frames that support and anchor the Tunnel ventilation axial fans.

b) Tunnel ventilation axial fan mounting frames must be coordinated with the structural design of the fan room and any plinths provided for the fan assembly.

c) Tunnel ventilation axial fan mounting frames must:

i) be designed to the design loads in section 3.3;

ii) withstand the high temperature rating in section 3.4; and

iii) facilitate ease of removal for maintenance.

4.10.10 Anti-vibration mounts and flexible connections

a) Tunnel ventilation axial fans must be mounted on anti-vibration spring mounts designed to isolate the fan vibration from the support structure.

b) Tunnel ventilation axial fan anti-vibration spring mounts must:

i) be designed to the design loads in section 3.3; and

ii) withstand the high temperature rating in section 3.4.

c) Tunnel ventilation axial fans must be provided with flexible connections between the flanges of the fan casing and any transition ductwork.

d) Tunnel ventilation axial fan flexible connections must:

i) isolate axial and transverse forces between the fan and the ductwork;

ii) be of sufficient length to allow for any vibration and thermal expansion; and

iii) withstand the high temperature rating in section 3.4.

4.10.11 Transition pieces and ductwork

a) Tunnel ventilation axial fans must be supplied complete with transitions, associated ductwork and connection pieces to attach fans, attenuators and dampers to form the required ventilation airflow path.

b) Transition pieces and associated ductwork must be manufactured from minimum 4 mm thickness galvanised mild steel.

c) Transition pieces and associated ductwork must be supplied complete with mounting frames or mounting supports.

d) Transition pieces, associated ductwork and mounts must be coordinated with the structural design of the fan room including pressure wall penetrations and any plinths provided for the Tunnel ventilation fan assembly.

e) Transition pieces and associated ductwork must be supplied complete with access hatches to enable inspection and adjustment of fans, dampers, and attenuators.

4.10.12 Surface treatment and protection

Tunnel ventilation axial fan casings, mounting frames, transition pieces and connected ductwork must be:

a) galvanised in accordance with section 3.5b);

b) electro-statically epoxy powder coated in accordance with AS 4506 Metal finishing - Thermoset powder coatings; and

c) supplied in a jet black finish (RAL 9005).

4.10.13 Identification

a) Tunnel ventilation axial fans must be supplied with identification to comply with section 3.6.

b) In addition to the requirements of section 4.8b), Tunnel ventilation axial fan casing identification plates must include the design duty point of the fan (pressure and airflow).

4.10.14 Control and monitoring

a) Tunnel ventilation axial fans must be provided with monitoring instruments including:

i) fan motor RTDs in accordance with section 4.7;

ii) continuous shock pulse monitoring in accordance with section 4.10.15;

iii) vibration monitoring system in accordance with section 4.9.2; and

iv) electrical monitoring system in accordance with section 4.9.3.

b) Tunnel ventilation axial fan monitoring instruments must interface with the PMCS to allow the PMCS to receive continuous real time data for each monitored parameter.

c) Tunnel ventilation axial fans must be supplied with manufacturer recommended measuring ranges and alarm set point levels for each type of monitoring instrument installed.

4.10.15 Continuous shock pulse monitoring

a) The continuous shock pulse monitoring system required by section 4.10.14a)ii) must consist of transducers to:

   i) monitor shock pulses on the non-drive bearings of each Tunnel ventilation axial fan motor; and

   ii) monitor shock pulses on the drive bearings of each Tunnel ventilation axial fan motor.

b) The continuous shock pulse monitoring system required by section 4.10.15a) must be:

   i) permanently installed;

   ii) fully automated;

   iii) suitable for use with variable speed axial fans; and

   iv) fully integrated with the condition monitoring system required by section 4.9.1.

c) The continuous shock pulse monitoring system must use a dedicated condition monitoring controller that:

   i) sends overall levels to the PMCS for each instrument required by section 4.10.15a);

   ii) sends warning and critical status information to the PMCS;

   iii) receives warning and critical set-point information from PMCS;

   iv) receives fan operating direction from the PMCS (where applicable);

   v) receives fan speed from the PMCS;

   vi) receives fan running status (on/off) from PMCS; and

   vii) sends data to the condition monitoring software required by section 4.9.1.

d) The instrumentation required by section 4.10.15a) must be provided and configured such that the system is capable of identifying, as a minimum, the following:

   i) severity of any bearing damage or wear;

   ii) bearing lubrication condition; and

   iii) indication of the location of the damage for damaged bearings.

4.11 Tunnel ventilation jet fans

4.11.1 Tunnel ventilation jet fan performance

Tunnel ventilation jet fans must be:

a) designed for maximum aerodynamic efficiency in the forward flow direction; and

b) able to operate in the required flow direction accounting for vehicle piston effects.

4.11.2 Arrangement

Tunnel ventilation jet fans must be designed for operating:

a) in an inclined position of up to 15° from the horizontal; and

b) grouped as a bank of jet fans within the Tunnel cross-section.

