Master Specification
Part TUN-ME-DC7

Ventilation Design

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Government of South Australia
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Contents

TUN-ME-DC7 Ventilation Design

1 General

a) This Master Specification Part sets out the requirements for the design and testing and commissioning of ventilation systems for Tunnel infrastructure including:

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

ii) the technical requirements, as set out in section 3;

iii) the control and monitoring requirements, as set out in section 4;

iv) the reliability, Design Life, and functional safety requirements, as set out in section 5;

v) the maintainability requirements, as set out in section 6; and

vi) the verification and testing requirements, as set out in section 7.

b) For the purposes of this Master Specification Part, ventilation systems for Tunnel infrastructure include the following subsystems:

i) Tunnel carriageway ventilation systems;

ii) Tunnel egress pressurisation systems;

iii) Tunnel services passageway ventilation systems;

iv) Tunnel sump ventilation systems; and

v) Tunnel equipment room ventilation systems.

c) This Master Specification Part does not apply to:

i) Tunnel carriageway ventilation systems for Tunnels with bi-directional traffic;

ii) heating, ventilation and air conditioning (HVAC) systems for surface infrastructure;

iii) HVAC systems for plant rooms (refer to TUN-FAC-DC1 “Requirements for Tunnel Facilities”); or

iv) HVAC systems for remote facilities such as maintenance areas and control rooms.

d) The design and testing and commissioning of ventilation systems for Tunnel infrastructure must comply with the Reference Documents, including:

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

ii) AS 1668.1 The use of ventilation and air conditioning in buildings, Part 1: Fire and smoke control in buildings;

iii) AS 1668.2 The use of ventilation and air conditioning in buildings, Part 2: Mechanical ventilations in buildings;

iv) AS 1682 Fire, smoke and air dampers;

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

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

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

viii) AS 4391 Smoke management systems - Hot smoke test;

ix) AS 4825 Tunnel fire safety; and

x) AS/NZS 60079 Explosive atmospheres.

e) Without limiting the obligation to comply with the document to the extent they form Reference Documents in other Master Specification Parts, the following guidance documents must be considered and applied to the extent required by Law and to meet the Contractor's Best Industry Practice obligations:

i) PIARC Road Tunnels: Vehicle Emissions and Air Demand for Ventilation, 2019R02EN;

ii) PIARC Pollution by Nitrogen Dioxide in Road Tunnels;

iii) Australian Design Rules - Emission Control Set;

iv) AGRT Part 2: Planning, Design and Commissioning; and

v) In-Tunnel Air Quality (Nitrogen Dioxide) Policy, NSW Advisory Committee on Tunnel Air Quality.

f) Without limiting the Contractor's obligation to comply with the Contract Documents, including the Master Specification, the Tunnel ventilation systems must comply with all relevant derived requirements from:

i) the Fire Engineering processes required by TUN-FIRE-DC3 "Tunnel Fire Engineering";

ii) TUN-PMCS-DC1 "Tunnel Plant Monitoring and Control Systems";

iii) TUN-ME-DC6 "Tunnel Ventilation Equipment"; and

iv) TUN-ME-DC5 "Supply of Tunnel Air Monitoring Instrumentation".

g) The ventilation plant and equipment comprising the ventilation systems which are the subject of this Master Specification Part must not be used to support temporary ventilation as required by TUN-CIV-DC1 "Tunnel Civil Requirements" prior to completion of the civil construction Works.

2 Documentation

2.1 Design Documentation

2.1.1 General

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

a) Ventilation Modelling Report in accordance with section 2.1.3; and

b) Ventilation Functionality Report in accordance with section 2.1.5.

2.1.2 Design Basis

In addition to the requirements of PC-EDM1 "Design Management", the Design Basis must include:

a) Tunnel alignment and geometry;

b) vehicle aerodynamic parameters;

c) Tunnel aerodynamic parameters;

d) normal operations traffic parameters including hourly vehicle volumes during the day;

e) normal operations lane capacity traffic volumes;

f) definition of the design case traffic scenarios;

g) ambient background air quality;

h) ambient wind conditions;

i) Tunnel portal pressures;

j) vehicle age parameters;

k) vehicle group profile;

l) vehicle fuel type profile;

m) Australian Design Rules applied to the vehicle profile for emissions modelling;

n) conversion factors for nitrogen oxides to nitrogen dioxide;

o) methodology for determining the air flows to control smoke backlayering at the fire location;

p) preliminary ventilation jet fan installation factors;

q) descriptions of proposed modelling software to be used;

r) modelling software verification details;

s) egress passageway geometric details;

t) egress passageway design parameters;

u) services passageway geometric details;

v) services passageway heat loads;

w) services passageway smoke management design parameters;

x) Tunnel equipment room locations and geometry;

y) Tunnel equipment room heat loads;

z) Tunnel equipment room temperature and air quality design parameters;

aa) Tunnel drainage sump location and geometry; and

bb) design assumptions.

2.1.3 Ventilation Modelling Report

a) The Ventilation Modelling Report required by section 2.1.1a) must include:

i) at Preliminary Design review:

A. a description of the modelling methodology;

B. details of the modelling software required by sections 3.1.9a) and 3.1.9f);

C. model software verification and validation details as required by section 3.1.9i);

D. description of the Tunnel ventilation strategy and system design;

E. a list of modelling input parameters including any changes from the Design Basis;

F. methodology showing all steps to derive vehicle emissions;

G. vehicle emission tables derived from the input parameters defined in the Design Basis which includes:

I. carbon monoxide emissions;

II. nitrogen oxides emissions; and

III. exhaust and non-exhaust generated particulate matter emissions;

H. preliminary modelling results showing air quality outcomes for all operating scenarios including:

I. Tunnel air-quality profiles and airflows for the full range of normal operations traffic speeds;

II. total Tunnel emissions generated for the full range of normal operations traffic speeds;

III. Tunnel air-quality profiles and airflows for incident operations; and

IV. Tunnel air-quality profiles and airflows for sensitivities including stopped traffic conditions;

I. details demonstrating in-Tunnel air quality compliance as required by section 3.1.3;

J. vehicle emissions and discharge condition parameters (e.g. airflows and temperatures) for use in ambient air quality assessments;

K. analysis to determine vehicle carbon dioxide emissions and in-Tunnel concentrations (if required to be used in concrete carbonation durability assessments);

L. analysis to demonstrate the requirements for smoke control velocities and flowrates;

M. preliminary modelling results demonstrating that emergency operations requirements can be achieved including;

I. egress passageway ventilation requirements; and

II. service passageway ventilation requirement; and

N. preliminary modelling results demonstrating the ability of the ventilation system design to achieve:

I. sump ventilation requirements;

II. equipment room ventilation requirements; and

III. optimal balance as specified in section 3.1.7;

ii) at Detailed Design review:

A. design development from the Preliminary Design;

B. updates to modelling input parameters;

C. updated modelling results based on design development, showing air quality outcomes for all operating scenarios including those scenarios set out in section 2.1.3a)i)H;

D. updated vehicle emissions and discharge parameters for use in ambient air quality assessments;

E. analysis and modelling to determine requirements for smoke control velocities and flowrates;

F. updated modelling results demonstrating that emergency operations requirements can be achieved;

G. clear definition of the ventilation system capability and limitations for incident scenarios in order to inform operational procedures;

H. modelling results to demonstrate that egress pressurisation systems meet performance requirements;

I. Tunnel temperature conditions for different non-emergency operations;

J. all modelling coordinated with other disciplines;

K. all modelling is complete with updates only required to address changes by other disciplines; and

L. documented outcomes and requirements to enable Final Design development by other disciplines; and

iii) at Final Design review:

A. only document design updates required to address changes by other disciplines;

B. document results from unheated airflow fire scenarios for use in cold flow tests during testing and commissioning; and

C. document the required ventilation modes for all operating scenarios.

b) The Ventilation Modelling Report must be updated in accordance with PC-EDM1 “Design Management” for:

i) Issued for Acceptance; and

ii) Issued for Construction.