4.11.3 Reversibility

Tunnel ventilation jet fans that are reversible must:

a) generate at least 90% thrust in the reverse direction compared to the forward direction;

b) reverse from full flow in one direction to full flow in the opposing direction in 90 seconds or less;

c) change from full flow in one direction to full flow in the opposing direction with a de-energised period of 30 seconds or less; and

d) be rated for 6 starts per hour in either direction, including at least 3 reversals within 20 minutes.

4.11.4 Casing

In addition to the requirements of section 4.2, Tunnel ventilation jet fan casings must be provided with flange ends for assembly to noise silencers.

4.11.5 Motors

In addition to the requirements of section 4.3, Tunnel ventilation jet fans motors must be:

a) of the “totally enclosed, air over” type;

b) rated to 45 kW or less; and

c) earthed to multiple earthed neutral (TN-C-S).

4.11.6 Bearings

In addition to the requirements of section 4.4, Tunnel ventilation jet fan bearings must be:

a) of the “sealed for life” type; and

b) designed to achieve the required Design Life with no intermediate lubrication maintenance.

4.11.7 Fixed pitch blades

Tunnel ventilation jet fans must be fitted with fixed pitch blades that are not adjustable.

4.11.8 Silencers

a) Tunnel ventilation jet fans must be provided with silencers to achieve the noise requirements in accordance with TUN-ME-DC7 “Ventilation Design”.

b) Tunnel ventilation jet fan silencers must be:

   i) provided with a mild steel outer skin continuously welded to flanges;

   ii) provided with a bellmouth on the inlet side of the jet fan for unidirectional fans; and

   iii) provided with a bellmouth on both sides of the jet fan for reversible fans.

c) Tunnel ventilation jet fan silencer acoustic lining must be:

   i) perforated stainless-steel;

   ii) integral with the silencer body;

   iii) easily and readily replaceable;

   iv) non-combustible and non-toxic; and

   v) provided with dissimilar metal separation between the liner and the casing.

4.11.9 Mounting frame

a) Tunnel ventilation jet fans must be supplied with a mounting frame that supports the complete fan assembly including silencers from the Tunnel structure.

b) Tunnel ventilation jet fan mounting frames must:

   i) be designed such that no part of the Tunnel ventilation jet fan assembly and any associated ancillaries encroach on the vehicle envelope when installed in the Tunnel;

ii) provide bracing such that the Tunnel ventilation jet fan assembly remains stable during start-up, operation and shut down; and

iii) allow for the removal of any Tunnel ventilation jet fan without impacting the operation of all other Tunnel ventilation jet fans within the same Tunnel ventilation jet fan bank.

4.11.10 Anti-vibration mounts

a) Tunnel ventilation jet fans must be provided with anti-vibration mounts.

b) Tunnel ventilation jet fan anti-vibration mounts required by section 4.11.10a) must be:

i) designed to the design loads in section 3.3;

ii) supplied integral with the Tunnel ventilation jet fan assembly;

iii) neoprene or rubber in compression;

iv) designed to provide an isolation efficiency of 95% or greater;

v) supplied to suit the Tunnel ventilation jet fan's suspension from the mounting frame;

vi) supplied to suit the Tunnel ventilation jet fan's required angle of suspension; and

vii) of the same high temperature rating as the Tunnel ventilation jet fan in accordance with section 3.4a).

c) Tunnel ventilation jet fan anti-vibration mounts required by section 4.11.10a) must be designed such that a complete failure of an anti-vibration mount would not allow the Tunnel ventilation jet fan to fall.

4.11.11 Cradles

a) Tunnel ventilation jet fans must be supplied with cradles for installation and maintenance.

b) Tunnel ventilation jet fan cradles must be:

i) suitable for the proposed installation methodology;

ii) suitable for maintenance and removal of Tunnel ventilation jet fans using a scissor lift or similar platform; and

iii) fully protected from corrosion for the same Design Life as the Tunnel ventilation jet fans; and

c) Tunnel ventilation jet fan cradles must be provided for each type of Tunnel ventilation jet fan supplied.

4.11.12 Structural anchors

a) Tunnel ventilation jet fan frames and supports must be coordinated with cast-in ferrule locations where cast-in ferrules are provided for the anchoring of Tunnel ventilation jet fans.

b) Tunnel ventilation jet fan frames and supports must be coordinated with predefined drilling locations where Tunnel ventilation jet fans are anchored via post-drilling.

4.11.13 Surface treatment

In addition to the requirements of section 3.5, Tunnel ventilation jet fan casings, silencers and mounting frames must be electro-statically epoxy powder coated in accordance with AS 4506 Metal finishing - Thermoset powder coatings.

4.11.14 Identification

a) Tunnel ventilation jet fans must be supplied with identification in accordance with section 3.6.

b) In addition to the requirements of section 4.8b), Tunnel ventilation jet fan casing identification plates must include the design thrust of the fan.

4.11.15 Control and monitoring

a) Tunnel ventilation jet fans must be provided with monitoring instruments integrated with the PMCS including the following:

i) fan motor RTDs in accordance with section 4.7;

ii) vibration monitoring system in accordance with section 4.9.2; and

iii) electrical monitoring system in accordance with section 4.9.3.

b) Tunnel ventilation jet fans must be supplied with manufacturer recommended measuring ranges and alarm set point levels for each type of monitoring instrument installed.

5 Tunnel ventilation dampers

5.1 Tunnel ventilation damper performance

Tunnel ventilation dampers must be designed:

a) for a maximum average face air velocity of 10 m/s;

b) for a maximum loss coefficient of 0.5 for a face air velocity of 10 m/s when fully open;

c) to retain structural integrity for a face air velocity of up to 25 m/s;

d) to achieve Leakage Class 1 in accordance with UL 555S Smoke dampers;

e) to maintain performance after at least 2 million pressure cycles of ±2 kPA; and

f) for a differential pressure in either direction that is the greater of:

i) 200% of the maximum pressure the ventilation system can develop; or

ii) 6 kPa.

5.2 Arrangement

a) Tunnel ventilation dampers must be suitable for vertical, horizontal, and angled installation.

b) Tunnel ventilation dampers must:

i) be designed to be installed with the blade shafts horizontal;

ii) consist of modules for ease of installation and removal of the complete assembly;

iii) be configured for safe installation, maintenance, disassembly, and reassembly; and

iv) be provided with multiple lifting points suitable for lifting the complete assembly.

c) Tunnel ventilation dampers must have:

i) bearings located outside of the airstream; and

ii) actuators and bearings isolated from the heated airstream.

d) The requirement of section 5.2c) must not apply where the application warrants a special type of bearing, or where it is impossible to locate the bearings in a position that is clear of the airstream.

5.3 Modules

a) Tunnel ventilation dampers must be constructed of one or more modules to enable transport, installation, and removal.

b) Tunnel ventilation dampers must be designed to be assembled on Site by bolting each individual module onto a steelwork frame or concrete support.

c) Tunnel ventilation damper modules must be:

i) a complete factory assembled unit contained in a steel channel frame;

ii) interlinked to open and close in unison with other modules in the damper; and

iii) able to be removed from a damper without having to remove adjacent modules.

d) Tunnel ventilation dampers must have an open area of greater than 85% when measured inside the damper module frame.

5.4 Frames

a) Tunnel ventilation damper frames must:

i) have a minimum steel thickness of 3 mm;

ii) be galvanised mild steel or Grade 316 stainless steel;

iii) have channel type cross sections with a maximum web of depth 300 mm;

iv) have a maximum unsecured flange width of 55 mm on all 4 sides;

v) have a minimum secured flange width of 100 mm on all 4 side;

vi) be suitable for connection to ductwork, concrete or steel framing as required by the ventilation design;

vii) be designed for lifting without permanent distortion or buckling; and

viii) be provided with airflow direction arrows on all 4 sides of the frame.

b) Tunnel ventilation damper frame corners must be fully welded and suitably ground back prior to surface treatment and protection.

c) Tunnel ventilation damper blade seals must not locally wear the surface treatment of the Tunnel ventilation damper frame or blades.

5.5 Blades

a) Tunnel ventilation dampers must be the parallel or opposed blade type.

b) Tunnel ventilation damper blades must be:

i) Grade 316 stainless steel;

ii) hollow aerofoil cross-sections;

iii) between 100 mm and 200 mm in width as measured when fully open;

iv) within the depth of the damper frame when fully open; and

v) bolted to the shafts and not welded.

c) Tunnel ventilation damper blade shafts must:

i) extend the full width of the damper module; and

ii) be supported by maintenance free bearings at each end.

d) Tunnel ventilation damper shaft bearings must be removable for maintenance without disassembling adjacent Tunnel ventilation damper modules.

e) Tunnel ventilation dampers must have blades that deflect less than L/360 under maximum pressure differential loading.

5.6 Shafts and linkages

a) Tunnel ventilation dampers must be provided with:

i) drive shafts extending clear beyond the extents of the frame;

ii) drive arms designed to withstand the maximum torque of the fitted actuator; and

iii) a jackshaft or shafts installed between Tunnel ventilation damper modules to enable blades to operate simultaneously when one actuator drives multiple modules.

b) Tunnel ventilation damper shafts and linkages must be;

i) provided with bearing that are self-lubricating;

ii) adjustable and readily removable from the frame;

iii) designed for at least 150% of the rated actuator torque; and

iv) designed with a deflection to length ratio of less than 1/360.