2.1.4 Design Report

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

i) at Preliminary Design review:

A. description of the Tunnel ventilation system strategy including the objectives and operating modes;

B. description of the Tunnel ventilation system elements including the equipment and associated accessories;

C. a list of input parameters and design assumptions including any changes from the Design Basis;

D. preliminary space-proofing including equipment arrangement, installation, access and maintenance clearance requirements;

E. preliminary equipment installation, lifting and removal methodology;

F. preliminary ventilation schematics showing;

I. airflow paths;

II. airflow quantities for different operations;

III. equipment; and

IV. equipment connectivity;

G. preliminary equipment schedules and datasheets including:

I. axial fans;

II. jet fans;

III. dampers;

IV. attenuators;

V. instruments and sensors; and

VI. plantroom ventilation systems;

H. preliminary equipment schedules and datasheets in the same format that will be used in Detailed Design;

I. preliminary power and energy consumption requirements including:

I. power profiles for each hour of each day of the week;

II. annual energy use; and

III. breakdown of use between ventilation sub-systems;

J. technical information to demonstrate that the ventilation design achieves the required ventilation responses for each PMCS mode;

K. description of provisions for mitigation of break-out noise from the plantrooms, shafts, plenums and louvres; and

L. interface requirements with other systems;

ii) at Detailed Design review:

A. development and changes from Preliminary Design;

B. updates to input parameters and design assumptions;

C. final space-proofing including any updates to the equipment arrangement, installation, access and maintenance clearance requirements;

D. Tunnel carriageway ventilation equipment installation, lifting and removal methodology, as required by section 3.1.8p);

E. updates to equipment installation, lifting and removal methodology;

F. updates to ventilation schematics;

G. updates to equipment schedule required by section 2.1.4a)i)G;

H. updates to power and energy consumption required by section 2.1.4a)i)I;

I. updates to provisions for mitigation of break-out noise from the plantrooms, shafts, plenums and louvres;

J. results of in-Tunnel and external acoustic assessments demonstrating compliance;

K. ventilation response tables providing in a matrix format a description of the operational status of the individual ventilation fans and dampers for all operating scenarios;

L. evidence that the Tunnel carriageway ventilation strategy, design and operation achieves the in-Tunnel environmental requirements set out in the Contract Documents, as required by section 3.1.3a);

M. evidence that the Tunnel carriageway ventilation strategy, design and operation achieves the external air quality environmental requirements set out in the Contract Documents as required by section 3.1.5;

N. evidence that all Tunnel ventilation monitoring instrumentation arrangements will comply with manufacturer recommendations;

O. identification of all deviations to manufacturer recommendations for Tunnel ventilation monitoring instrumentation arrangements;

P. detailed analysis and justification to confirm the Tunnel ventilation monitoring instrumentation performance requirements will be achieved for each deviation identified by section 2.1.4a)ii)O;

Q. detailed interface requirements with other systems;

R. equipment datasheets including sufficient technical information to enable procurement; and

S. all design is complete with updates only required to address changes by other disciplines; and

iii) at Final Design review, any developments that result from the Detailed Design stage including changes resulting from other disciplines.

b) The Design Report must be updated in accordance with PC-EDM1 “Design Management” for:

i) Issued for Acceptance; and

ii) Issued for Construction.

2.1.5 Ventilation Functionality Report

a) The Ventilation Functionality Report required by section 2.1.1b) must include:

i) sufficient detail to be a standalone report that does not require reference to other documentation in order to be used for operational purposes and control system programming;

ii) at Preliminary Design review:

A. definition of the ventilation scenarios for each PMCS mode;

B. preliminary ventilation response tables derived from the Ventilation Modelling Report and Design Report;

C. narrative and schematic descriptions of the functionality for each ventilation response;

D. the control priority for each PMCS mode and ventilation response;

E. equipment interlocking methodology required for safe ventilation operation; and

F. fail-safe operation of all mechanical devices;

iii) at Detailed Design review:

A. input/output lists for each ventilation instrument and sensor;

B. input/output lists for ventilation equipment that includes event and alarm triggers;

C. ventilation control algorithms (VCAs) and control functionality for:

I. each ventilation response;

II. control and protection of each ventilation device;

III. equipment duty sharing, transitioning, starting and stopping;

IV. fault detection and managing equipment failures;

V. self-test capabilities; and

VI. routine testing and maintenance;

D. control parameters and settings to automatically trigger and release ventilation responses; and

E. ventilation response tables that detail the transition and ultimate state of each ventilation device; and

iv) at Final Design Review, be fully coordinated with the requirements of the PMCS programmer to enable programming of the ventilation system functionality.

b) The Ventilation Functionality Report must be updated in accordance with PC-EDM1 “Design Management” for:

i) Issued for Acceptance; and

ii) Issued for Construction.

2.1.6 Design Drawings

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

a) ventilations schematics showing the equipment arrangement;

b) equipment arrangement plantroom layouts;

c) equipment arrangement plantroom longitudinal and cross sections;

d) equipment delivery route and equipment clearances for maintenance;

e) ventilation jet fan arrangement and location drawings showing coordination with other Tunnel services and Tunnel fixtures to maximise ventilation jet fan performance;

f) clearance for installation, access and maintenance;

g) Tunnel ventilation control system schematics;

h) combined services drawings outlining the combined services routings including cable containments, floor slab and wall openings;

i) equipment standard details; and

j) demonstration that the ventilation equipment (including air monitoring instrumentation) and air pathways have been coordinated with all civil and structural works.

3 Technical requirements

3.1 Tunnel carriageway ventilation system

3.1.1 General requirements

The Contractor must provide a Tunnel carriageway ventilation system that:

a) continuously provides acceptable in-Tunnel air quality conditions for all Tunnel users including motorists, maintenance workers and operational staff;

b) continuously provides acceptable air quality conditions for individuals and communities external to the Tunnel;

c) manages smoke to protect Tunnel users and provide for Emergency Services intervention in the event of a fire;

d) provides acceptable conditions in emergency egress paths in the event of a fire;

e) provides acceptable air quality conditions in accessible services ducts and enclosures;

f) is energy efficient and incorporates systems and features to maximise aerodynamic performance;

g) continuously measures and records in-Tunnel air quality and airflows; and

h) is able to be controlled locally, manually and automatically.