5.7 Actuators

a) Tunnel ventilation dampers must be supplied complete with electrically operated fire rated actuators.

b) Tunnel ventilation damper actuators must be:

i) configured to operate no more than half of the modules of each Tunnel ventilation damper;

ii) electrically driven with a worm wheel gear box;

iii) suitable for 400 V 3 phase / 230 V single phase, 50 Hz power supply;

iv) provided with a hand wheel for manual operation;

v) provided with a visual position indicator;

vi) provided with over-travel and overload protection devices;

vii) fitted with anti-condensation heaters; and

viii) rated for at least 300,000 operating cycles without fatigue or loss of performance.

c) Tunnel ventilation damper actuators must be able to drive the blades:

i) from fully closed to fully open in 30 seconds or less;

ii) from fully open to fully closed in 30 seconds or less;

iii) under the operating pressure of the Tunnel ventilation fan system; and

iv) in a smooth action without shock or slamming.

d) Tunnel ventilation dampers that are modulating must have actuators selected to:

i) throttle the damper to balance the airflows as required by the design; and

ii) operate in maximum 5° increments between fully open and fully closed.

e) Tunnel ventilation damper actuators must be:

i) mounted on the outside frame and not unnecessarily obstruct the airflow;

ii) rigidly mounted in positions that allow in-situ servicing and ease of removal;

iii) fixed to the damper assembly via bolted connection utilising locking washers; and

iv) directly coupled to the damper shaft, inclusive of an anti-rotation fixing bracket to fix the actuator in place.

f) Tunnel ventilation damper actuators must be selected to achieve the fail-safe position defined by the ventilation design.

g) Tunnel ventilation dampers that fail in a single position (fail open or fail closed) must have a spring return mechanism to enable the fail-safe position to be achieved on loss of power.

h) Tunnel ventilation dampers that fail in the current position must be drive open and drive closed with no spring return mechanism.

i) Tunnel ventilation damper actuators must be selected such that each actuator has at least 50% excess torque capacity over that required to fully close the entire damper.

j) Tunnel ventilation damper actuators must be provided with integral torque limit switches that automatically protects the actuator against overloading.

5.8 Control and monitoring

a) Tunnel ventilation damper limit switches must:

i) be provided on each damper module to indicate the fully open position;

ii) be provided on each damper module to indicate the fully closed position;

iii) be positioned on the furthest blade shaft from the actuator coupled blade shaft;

iv) be protected against overvoltage, voltage spikes and electrical interference;

v) be wired to a dedicated terminal box using a fire rated cabling system of WS52W to AS/NZS 3013 Electrical installations - Classification of the fire and mechanical performance of wiring system elements;

vi) be rated for operation at 24 VDC; and

vii) provide a 4-20 mA analogue output signal to indicate the open and closed position.

b) Tunnel ventilation damper position transducers must:

i) be provided on modulating dampers in addition to limit switches;

ii) be provided for each modulating damper actuator;

iii) be protected against overvoltage, voltage spikes and electrical interference;

iv) be rated for operation at 24 VDC; and

v) provide a 4-20 mA analogue output signal to indicate the position.

c) Tunnel ventilation damper actuators for non-modulating dampers must:

i) receive a 4-20 mA analogue input to rotate the shaft between the open and closed position; and

ii) provide a 4-20 mA analogue output signal that enables an over-torque alarm in the PMCS.

d) Tunnel ventilation damper actuators for modulating dampers must:

i) receive a 4-20 mA analogue input to accurately rotate the shaft between the limits of its travel directly proportional to the input signal;

ii) provide a 4-20 mA analogue output signal that provides the damper position across the full travel range; and

iii) provide a 4-20 mA analogue output signal that enables an over-torque alarm in the PMCS.

5.9 Surface treatment

a) In addition to the requirements of section 3.5, Tunnel ventilation dampers must be suitable to be installed at a minimum 1% grade to mitigate water ponding.

b) Tunnel ventilation dampers that are hot dip galvanized must be electro-statically epoxy powder coated in accordance with AS 4506 Metal finishing - Thermoset powder coatings.

c) Tunnel ventilation damper actuators must be painted to achieve the Design Life requirements.

5.10 Identification

a) Tunnel ventilation dampers must be provided with identification plates on each:

i) damper module; and

ii) damper actuator.

b) Tunnel ventilation damper module identification plates must be provided with:

i) identification plate information in accordance with section 3.6; and

ii) unique identifiers for each module.

c) Tunnel ventilation damper actuator identification plates must be provided with:

i) identification plate information in accordance with section 3.6;

ii) with motor power and torque; and

iii) with spring rating (for spring return dampers only).

6 Tunnel ventilation attenuators

6.1 Tunnel ventilation attenuator performance

a) Tunnel ventilation attenuators must be designed:

i) for a maximum average face air velocity of 10 m/s;

ii) to retain structural integrity for a face air velocity of up to 25 m/s;

iii) for turbulent airflow effects and variable high pressures between splitters;

iv) for bi-directional airflow when required for the connected fan operations;

v) for aerodynamic efficiency to minimise the attenuator pressure drop;

vi) to withstand 125% of the maximum pressure that can be developed by the ventilation system;

vii) to achieve the required insertion loss for all axial fan operational scenarios; and

viii) to account for self-generated noise of the attenuator in the required insertion loss.

b) Tunnel ventilation attenuators must be provided with sound-absorbing fill material that is:

i) non-combustible;

ii) non-toxic; and

iii) stable at the temperatures specified in section 3.4.