3.1.2 Tunnel carriageway ventilation design definitions

For the purposes of Tunnel carriageway ventilation system design:

a) informational guidance on the relationship between PMCS modes, ventilation operations, ventilation scenarios and ventilation responses is provided in Appendix 1: PMCS modes mapped to ventilation operations, scenarios and responses;

b) PMCS modes means the normal, pre-fire and fire modes of operation as defined by TUN-PMCS-DC1 “Tunnel Plant Monitoring and Control Systems”;

c) operation means the normal, incident, maintenance and emergency operations used for the design of the Tunnel carriageway ventilation system as defined within this section 3.1.2;

d) scenario means a specific traffic, air quality, emergency or other condition that occurs which the Tunnel carriageway ventilation is designed to manage with a ventilation response;

e) ventilation response means the specific configuration of equipment and ventilation control algorithms that enable the Tunnel carriageway ventilation system to manage a scenario;

f) normal operations means scenario conditions where:

    i) traffic is flowing in all lanes at average speeds within a defined range;

    ii) all motorists are located within vehicles; and

    iii) there are no lane closures required to manage the ventilation operations;

g) incident operations means scenario conditions where traffic is stopped or flowing at speeds outside of the normal operations range including scenarios:

    i) with heavy congestion within the Tunnel;

    ii) caused by vehicle breakdown or traffic accident within or downstream of the Tunnel;

    iii) with motorists located in or out of their vehicles; and

    iv) with incident response teams located in the Tunnel;

h) emergency operations means scenario conditions where a fire or other hazard has occurred that may require evacuation or intervention by Emergency Services including:

    i) fires; and

    ii) chemical spills;

i) maintenance operations means scenario conditions where maintenance personnel will be located in the Tunnel for inspections or other maintenance activities;

j) air supply and air exhaust points can be:

    i) Tunnel portals; or

    ii) ventilation connections to the Tunnel such as shafts;

k) a Tunnel carriageway ventilation section is defined as:

    i) a section of Tunnel or ramp bounded only by:

        A. an air supply point; and

        B. an air exhaust point; or

    ii) a section of Tunnel or ramp bounded only by:

        A. a supply or exhaust point; and

        B. a connection to another Tunnel or ramp such as at an underground intersection; and

l) a ventilation response means one of the following:

    i) normal ventilation responses that enable in-Tunnel air quality and airflows to be managed within the Tunnel carriageway during normal operations while the PMCS is in normal mode;

    ii) incident ventilation responses that enable in-Tunnel air quality and airflows to be managed within the Tunnel carriageway during incident operations while the PMCS is in normal mode;

iii) pre-fire ventilation responses, if required by the Contractor's ventilation strategy, that are activated upon detection of a fire and prior to fire mode being activated while the PMCS is in pre-fire mode;

iv) fire ventilation responses that are activated to manage the products of combustion within the Tunnel carriageway for fire scenarios during emergency operations while the PMCS is in fire mode;

v) chemical spill ventilation responses that are activated to manage vapour emitted within the Tunnel carriageway for chemical spill scenarios during emergency operations while the PMCS is in fire mode; and

vi) maintenance ventilation responses that are activated to enable maintenance operations to be undertaken safely within the Tunnel carriageway while the PMCS is in normal mode.

3.1.3 In-Tunnel air quality performance requirements

a) The Contractor must demonstrate as part of the Design Documentation that the Tunnel carriageway ventilation strategy, design and operation achieves the in-Tunnel environmental requirements set out in the Contract Documents.

b) During normal operations the Tunnel carriageway ventilation system for any Tunnel must:

i) maintain in-Tunnel carbon monoxide concentration to a level less than 50 ppm at any Tunnel location when measured as a 15 minute rolling average;

ii) maintain in-Tunnel carbon monoxide concentration to a level less than 150 ppm at any Tunnel location when measured as a 3 minute rolling average;

iii) maintain in-Tunnel particulate matter concentration to a level such that visibility defined as an extinction coefficient is less than 0.005/m at any Tunnel location when measured as a 15 minute rolling average; and

iv) maintain in-Tunnel nitrogen dioxide concentration to a level less than 0.5 ppm averaged along any route that could be driven through the Tunnel when measured as a 15 minute rolling average.

c) During incident operations the Tunnel carriageway ventilation system for any Tunnel must:

i) provide integrated operations where traffic management systems allow for this integration;

ii) operate as defined by the operational management procedures for each incident scenario; and

iii) once the requirements of section 3.1.3c)i) are implemented, maintain the same air quality requirements as that for normal operations as set out in section 3.1.3b).

d) During emergency operations the Tunnel carriageway ventilation system for any Tunnel must:

i) maintain velocity and tenability conditions in accordance with the requirements of TUN-FIRE-DC3 "Tunnel Fire Engineering";

ii) be capable of reaching full operational response within a maximum of 180 seconds of activation; and

iii) be coordinated with the pressurisation of egress passageways.

e) During maintenance operations the Tunnel carriageway ventilation system for any Tunnel must maintain air quality conditions to comply with relevant occupational health and safety requirements.

3.1.4 In-Tunnel air velocity performance requirements

a) During incident operations or maintenance operations the air velocity in a Tunnel must:

i) not exceed 10 m/s for operating scenarios where motorists are outside of vehicles or incident response teams or maintenance personnel are located inside the Tunnel; and

ii) be maintained at a minimum of 0.5 m/s.

b) During normal operations an air velocity in a Tunnel in excess of 10 m/s is acceptable:

i) when the velocity is generated by vehicle movement only; and

ii) if it can be demonstrated that the air velocity will not result in any:

A. damage to in-Tunnel infrastructure; and

B. impact on the safety of vehicles travelling at the design speeds.

c) During any operations, air velocities in the Tunnel or changes in air velocity that occur at exhaust points, supply points or changes in cross section must not cause a safety issue for:

i) motorists;

ii) motorcycle users; or

iii) Tunnel occupants.

d) During emergency operations the Tunnel carriageway ventilation system for any Tunnel must:

i) maintain velocity conditions in accordance with the requirements of TUN-FIRE-DC3 “Tunnel Fire Engineering”; and

ii) maintain velocity conditions in accordance with the requirements of the Contractor’s Fire Engineering design.

e) During chemical spill emergencies the Tunnel carriageway ventilation system for any Tunnel must maintain velocity conditions appropriate to each type of chemical spill hazard identified by the Contractor’s risk and hazard assessment process.

3.1.5 External air quality performance requirements

The Contractor must demonstrate as part of the Design Documentation that Tunnel carriageway ventilation strategy, design and operation achieves the external air quality environmental requirements set out in the Contract Documents.

3.1.6 Tunnel carriageway ventilation system design inputs

a) Background air quality values to be applied at each Tunnel portal must be determined that:

i) are based on measurements from local air quality monitoring stations;

ii) allow for vehicle emissions from any recirculation from local Tunnel ventilation discharge points; and

iii) allow for any vehicle emissions due to road features and traffic near the portal.

b) Wind pressure conditions to be applied at each Tunnel portal must be determined that:

i) are based on a minimum of 10 years of measurements from local weather monitoring stations; and

ii) allows for the geometric configuration at portals.

c) Atmospheric pressure conditions to be applied at each Tunnel portal must be determined that:

i) are based on elevation differences between portals at each end of a Tunnel; and

ii) are based on any demonstrable ambient conditions between portals at each end of a Tunnel.

d) The Tunnel carriageway ventilation design must use the following vehicle groups for aerodynamic and emissions analysis:

i) passenger cars (PC);

ii) light commercial vehicles (LCV); and

iii) trucks and buses denoted as heavy goods vehicles (HGV).

e) The vehicle groups required by section 3.1.6d) must be based on definitions contained in PIARC Road Tunnels: Vehicle Emissions and Air Demand for Ventilation, 2019R02EN.

f) Traffic volumes to be used in the Tunnel carriageway ventilation design for each Tunnel must:

i) be based on values provided in the Contract Documents where available;

ii) be based on traffic modelling assessments;

iii) include hourly traffic volumes representing 24-hour daily traffic figures; and

iv) include proportions of vehicle groups for each hour.

g) Traffic volumes to be used for low-speed traffic and lane capacity assessments must be based on input provided by the Contractor's specialist traffic modelling engineers using:

i) values provided in PIARC Road Tunnels: Vehicle Emissions and Air Demand for Ventilation, 2019R02EN including:

A. vehicle density; and

B. PC and LCV space and speed relationship with HGV;

ii) published traffic flow data and observations; and

iii) traffic modelling assessments.

h) The Tunnel carriageway ventilation design must be based on and analysed for traffic volumes and vehicle groups that are expected to use the Tunnel:

i) as at the Tunnel opening date; and

ii) 10 years after the Tunnel opening date.

i) The vehicle fleet parameters used for vehicle emissions estimates must:

i) be based on a South Australian vehicle fleet age determined from:

A. local vehicle registration data;

B. Australian Bureau of Statistics data; and

C. an assessment of the vehicle fleet age profile to represent the fleet at future design years as set out in section 3.1.6h);

ii) account for petrol and diesel fuel types based on:

A. local registration data;

B. estimates of diesel vehicle use growth or decline; and

C. Australian Bureau of Statistics data;

iii) include for current and future vehicle alternative fuel types and use determined from:

A. South Australian government data and predictions; and

B. Federal government data and predictions;

iv) account for engine technology types based on Australian Design Rules - Emission Control Set implementation years;

v) include an average HGV mass determined on buses and heavy goods vehicles that are expected to use the Tunnel;

vi) account for effects on engine emissions performance due to:

A. altitude;

B. cold starting; and

C. age degradation; and

vii) consider and apply vehicle age adjustments based on newer vehicles using the Tunnel that would reduce emissions generation.

j) Vehicle emissions estimates used in the Tunnel carriageway ventilation design must:

i) be determined for:

A. carbon monoxide;

B. nitrogen oxides; and

C. exhaust and non-exhaust generated particulate matter;

ii) be based on the detailed emissions database tables published in PIARC Road Tunnels: Vehicle Emissions and Air Demand for Ventilation, 2019R02EN;

iii) be derived using the detailed methodology as described in PIARC Road Tunnels: Vehicle Emissions and Air Demand for Ventilation, 2019R02EN or a similar methodology approved as part of the Ventilation Modelling Report required by section 2.1.3;

iv) be a function of both grade and speed;

v) be derived for each vehicle group; and

vi) include non-exhaust generated particulate matter for vehicles without exhaust emissions.

k) Factors to convert nitrogen oxides emissions estimates to nitrogen dioxide emissions estimates must be determined based on:

i) the vehicle group;

ii) the emission technology standard; and

iii) fuel type.

l) The Tunnel carriageway ventilation design must assess and account for:

i) current and the future fuel standard implementation; and

ii) aerodynamic parameters for current and projected uptake of modern PC types such as large SUVs and utility vehicles.

3.1.7 Tunnel carriageway ventilation strategy

a) The Contractor must determine the Tunnel carriageway ventilation strategy to meet the performance requirements.

b) The Tunnel carriageway ventilation strategy must be an optimal balance between:

i) in-Tunnel emissions control performance;

ii) fire safety performance requirements;

iii) external air quality performance requirements;

iv) operational complexity;

v) minimising energy use; and

vi) minimising whole of life costs.

c) A longitudinal Tunnel carriageway ventilation system must be implemented unless it can be clearly demonstrated that an alternative strategy has superior performance, control, energy and whole of life cost benefits.

d) Tunnel carriageway ventilation strategies that include portal emissions must include infrastructure and operational strategies to control recirculation of emissions between adjacent portals.

e) Tunnel carriageway ventilation strategies that include operations where portal emissions are controlled must:

i) be able to achieve no net portal emissions when airflow is measured as a 5 minute rolling average; and

ii) minimise the use of ventilation jet fans to be operated during normal operation in a direction opposed to traffic flow in the mainline Tunnels.

f) Tunnel carriageway ventilation strategies that include ventilation stations must:

i) comply with all external air quality requirements; and

ii) comply with all obstacle and plume rise requirements of CASA applicable to the Project.

3.1.8 Tunnel carriageway ventilation system design requirements

a) The range of traffic speeds that occur during normal operations must be determined by the Contractor, if not specified otherwise in the Contract Documents.

b) The Tunnel carriageway ventilation system must be designed such that during normal operations, traffic management procedures, including lane closures, are not required.

c) The Tunnel carriageway ventilation system must be demonstrated to meet performance requirements for:

i) free flowing traffic for each hour of operation during the day where all Tunnel lanes are operating and vehicles are moving at the posted speed limit or as otherwise defined in the Contract Documents; and

ii) traffic cases where all Tunnel lanes are operating and vehicles are moving at average speeds between the range of speeds as defined by normal operations.

d) The Tunnel carriageway ventilation system design must assess incident scenarios in order to provide input into operational procedures on the capability and limitations of the Tunnel carriageway ventilation system.

e) The Tunnel carriageway ventilation system design analysis must determine vehicle emissions and discharge parameters for use in ambient air quality assessments.

f) The Tunnel carriageway ventilation system design must:

i) not allow for the localised build-up of pollutants due to regions of relatively low velocity; and

ii) include aerodynamic features such as fairings and transitions within non-Tunnel air pathways to reduce pressure losses that would otherwise result in energy inefficiencies.

g) The Tunnel carriageway ventilation system design analysis must determine vehicle carbon dioxide emissions and in-Tunnel concentrations if required for use in concrete carbonation durability assessments.

h) The Tunnel carriageway ventilation system design and control functionality must:

i) demonstrate coordination with the traffic management strategies; and

ii) define if integration with traffic control systems is required for operational responses.

i) The Tunnel carriageway ventilation system design must determine if active velocity feedback controls are needed for any operations.

j) The Tunnel carriageway ventilation system design must determine smoke control velocities and flowrates using:

   i) industry recognised analytical equations; and

   ii) computational fluid dynamics modelling.

k) The Tunnel carriageway ventilation system smoke management design and operations must be demonstrated to:

   i) comply with the requirements derived from TUN-FIRE-DC3 “Tunnel Fire Engineering”;

   ii) maintain operational performance for a minimum of 2 hours;

   iii) prevent the recirculation of discharged smoke back into the Tunnel;

   iv) provide conditions acceptable to SAMFS at nominated staging areas;

   v) achieve emergency operations ventilation conditions within a time frame in accordance with Contractor’s Fire Engineering design;

   vi) have ventilation jet fan operations that minimise smoke de-stratification; and

   vii) account for the performance of ventilation jet fans exposed to elevated temperature conditions.

l) The Tunnel carriageway ventilation system design must:

   i) assess the balance between ventilation system operational and capital costs to demonstrate whole of life benefits; and

   ii) demonstrate that any greenhouse gas emissions targets related to the ventilation system operation have been achieved.

m) Tunnel carriageway ventilation equipment must:

   i) include commonality in ventilation jet fan and ventilation axial fan assemblies across the Project to reduce spare part holding requirements and enable commonality in maintenance;

   ii) include modularised dampers that have commonality of modules between different dampers to reduce spare part holding requirements;

   iii) include modularised dampers with modules sized such that the failure of a single module or actuator does not compromise system operation; and

   iv) incorporate sufficient access hatches on ducts and equipment casings to enable inspection and adjustment of fans without the need for equipment removal.

n) Tunnel carriageway ventilation equipment installation must:

   i) ensure actuators and instrumentation are accessible for safe maintenance purposes;

   ii) ensure actuators on horizontal dampers do not require access across the face of the damper;

   iii) include mesh on all airpaths directly connected to the Tunnel to prevent trash ingress into the fan rooms; and

   iv) allow for edge distance mounting requirements at damper penetrations.

o) The Tunnel carriageway ventilation system design must account for any fan starting restrictions such as fan starts per hour to ensure all required ventilation responses can be achieved as required.

p) The Tunnel carriageway ventilation equipment installation, lifting and removal methodology must form part of the Design Documentation.

q) Turning vanes incorporated into air flow paths as part of the Tunnel carriageway ventilation system must:

i) be demonstrated to have a clear operational benefit;

ii) have a fire rating equivalent to the equipment servicing the air flow path; and

iii) not block inspection access.

r) Operating and failure scenarios of the Tunnel carriageway ventilation system must be assessed to determine:

i) equipment interlocking requirements; and

ii) maximum system pressures that can be developed.