6.2 Arrangement

a) Tunnel ventilation attenuators must be suitable for:

i) horizontal or vertical mounting as required by the ventilation design; and

ii) in-duct or common plenum arrangements as required by the ventilation design.

b) Tunnel ventilation attenuators must:

i) consist of modules for ease of installation and removal of the complete assembly;

ii) be configured for enable safe installation, maintenance, disassembly, and reassembly;

iii) be provided with multiple lifting points suitable for lifting each module; and

iv) be supplied such that any baffling, sealing, or finishing required for installation maintains the acoustic performance of the attenuator.

6.3 Casings

a) Tunnel ventilation attenuator casings must be constructed of either:

i) stainless steel not less than 3 mm thick; or

ii) galvanised mild steel not less than 3 mm thick.

b) Tunnel ventilation attenuator casings must be:

i) constructed as modules with sections not exceeding 2 m in length;

ii) bolted together to achieve an airtight seal between modules;

iii) provided with flanges or hardware for connection to ductwork or headwall as required by the ventilation system design; and

iv) lined with the same acoustic material and sheet steel as the splitters.

6.4 Splitters

a) Tunnel ventilation attenuators must be ductwork style rectangular parallel splitter type.

b) Tunnel ventilation attenuators must be provided with:

i) a splitter no longer than 2 m; and

ii) a means of securely interlocking splitters to achieve a tight fit and minimise free-play.

c) Tunnel ventilation attenuator splitters must:

i) be non-hygroscopic vermin proof glass wool or equivalent;

ii) be covered with a gauze scrim to prevent erosion of fibres;

iii) be faced with perforated Grade 304 stainless steel sheet of minimum 1 mm thickness;

iv) have perforated sheet that is CNC machined or punched from sheet;

v) have perforated sheet that is border free from perforations where rivets are fastened;

vi) have perforated sheet that is fixed to the splitters with larger head rivets;

vii) have perforated sheet that is fixed to the splitters with equally spaced rivets; and

viii) be fixed with Grade 304 stainless steel fastenings and fixings.

d) Tunnel ventilation attenuator splitters must be provided with rigidly added bull noses:

i) designed to reduce entry pressure losses;

ii) that are smooth with no perforations;

iii) on the splitter leading edges facing the airflow; and

iv) on both ends of splitters used for bi-directional airflow.

6.5 Frames and fixings

a) Tunnel ventilation attenuators must be supplied complete with all support frames, fixings, and associated structure necessary to accommodate the Site installation conditions.

b) Tunnel ventilation attenuator frames must:

i) be galvanized rectangular hollow sections or galvanized channel sections;

ii) support and secure the modules in place; and

iii) prevent lateral movement between individual modules once installed and operational.

6.6 Surface treatment

a) Tunnel ventilation attenuators must be corrosion protected by either:

i) a hot-dip zinc-aluminium-magnesium alloy coated steel sheeting; or

ii) Grade 304 stainless steel.

b) Tunnel ventilation attenuator components that are galvanized must be:

i) galvanized in accordance with section 3.5; and

ii) painted with a primer followed by a minimum of 3 topcoats.

6.7 Identification

a) Tunnel ventilation attenuators must be provided with identification plates on each:

i) attenuator module; and

ii) attenuator splitter.

b) Tunnel ventilation attenuator module identification plates must be provided with:

i) identification plates in accordance with section 3.6; and

ii) a unique identifier for each module.

c) Tunnel ventilation attenuator splitter identification plates must be provided with:

i) identification plates in accordance with section 3.6; and

ii) a unique identifier for each splitter.

7 Reliability, Design Life, and functional safety requirements

a) Tunnel ventilation equipment must be designed and supplied to comply with the systems engineering requirements and the analysis for reliability, availability, maintainability, and safety (RAMS) in accordance with PC-EDM6 “Systems Engineering Management”.

b) Tunnel ventilation axial fans must be designed to achieve a MTBF of greater than 100,000 hours.

c) Tunnel ventilation jet fans must be designed to achieve a MTBF of greater than 40,000 hours.

d) Tunnel ventilation dampers must be designed to achieve a MTBF equivalent to greater than 40,000 operating cycles.

e) Tunnel ventilation equipment must comply with the Design Life requirements of the Contract Documents.

8 Maintainability

The Contractor must ensure that the Tunnel ventilation equipment is:

a) designed for safe maintenance access;

b) designed to be readily removable from any mounting frame and connected ductwork; and

c) supplied with 2 complete sets of any specialised tools required for the assembly, maintenance, or replacement of any component of the equipment.