3.1.9 Modelling requirements

a) One-dimensional computational modelling must be undertaken to assess the performance of the Tunnel carriageway ventilation design.

b) The one-dimensional modelling software required by section 3.1.9a) must be commercial software specifically developed for Tunnel carriageway ventilation analysis.

c) The one-dimensional modelling software required by section 3.1.9a) must have been verified and validated for the specific purpose of the modelling being undertaken.

d) Modelling must evaluate Tunnel temperature conditions for different non-emergency operations to enable assessment of buoyant plume effects if required.

e) Modelling of unheated airflow fire scenarios must be undertaken to provide data to be used for cold flow tests during testing and commissioning.

f) 3-dimensional computational modelling must be undertaken where detailed aerodynamic information is required including:

i) recirculation of emissions;

ii) velocity fields affecting motorists and motorcycle users;

iii) ventilation jet fan installation factors;

iv) ventilation station velocity profiles; and

v) pressure loss factors for complicated geometric airflow paths.

g) 3-dimensional modelling software required by section 3.1.9f) must be software specifically developed for the numerical analysis of incompressible airflows in complex geometries.

h) 3-dimensional modelling software required by section 3.1.9f) must have been verified and validated for the specific purpose of the modelling being undertaken.

i) Verification and validation documentation must be provided as part of the Ventilation Modelling Report required by section 2.1.3 for each modelling software package proposed.

j) A detailed modelling register must be maintained and made available to the Principal.

k) Models and associated modelling data must be made available to the Principal when requested.

3.1.10 Ventilation station design

a) This section 3.1.10 relates to Tunnel carriageway ventilation strategies that include ventilation stations to provide exhaust from or supply to the Tunnel.

b) Ventilation station fan assemblies must include fans, transitions, noise attenuators, dampers and duct pieces.

c) Ventilation station equipment must comply with the requirements of TUN-ME-DC6 “Tunnel Ventilation Equipment”.

d) The design of ventilation station equipment must:

i) adopt fan assembly arrangements that minimise assembly pressure losses;

ii) consider the use of:

A. common attenuators servicing multiple fans;

B. aerodynamic nosing on attenuators;

C. bell mouth fan inlets; and

D. transition pieces with a maximum included angle of 15°;

iii) adopt VSDs on all ventilation axial fans to optimise speed, pressure losses and operating fan numbers;

iv) demonstrate that system effect pressure losses such as fan swirl, transition angles and fan discharge velocity profiles onto attenuators have been accounted for in fan pressure assessments and minimised;

v) allow for ventilation fans arranged in parallel to be started individually whilst other fans are operating at full speed; and

vi) include at least one redundant ventilation fan.

e) Vertical ventilation station fan room arrangements must:

i) only be adopted if clear advantages over a horizontal arrangement can be demonstrated; and

ii) have trafficable floor levels to allow direct access to different elements of the ventilation fan assembly.

f) Ventilation station fan room design must:

i) be demonstrated to have sufficient clearances to all ventilation equipment for safe and efficient maintenance access;

ii) have adit connections and plenums arranged to ensure uniform airflow into and out of the fan room;

iii) provide lay down spaces to facilitate equipment:

A. assembly;

B. installation; and

C. maintenance;

iv) include safety rails around openings to prevent fall hazards;

v) include permanent stairs for equipment access;

vi) be constructed and arranged such that acoustic linings are not required to meet noise requirements;

vii) include details of equipment mounting plinths and upstands;

viii) include details of pressure walls required;

ix) include infrastructure and operational procedures to allow the inspection of individual fans and dampers without stopping operation of the Tunnel; and

x) have equipment junction boxes located to enable direct access from floor level.

g) Ventilation station fans must be provided with:

i) motor starters and damper actuator switchgear located in a room separate to the fan room; and

ii) a local isolator switch adjacent to the fan.

h) For ventilation stations where reversible fan operations are required:

i) fan assemblies must operate efficiently in both directions; and

ii) maximum efficiency must be in the direction that the fan normally operates.

i) Ventilation stations must include equipment delivery routes and equipment clearances for maintenance activities to ensure efficient installation and maintenance can be undertaken.

j) Ventilation station equipment must be able to be installed and removed:

i) without the need to move cable trays or other services;

ii) without having to lift and transfer equipment over other equipment;

iii) without the need to undertake significant disassembly of the ventilation station building including structure and any facades; and

iv) without the need of permanent lifting beams or monorails.

k) Floor and wall hatch provisions for ventilation station equipment installation and removal must:

i) be arranged to minimise the number of hatches required to remove equipment;

ii) allow sufficient clearance around the hatch for hatch removal;

iii) allow sufficient space around the hatch to manoeuvre equipment;

iv) ensure the safety of maintenance personnel when hatches are open; and

v) allow for the temporary local storage of hatches.

3.1.11 Ventilation station outlet design

a) The design of any required ventilation station outlet (VSO) must:

i) where needed by location, allow for CASA requirements regarding:

A. obstacle limitation surface;

B. procedures for air navigational services or aircraft operation services; and

C. discharge velocity;

ii) include partitioning and partitioning dampers to improve performance and optimise energy requirements;

iii) include an assessment of the VSO velocity profile; and

iv) where required by the EPA or the environmental requirements set out in the Contract Documents, make provisions for air monitoring instruments and equipment including:

A. spatial provision of field instrumentation;

B. spatial provision of analysis equipment; and

C. installation and maintenance access.

3.1.12 Tunnel carriageway ventilation jet fan system design

a) Tunnel carriageway ventilation jet fans must meet the requirements of TUN-ME-DC6 “Tunnel Ventilation Equipment”.

b) Tunnel carriageway ventilation jet fans must be arranged to limit aerodynamic performance reduction by:

i) aerodynamic interference from parallel jet fans;

ii) aerodynamic interference from downstream jet fans; and

iii) ceiling and wall effects.

c) Tunnel carriageway ventilation jet fan arrangement and location must be coordinated with other Tunnel services and Tunnel fixtures to maximise ventilation jet fan performance.

d) The aerodynamic installation factor for each type of Tunnel carriageway ventilation jet fan arrangement adopted must be determined:

   i) using established empirical factors where applicable; and

   ii) using computational fluid dynamics modelling where the use of empirical factors is not appropriate.

e) Sufficient redundant Tunnel carriageway ventilation jet fans must be provided in each Tunnel:

   i) to meet maintenance operational requirements;

   ii) to meet ventilation requirements in each Tunnel carriageway ventilation section;

   iii) to meet system availability requirements;

   iv) to allow for jet fans affected by fire; and

   v) to achieve a minimum of 10% (or next rounded-up whole number) of redundant jet fans for the most onerous ventilation response in each Tunnel carriageway ventilation section.

f) Tunnel carriageway ventilation jet fans must be operated to avoid disruption of the smoke layer initially by operating jet fans that are farthest away from the fire site first rather than those located near to the fire site.

3.1.13 Tunnel carriageway ventilation system acoustic performance

a) The Tunnel carriageway ventilation system must achieve a maximum sound level at any point 1.5 m above the Tunnel roadway of NR 85 for all ventilation responses.

b) Noise assessments of the Tunnel carriageway ventilation system must be undertaken accounting for intelligibility requirements of any PA or emergency warning systems.

c) Tunnel carriageway ventilation system noise at portals and ventilation outlets must comply with ambient noise requirements set out in the Contract Documents.

3.1.14 In-Tunnel air monitoring

a) The in-Tunnel air monitoring system must meet the requirements of TUN-ME-DC5 “Supply of Tunnel Air Monitoring Instrumentation”.

b) In-Tunnel air quality monitoring instruments must be provided to:

   i) continuously measure and report the in-Tunnel air quality parameters as specified; and

   ii) provide input to the Tunnel carriageway VCAs.

c) In-Tunnel air velocity monitoring instruments must be provided within each Tunnel bore to:

   i) continuously measure and report the in-Tunnel air flow velocity and direction; and

   ii) provide input to the Tunnel carriageway VCAs.

d) In-Tunnel air monitoring equipment must be located and provided with sufficient redundancy to achieve the RAMS requirements of the Tunnel ventilation system.

e) In-Tunnel air quality monitoring instruments must be provided in sufficient numbers and locations to enable:

   i) control of the Tunnel carriageway ventilation system to achieve the emissions criteria set out in the Contract Documents for air quality;

   ii) EPA monitoring requirements; and

   iii) reporting of Tunnel emissions as required.

f) In-Tunnel air monitoring equipment numbers and locations must be:

i) defined by the Contractor's Design Documentation;

ii) be compliant with the manufacturer's recommendations; and

iii) provided in sufficient numbers to satisfy the level granularity required by the VCAs.

g) In-Tunnel air monitoring equipment must be arranged such that the failure of any instrument does not adversely impact:

i) the functionality of the remaining instrumentation; or

ii) the overall functional accuracy of the VCAs; or

iii) the functionality of the PMCS for Tunnel carriageway ventilation control purposes.

h) In-Tunnel air velocity monitoring instruments must have measurement paths:

i) clear of any obstructions such as luminaires, cable ladders and ventilation jet fans;

ii) clear of the effects of any localised ventilation jet fan exhaust or intake air velocities; and

iii) configured to comply with manufacturer's recommendations.

i) During normal, incident or maintenance operations the in-Tunnel air monitoring system for any Tunnel must:

i) be able to measure and report all air quality quantities as a rolling average over a measuring period that is continuously incrementally updated as measurements are taken;

ii) be able to measure and report all air quality quantities as a discrete average for a discrete measuring period;

iii) be able to measure and report all air quality quantities as instantaneous values;

iv) have sufficient measurement time resolution to allow the accurate determination of average air quality quantities;

v) be able to measure all air quality parameters in each Tunnel carriageway ventilation section with an equal level of accuracy;

vi) be able to measure nitrogen dioxide concentrations at sufficient locations along the full length of a Tunnel to allow the determination of an average concentration that motorists could be exposed to as they travel along any possible route through the Tunnel; and

vii) have sufficient redundancy such that the loss of the greater of 2 air quality instruments or 10% of all air quality instruments in a Tunnel:

A. will not impact the Tunnel carriageway ventilation system control; and

B. will still allow the accurate reporting of all air quality quantities.

j) During emergency operations the air quality monitoring system for any Tunnel must maintain the measurement, data management, analysis, and data storage requirements for air monitoring equipment unless the equipment is directly affected by the emergency incident.

k) During normal, incident or maintenance operations the air velocity monitoring system for any Tunnel must:

i) be able to measure and report all air velocities as a rolling average over a measuring period that is continuously incrementally updated as measurements are taken;

ii) be able to measure and report all air velocities as a discrete average for a discrete measuring period;

iii) be able to measure and report all air velocities as instantaneous values;

iv) have sufficient measurement time resolution to allow the accurate determination of average air velocity quantities;

v) be able to report the air velocity direction;

vi) be calibrated and commissioned such that air velocity measurements can be reported as airflow quantities in all Tunnel carriageway ventilation sections; and

vii) have sufficient redundancy such that the loss of the greater of 2 air velocity instruments or 10% of all air velocity instruments in a Tunnel:

A. will not impact the Tunnel carriageway ventilation system control; and

B. will still allow the accurate reporting of all air velocity quantities.

l) During emergency operations the air velocity monitoring system for any Tunnel must:

i) be able to maintain operation unless directly affected by the emergency incident;

ii) provide accurate readings during fire incidents accounting for the presence of smoke, temperature changes and air density changes within the thermal operating range of the instrument; and

iii) be able to provide air velocity and airflow measurements as required by the Contractor's Fire Engineering design.

3.1.15 Ventilation station monitoring

a) If the Tunnel carriageway ventilation strategy includes a VSO, VSO air monitoring instruments must meet the requirements of TUN-ME-DC5 "Supply of Tunnel Air Monitoring Instrumentation".

b) VSO air monitoring instruments must be provided at locations within the VSOs that:

i) comply with manufacturer's recommendations for installed conditions;

ii) are suitable in terms of internal airflow conditions;

iii) ensure reliable measurement of the parameters specified; and

iv) enable access for safe maintenance using standard equipment.

c) VSO air monitoring must include an ambient weather station which:

i) is provided in close proximity to the VSO; and

ii) is located to measure representative external ambient conditions.

d) Any span, zero or calibration gases required by the VSO air monitoring instruments must be located at ground level and be Readily Accessible for periodic replenishment or replacement.

3.2 Egress passageway pressurisation

3.2.1 Egress passageway pressurisation performance requirements

a) Egress passageway pressurisation must be provided for:

i) cross-passageways;

ii) longitudinal egress passageways; and

iii) fire isolated stair passageways servicing the Tunnel.

b) Egress passageway pressurisation must be achieved using either:

i) dedicated egress passageway pressurisation systems; or

ii) the Tunnel carriageway ventilation system configured to achieve the performance requirements.

c) The use of dedicated egress passageway pressurisation systems described by section 3.2.1b)i) must be minimised where the Tunnel carriageway ventilation system can achieve the performance requirements.

d) Egress passageway pressurisation must achieve:

i) a minimum average velocity of 1 m/s through open doors that could be exposed to smoke; and

ii) a maximum door opening force in accordance with TUN-FIRE-DC2 “Tunnel Evacuation Systems” accounting for both the Tunnel carriageway and passageway side pressures.

e) Egress passageway pressurisation must comply with TUN-FIRE-DC3 “Tunnel Fire Engineering” including:

i) minimum number of egress passageway doors open;

ii) operation on detection of fire in the Tunnel;

iii) deactivation on detection of smoke within the area served; and

iv) fire separation and fire rating requirements.

3.2.2 Egress passageway pressurisation system requirements

a) Dedicated egress passageway pressurisation systems must comply with the requirements of this section 3.2.2 in addition to the requirements of section 3.2.1.

b) Egress passageway pressurisation systems must:

i) achieve the performance requirements allowing for the Tunnel side pressure profiles that could occur due to the operation of the Tunnel carriageway ventilation system;

ii) be designed in accordance with AS 1668.1 The use of ventilation and air conditioning in buildings, Part 1: Fire and smoke control in buildings;

iii) have functionality to enable periodic purging of the egress passageway to mitigate the accumulation of stale and polluted air within the area when necessary to facilitate maintenance activities; and

iv) provide sufficient ventilation to maintain occupational health and safety air quality requirements within the area served for maintenance and inspection activities.

c) Egress passageway pressurisation system fans must be:

i) started with soft starters or VSDs; and

ii) provided with attenuation to achieve the internal and external noise limits.

d) Egress passageway pressurisation motorised dampers must be provided to:

i) isolate the fan airflows as required for the fan operations; and

ii) provide fire and smoke separation between different fire compartments.

e) Egress passageway pressurisation system dampers must be specified with failure positions that are suitable for their use and location.

f) Egress pressurisation system relief dampers must be provided to:

i) relieve pressure within the pressurised area to be able to open doors; and

ii) provide fire and smoke separation between different fire compartments.

g) Egress passageway pressurisation system monitoring and status indication data must include:

i) fan run status;

ii) fan run hours; and

iii) damper status indication.

h) Egress passageway pressurisation systems must have ventilation equipment installed:

i) outside of the Tunnel carriageway; and

ii) to be Readily Accessible for inspection and maintenance.