9 Transportation, packing and storage

a) Tunnel ventilation components that are transported unassembled must be packed ensuring that they are not in contact with other components or equipment.

b) Tunnel ventilation components that are transported unassembled must be packed ensuring that they have no external loads applied on them.

c) Tunnel ventilation components that are transported unassembled must be catalogued to enable identification and location of individual blades within the packaging.

d) Tunnel ventilation dampers must be transported to Site in modules for final assembly.

e) Tunnel ventilation attenuators must be transported to Site in modules for final assembly.

f) Any spare items for Tunnel ventilation equipment provided must be:

i) packaged suitable for long-term indoor storage; and

ii) clearly identified with the Project details, contents, description, and quantities.

10 Hold Points and Witness Points

a) Table TUN-ME-DC6 10-1 details the review period or notification period, and type (documentation or construction quality) for each Hold Point referred to in this Master Specification Part.

b) Table TUN-ME-DC6 10-2 details the review period or notification period, and type (documentation or construction quality) for each Witness Point referred to in this Master Specification Part.

Table TUN-ME-DC6 10-1 Hold Points

Section reference	Hold Point	Documentation or construction quality	Review period or notification period
11.2c)	Type test certification for Tunnel ventilation equipment	Documentation	20 Business Days review
11.3b)	Non-destructive examination methods for Tunnel ventilation equipment	Documentation	20 Business Days review
11.5.1a)	Tunnel ventilation equipment Factory Acceptance Testing plans	Documentation	20 Business Days review
11.5.1h)	Tunnel ventilation equipment Factory Acceptance Testing results and compliance documentation	Documentation	20 Business Days review

Table TUN-ME-DC6 10-2 Witness Points

Section reference	Witness Point	Documentation or construction quality	Review period or notification period
11.5.1b)	Tunnel ventilation equipment Factory Acceptance Testing	Construction quality	40 days notification

11 Verification requirements and records

11.1 General

Testing and commissioning procedures and documentation must comply with the requirements of PC-CN1 “Testing and Commissioning”.

11.2 Type certification

a) As part of the Design Documentation, the Contractor may propose that current type test certificates replace the Factory Acceptance Testing of Tunnel ventilation equipment required by section 11.5.

b) Where type test certification is approved by the Principal, Tunnel ventilation equipment type testing must be undertaken:

   i) by a third party NATA accredited facility (or equivalent) that is certified for performance testing for the specific type of equipment; and

   ii) for the complete assembly in the final configuration including all ancillaries and surface protection applied.

c) Where the Principal has approved the use of type test certification as part of the Design Documentation review process, the type test certification for Tunnel ventilation equipment must be submitted to the Principal for approval, which constitutes a **Hold Point**. Production of the relevant Tunnel ventilation equipment or Factory Acceptance Testing of that equipment must not take place until the Hold Point is released.

11.3 Non-destructive examination

a) Non-destructive evaluation of Tunnel ventilation equipment must be undertaken for all:

   i) Tunnel ventilation fan impellor blades;

   ii) Tunnel ventilation fan impellor hubs;

   iii) Tunnel ventilation fan casing and motor mount welds;

   iv) Tunnel ventilation fan support frames welds;

   v) Tunnel ventilation fan cradle welds; and

   vi) Tunnel ventilation damper welds.

b) The Contractor must submit non-destructive examination methods for Tunnel ventilation equipment to the Principal for approval, which constitutes a **Hold Point**. The non-destructive examination of Tunnel ventilation equipment must not commence until this Hold Point is released.

c) Non-destructive examination of Tunnel ventilation equipment must be recorded to be uniquely identifiable and traceable to each element examined.

d) Non-destructive examination must be undertaken for Tunnel ventilation equipment:

   i) to demonstrate freedom from imperfections and cracking;

   ii) using visual and dye penetration inspection methods to identify surface Defects; and

   iii) using ultrasonic or radiographic methods to identify internal Defects.

e) Tunnel ventilation fan blades and hubs must be subject to radiographic methods to identify internal Defects.

f) The Contractor must submit non-destructive examination results and documentation for Tunnel ventilation equipment to the Principal for approval as part of the Construction Documentation.

11.4 Balancing

a) Tunnel ventilation fans must be:

   i) statically and dynamically balanced;

   ii) balanced in accordance with ISO 21940-11 Mechanical vibration - Rotor balancing, Part 11: Procedures and tolerances for rotors with rigid behaviour; and

iii) balanced to the fan application category BV-4 in accordance with ISO 14694 Industrial fans - Specifications for balance quality and vibration levels.

b) Tunnel ventilation fans must achieve a maximum vibration of 4.5 mm/s once balanced.

c) The Contractor must submit Tunnel ventilation fan balancing certification to the Principal for approval as part of the Construction Documentation.