3.3 Services passageway ventilation

a) Accessible Tunnel services passageways including under road culverts must be provided with mechanical ventilation systems.

b) Tunnel services passageway ventilation systems must be designed to:

i) maintain occupational health and safety air quality requirements within the area served;

ii) provide cooling as required for equipment housed within the area served;

iii) provide condensation control within the area served;

iv) provide smoke purge capability after a fire incident within the area served; and

v) provide the smoke control requirements of the Contractor's Fire Engineering design.

c) Tunnel services passageway ventilation systems must be designed to the requirements of:

i) AS 1668.1 The use of ventilation and air conditioning in buildings, Part 1: Fire and smoke control in buildings, when smoke control functionality is required by the Contractor's Fire Engineering design; and

ii) AS 1668.2 The use of ventilation and air conditioning in buildings, Part 2: Mechanical ventilations in buildings, for acceptable air quality.

d) The Contractor must assess if specific gas species monitoring is required within the Tunnel services passageway due to:

i) noxious gas that could be generated within the area;

ii) noxious gas infiltration from the surrounding ground; or

iii) infiltration of any polluted Tunnel air.

e) Tunnel services passageway air quality monitoring instruments must be provided to:

i) continuously measure and report the temperature conditions through the entire length of the services passageway;

ii) continuously measure and report the humidity conditions; and

iii) monitor any gas species deemed necessary by the gas species assessment undertaken pursuant to section 3.3d).

f) Tunnel services passageway ventilation systems must:

i) draw supply air from locations not affected by vehicle emissions;

ii) be arranged to mitigate recirculation of air from other ventilation systems;

iii) be provided with noise attenuation to achieve all noise requirements;

iv) achieve fire separation requirements defined by the Contractor's Fire Engineering design; and

v) be high temperature rated in accordance with the Contractor's Fire Engineering design.

g) Tunnel services passageway ventilation system monitoring and status indication data must include:

i) fan run status;

ii) fan run hours; and

iii) damper status indication.

h) Tunnel services passageway air quality monitoring equipment numbers and locations must:

i) be defined by the Contractor's Design Documentation;

ii) provide sufficient resolution to accurately report air quality along the services passageway;

iii) provide required feedback control for the ventilation system;

iv) comply with air quality monitoring manufacturer's location recommendations;

v) not impair the functionality of any other services; and

vi) enable safe access during maintenance using standard equipment.

3.4 Tunnel drainage sump ventilation

a) Tunnel drainage sumps must be provided with mechanical ventilation systems.

b) Tunnel drainage sump ventilation systems must comply with the requirements of:

i) AS 1668.2 The use of ventilation and air conditioning in buildings, Part 2: Mechanical ventilations in buildings, for acceptable air quality for maintenance operations;

ii) the hazardous area assessment to be undertaken in accordance with TUN-ME-DC1 "Tunnel Hydraulics Treatment and Pumping"; and

iii) sump ventilation modelling to be undertaken in accordance with TUN-ME-DC1 "Tunnel Hydraulics Treatment and Pumping".

c) Tunnel drainage sump ventilation systems must provide airflows to:

i) prevent the accumulation of noxious vapours within the sump;

ii) maintain hydrocarbon vapour levels to less than 5% of the lower explosive limit;

iii) respond to the hazardous area classification of the sump;

iv) provide cooling as required for equipment within the area served; and

v) provide fresh air for maintenance operations.

d) Tunnel drainage sump ventilation systems must:

i) be continuously operating systems;

ii) maintain a negative pressure within the sump;

iii) be configured to ensure no fluid or foam can be ingested into the ventilation ducting;

iv) be in a duty/standby arrangement with 100% redundancy in fans;

v) be fed via a redundantly configured HV / LV power system;

vi) achieve the required internal and external noise levels;

vii) be provided with gaskets and fittings to prevent the leakage of hydrocarbon vapours;

viii) maintain the fire separation requirements of the Contractor's Fire Engineering design;

ix) minimise the risk of equipment being submersed in the event of a sump overflow; and

x) enable maintenance without personnel being located in the operating roadway.

e) Tunnel drainage sump ventilation systems must discharge air to outside the Tunnel when these systems service a portal sump.

f) Tunnel drainage sump ventilation systems that discharge air into the Tunnel must:

i) exhaust air on the downstream ventilation side of the associated supply intake; and

ii) have a discharge point that directs air away from Tunnel occupants.

g) Tunnel drainage sump ventilation system monitoring and status indication data provided by the PMCS must include:

i) fan run status;

ii) fan run hours; and

iii) damper status indication.

3.5 Tunnel equipment room ventilation

a) Tunnel equipment room ventilation must:

i) maintain temperature and humidity conditions to achieve reliable equipment operation;

ii) maintain safe working temperatures and air quality suitable for personnel undertaking maintenance activities;

iii) not use air drawn from the Tunnel carriageway for forced ventilation;

iv) comply with the strategy and requirements derived from the process in TUN-FIRE-DC3 “Tunnel Fire Engineering”; and

v) be arranged and operated to maintain smoke separation with interfacing areas.

b) Tunnel equipment rooms with gaseous suppression systems must be provided with pressure relief venting and gas purging mechanical systems.

4 Control and monitoring requirements

4.1 General requirements

a) Tunnel VCAs must:

i) be developed by the Contractor for the PMCS; and

ii) automatically control ventilation equipment required for each operational condition.

b) VCAs for each Tunnel ventilation system must:

i) be implemented in the PMCS PLC;

ii) have functionality defined by Contractor’s Design Documentation;

iii) allow for automatic control of the Tunnel ventilation fans and dampers;

iv) allow for manual and local control of the Tunnel ventilation fans and dampers;

v) provide protection of the Tunnel ventilation fans and dampers from incorrect operation;

vi) allow for adjustment of user-configurable parameters by the TMC operators;

vii) contain self-diagnostic functionality to provide fault detection to TMC operators; and

viii) provide compensation for unhealthy and unavailable equipment.

c) Tunnel ventilation equipment setpoints for warnings, alarms and trip protection must be:

i) in accordance with manufacturer’s requirements; and

ii) user configurable via SCADA.

d) The VCAs must be designed to allow continued operation via the PMCS PLC in the event that SCADA is not available.

4.2 Tunnel carriageway ventilation system

4.2.1 General

a) Tunnel carriageway VCAs must incorporate feedback control from multiple inputs including:

i) in-Tunnel airflows;

ii) in-Tunnel air quality;

iii) ambient air quality (when required by the Contractor's ventilation strategy);

iv) ambient wind conditions (when required by the Contractor's ventilation strategy);

v) time of day;

vi) real time traffic flow (when integrated with traffic management systems);

vii) real time traffic speed (when integrated with traffic management systems);

viii) traffic incident detection (when integrated with traffic management systems);

ix) traffic management response (when integrated with traffic management systems); and

x) emergency operations.

b) Tunnel carriageway VCAs must:

i) allow for safe transitioning of equipment between ventilation responses;

ii) allow for set-point modification of target in-Tunnel conditions by the TMC operators;

iii) incorporate automatic checking of Tunnel air monitoring instruments by cross-checking against other instruments and undertaking checks against expected values;

iv) incorporate Tunnel air monitoring instrument compensation algorithms to ensure that the failure of individual instruments does not affect operations and data logging;

v) undertake all required analysis of Tunnel monitoring instruments including time and spatial averaging;

vi) allow for changes to operational requirements without requiring system upgrades or reprogramming to enable optimisation for future vehicle emissions improvements; and

vii) have the capability to respond to any ambient air quality requirements.