11.5 Factory Acceptance Testing

11.5.1 General

a) The Contractor must submit Tunnel ventilation equipment Factory Acceptance Testing plans to the Principal for approval, which constitutes a **Hold Point**.

b) The Contractor must invite the Principal to attend the Tunnel ventilation equipment Factory Acceptance Testing, which constitutes a **Witness Point**.

c) Tunnel ventilation equipment Factory Acceptance Testing must be undertaken with the assembly in the final configuration including all surface protection and painting applied.

d) Tunnel ventilation equipment performance Factory Acceptance Testing must be certified by a third party NATA accredited test facility (or equivalent) that is certified for performance testing for the specific type of equipment.

e) Tunnel ventilation equipment subject to high temperature testing must not form part of the supplied equipment.

f) Tunnel ventilation equipment construction and quality Factory Acceptance Testing must be undertaken for each Tunnel ventilation equipment assembly to be supplied.

g) Tunnel ventilation equipment Factory Acceptance Testing must be documented to demonstrate compliance with the requirements of this Master Specification Part.

h) The Contractor must submit Tunnel ventilation equipment Factory Acceptance Testing results and compliance documentation to the Principal for approval prior to manufacture of the equipment to be supplied, which constitutes a **Hold Point**.

i) Tunnel ventilation fan motors must be tested in accordance with the requirements of AS 60034 Rotating electrical machines including:

i) performance tests on each type of motor; and

ii) routine tests on all motors.

11.5.2 Tunnel ventilation axial fans

a) Tunnel ventilation axial fan performance verification Factory Acceptance Testing must be undertaken for each type of Tunnel ventilation axial fan and variation in duty point to be supplied.

b) Tunnel ventilation axial fan performance verification Factory Acceptance Testing for high temperature must be undertaken for each type of Tunnel ventilation axial fan and at the duty points to be supplied where the Tunnel ventilation axial fans could be exposed to high temperature airflows.

c) Tunnel ventilation axial fan performance verification Factory Acceptance Testing must include:

i) high temperature tests in accordance with ISO 21927-3 Smoke and heat control systems, Part 3: Specification for powered smoke and heat exhaust ventilators (or EN 12101-3 Smoke and heat control systems, Part 3: Specifications for powered smoke and heat control ventilators (Fans));

ii) performance testing for the required range of blade pitch angles in accordance with ISO 5801 Industrial fans - Performance testing using standardised airways;

iii) noise tests for ducted fans to provide sound power levels in accordance with ISO 5136 Acoustics - Determination of sound power radiated into a duct by fans and other air-moving devices - In-duct method;

iv) noise tests for open ended fans in accordance with ISO 3744 Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane to provide sound power levels;

v) measurement of fan static pressure as a function of airflow rate;

vi) measurement of fan total pressure as a function of airflow rate;

vii) efficiency curves with the fan pressure curves;

viii) a maximum speed test at 100% of rated speed for 3 minutes;

ix) an over-speed test at 125% of maximum rated speed for 3 minutes;

x) noise tests at the nominal design duty point;

xi) noise tests at the maximum flow rate;

xii) measurements of the motor voltage, current, absorbed power and power factor;

xiii) proving the number of starts per hour;

xiv) proving of the reversing cycle and timing (for reversible Tunnel ventilation axial fans only);

xv) proving the instrumentation including output values when the fan is operating; and

xvi) demonstrating the vibration instrumentation output by comparison to separate independent vibration instrumentation.

d) Tunnel ventilation axial fan construction and quality Factory Acceptance Testing must be undertaken for each Tunnel ventilation axial fan supplied.

e) Tunnel ventilation axial fan construction and quality Factory Acceptance Testing must include:

i) a maximum speed test at 100% of rated speed for 3 minutes;

ii) an over-speed test at 125% of maximum rated speed for 3 minutes;

iii) vibration measurements for each speed test using the supplied vibration instrumentation and separate independent vibration instrumentation;

iv) measurements of the motor voltage, current, absorbed power and power factor;

v) proving of the reversing cycle and timing (for reversible Tunnel ventilation axial fans only);

vi) proving the instrumentation including output values when the fan is operating; and

vii) visual inspection of the Tunnel ventilation axial fan for manufacturing and assembly Defects.

11.5.3 Tunnel ventilation jet fans

a) Tunnel ventilation jet fan performance verification Factory Acceptance Testing must be undertaken for each type of Tunnel ventilation jet fan and variation in nominal thrust to be supplied.

b) Tunnel ventilation jet fan performance Factory Acceptance Testing must include:

i) thrust performance testing in accordance with ISO 13350 Fans - Performance testing of jet fans;

ii) noise level performance testing in accordance with ISO 13350 Fans - Performance testing of jet fans;

iii) high temperature tests in accordance with ISO 21927-3 Smoke and heat control systems, Part 3: Specification for powered smoke and heat exhaust ventilators (or EN 12101-3 Smoke and heat control systems, Part 3: Specifications for powered smoke and heat control ventilators (Fans));

iv) measurements of developed thrust in the forward direction;

v) measurements of developed thrust in the reverse directions (where applicable);

vi) a maximum speed test at 100% of rated speed for 3 minutes;

vii) an over-speed test at 125% of maximum rated speed for 3 minutes;

viii) measurements of thrust and speed of rotation at the duty point;

ix) measurements of the motor voltage, current, absorbed power and power factor;

x) proving of the reversing cycle and timing (for reversible Tunnel ventilation jet fans only); and

xi) proving the instrumentation including output values when the fan is operating.

c) Tunnel ventilation jet fan construction and quality Factory Acceptance Testing must be undertaken for each Tunnel ventilation jet fan supplied.

d) Tunnel ventilation jet fan construction and quality Factory Acceptance Testing must include:

i) a maximum speed test at 100% of rated speed for 3 minutes;

ii) an over-speed test at 125% of maximum rated speed for 3 minutes;

iii) vibration measurements for each speed test;

iv) measurements of the motor voltage, current, absorbed power and power factor;

v) proving the number of starts per hour;

vi) proving of the reversing cycle and timing (for reversible Tunnel ventilation jet fans only);

vii) proving the instrumentation including output values when the fan is operating; and

viii) visual inspection of the Tunnel ventilation jet fans for manufacturing and assembly Defects.

e) Tunnel ventilation jet fan cradle construction and quality Factory Acceptance Testing must be undertaken for each Tunnel ventilation jet fan cradle supplied.

f) Tunnel ventilation jet fan cradle construction and quality Factory Acceptance Testing must include:

i) proving the capabilities of the cradle to perform all functions with a complete Tunnel ventilation jet fan;

ii) testing lifting capacity of the cradle with at least twice the intended working load; and

iii) visual inspection of the cradle for manufacturing and assembly Defects before and after completion of both section 11.5.3f)i) and section 11.5.3f)ii).

11.5.4 Tunnel ventilation dampers

a) Tunnel ventilation damper performance Factory Acceptance Testing must be undertaken for each type of Tunnel ventilation damper to be supplied.

b) Tunnel ventilation damper performance Factory Acceptance Testing must include:

i) testing undertaken in accordance with EN 1751 Ventilation for buildings - Air terminal devices - Aerodynamic testing of damper and valves;

ii) performance curves for pressure drop versus flow across the damper face area;

iii) performance curves for duct pressure versus leakage across the damper face area;

iv) the high temperature performance requirements of section 3.4b) in accordance with BS 476-20 Fire tests on Building Materials and Structures - Part 20: Method for Determination of the Fire Resistance of Elements of Construction (General Principles);

v) proving the dampers achieve Leakage Class 1 in accordance with UL 555S Smoke dampers;

vi) maximum pressure drop across the damper in the fully open position with a uniform face velocity of 10 m/s;

vii) maximum blade deflection at 125% of the maximum pressure that can be developed by the ventilation system;

viii) maximum linkage deflection to length ratio prior to breakage;

ix) proving the limit switches correctly indicate when the damper is opened and closed;

x) for modulating dampers proving the modulation capability from fully closed to fully open in modulation increments of 5° and vice versa;

xi) for modulating dampers proving the position transducers correctly indicate all possible positions of the damper;

xii) proving the failure position of the damper; and

xiii) measurements of the actuator motor voltage and current.

c) Tunnel ventilation damper construction and quality Factory Acceptance Testing must be undertaken for each Tunnel ventilation damper supplied.

d) Tunnel ventilation damper construction and quality Factory Acceptance Testing must include:

i) trial assembly of each damper assembly type;

ii) proving the open and close operation of the damper;

iii) proving the failure position of the damper;

iv) proving all instrumentation functions correctly;

v) measurements of the actuator motor voltage and current; and

vi) visual inspection of the dampers for manufacturing and assembly Defects.

11.5.5 Tunnel ventilation attenuators

a) Tunnel ventilation attenuator performance Factory Acceptance Testing must be undertaken for each type of Tunnel ventilation attenuator to be supplied.

b) Tunnel ventilation attenuator performance Factory Acceptance Testing must include:

i) testing in accordance with ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air-terminal units - Insertion loss, flow noise and total pressure loss;

ii) insertion loss performance across the frequency bands;

iii) performance curves for regenerated noise versus airflow through the attenuator;

iv) performance curves for pressure loss versus airflow through the attenuator; and

v) the high temperature performance requirements of section 3.4c) in accordance with BS 476-20 Fire Tests on Building Materials and Structures - Part 20: Method for Determination of the Fire Resistance of Elements of Construction (General Principles).

c) Tunnel ventilation attenuator construction and quality Factory Acceptance Testing must be undertaken for each Tunnel ventilation attenuator supplied.

d) Tunnel ventilation attenuator construction and quality Factory Acceptance Testing must include:

i) trial assembly of the modules to form the overall attenuator configuration;

ii) proving that the splitters can be readily inserted and removed; and

iii) visual inspection of the attenuators for manufacturing and assembly Defects.