4.2.2 Tunnel carriageway ventilation traffic management interface

a) Tunnel carriageway VCAs must:

i) provide all necessary alerts and alarms to TMC operators to enable traffic management implementation if needed to control Tunnel conditions; and

ii) provide the necessary Tunnel carriageway ventilation system response when traffic management measures are implemented.

b) When required by the Contractor's ventilation strategy, the Tunnel carriageway ventilation control system must be interfaced to traffic management operations.

4.2.3 Tunnel carriageway ventilation control system simulation

a) The performance of Tunnel carriageway VCAs must be numerically simulated to demonstrate:

i) acceptable system response to changing inputs;

ii) acceptable system response to changing PMCS modes and ventilation responses; and

iii) acceptable time scales for changes in ventilation responses.

b) The numerical simulation of Tunnel carriageway VCAs required by section 4.2.3a) must mimic the proposed SCADA interface and functionality to enable:

i) Principal review of the proposed Tunnel carriageway ventilation system functionality; and

ii) programming of the VCAs into the PMCS.

4.2.4 Tunnel carriageway VCAs

a) Tunnel carriageway VCAs must describe how jet fans, axial fans and dampers are to be automatically controlled for the following scenarios as a minimum:

i) normal operation;

ii) time of day control;

iii) incident;

iv) maintenance;

v) chemical spill;

vi) pre-fire (when required); and

vii) fire.

b) The Contractor must confirm and augment the Tunnel carriageway VCAs required by section 4.2.4a) based on the specifics of the Contractor's ventilation strategy for the Project.

c) The Tunnel carriageway VCA for pre-fire scenarios listed in section 4.2.4a) is not required if the Contractor's ventilation strategy maintains the PMCS normal mode VCAs when PMCS pre-fire mode is active.

d) The Tunnel carriageway VCA for normal operation scenarios must:

i) implement ventilation responses based on the Contractor's ventilation strategy;

ii) enable feedback control based on the Tunnel air quality and air velocity conditions;

iii) be the default VCA; and

iv) be active when no other VCA is active.

e) The Tunnel carriageway VCA for pre-fire scenarios must:

i) implement ventilation responses based on the Contractor's ventilation strategy;

ii) be automatically activated when the PMCS enters pre-fire mode; and

iii) be automatically deactivated when the PMCS pre-fire mode is deactivated.

f) The Tunnel carriageway VCA for fire scenarios must:

i) implement ventilation responses based on the Contractor's ventilation strategy;

ii) be automatically activated when the PMCS enters fire mode; and

iii) be automatically deactivated when the PMCS fire mode is deactivated.

g) The Tunnel carriageway VCA for chemical spill scenarios must:

i) implement ventilation responses based on the Contractor's ventilation strategy;

ii) be automatically activated via a response plan implemented in STREAMS;

iii) be automatically activated when selected by the TMC operator via SCADA; and

iv) be automatically deactivated when no chemical spill response plan is active.

h) The Tunnel carriageway VCA for time-of-day control must:

i) implement ventilation responses based on the Contractor's ventilation strategy;

ii) be predefined ventilation responses for each hour of the day for each day of the week;

iii) change predefined ventilation response required by 4.2.4h)ii) at the start of each hour;

iv) control Tunnel carriageway ventilation equipment without air monitoring instrument input;

v) be manually activated by a TMC operator from SCADA; and

vi) be manually deactivated by a TMC operator from SCADA.

i) The Tunnel carriageway VCA for incident scenarios must:

i) implement ventilation responses based on the Contractor's ventilation strategy;

ii) be capable of automatic activation based on Tunnel monitoring inputs to the PMCS;

iii) be capable of automatic activation via a response plan implemented in STREAMS;

iv) be capable of automatic activation when selected by the operator via SCADA; and

v) be automatically deactivated when no incident response plan is active.

j) The Tunnel carriageway VCA for maintenance must:

i) implement ventilation responses based on the Contractor's ventilation strategy;

ii) be manually activated by a TMC operator from SCADA; and

iii) be manually deactivated by a TMC operator from SCADA.

k) When there are concurrent demands on the Tunnel carriageway VCAs the following applies:

i) the VCA for fire scenarios must have highest priority;

ii) the VCA for pre-fire scenarios must have second highest priority; and

iii) the priority of all other VCAs must be defined by the Contractor based on analyses accounting for the ventilation strategy and hazards specific to the Project.

l) The Tunnel carriageway VCAs must include functionality to compensate for unhealthy and unavailable equipment that is appropriate to each scenario defined by section 4.2.4a).

m) The Tunnel carriageway VCA functionality required by section 4.2.4l) must provide a hierarchy for replacement equipment in order to achieve as close as possible to the required response.

4.2.5 Manual controls

a) Manual Tunnel carriageway ventilation controls must be available from SCADA for each Tunnel that include:

i) predefined Tunnel carriageway ventilation responses;

ii) turn off each ventilation station (when provided);

iii) turn on each ventilation station at maximum capacity (when provided); and

iv) turn off all Tunnel carriageway ventilation jet fans.

b) The predefined Tunnel carriageway ventilation responses required by 4.2.5a) must:

i) be developed by the Contractor specific to the ventilation strategy for the Project;

ii) fully define the state of all Tunnel carriageway ventilation fans, jet fans and dampers; and

iii) operate without any feedback control from air monitoring instruments.

c) When Tunnel carriageway VCAs for fire, pre-fire and chemical spill scenarios are not active, the predefined Tunnel carriageway ventilation responses required by 4.2.5a) must provide:

i) each time-of-day response that is otherwise available in the time-of-day VCA;

ii) ventilation responses for each design case traffic scenario;

iii) ventilation responses for each incident scenario; and

iv) ventilation responses for each type and location of in-Tunnel maintenance activity.

d) When Tunnel carriageway VCAs for fire and pre-fire scenarios are active, the predefined Tunnel carriageway ventilation responses required by 4.2.5a) must:

i) provide incident Tunnel smoke control responses for each deluge zone that ventilate:

A. in the forward direction relative to traffic flow; and

B. in the reverse direction relative to traffic flow;

ii) provide non-incident Tunnel pressurisation responses that ventilate:

A. in the forward direction relative to traffic flow; and

B. in the reverse direction relative to traffic flow;

iii) use Tunnel carriageway ventilation jet fans and ventilation stations (where provided) to implement the responses required by section 4.2.5d)i) and section 4.2.5d)ii) to independently:

A. achieve the minimum airflow required for the responses; and

B. maximise the airflow for the responses; and

iv) use Tunnel carriageway ventilation jet fans only to implement the responses required by section 4.2.5d)i) and section 4.2.5d)ii) to independently:

A. achieve the minimum airflow required for the responses; and

B. maximise the airflow for the responses.

e) When Tunnel carriageway VCAs for chemical spill scenarios are active, the manual controls must be based on section 4.2.5d) and otherwise determined by the Contractor specific to the chemical spill hazards for the Project.

f) The predefined Tunnel carriageway responses required by 4.2.5d) must include manual responses agreed during consultation with SAMFS as part of the process in TUN-FIRE-DC3 “Tunnel Fire Engineering”.

g) When the VCA for fire scenarios is active, the Tunnel carriageway ventilation axial fans must be disabled and associated dampers closed if the fire location is within a user-configurable distance of the exit ventilation station (where installed).

4.2.6 Tunnel carriageway ventilation fan duty sharing

a) The PMCS must implement Tunnel carriageway ventilation jet fan duty sharing that balances operating hours across the jet fan population, without imposing excessive operation on new or restored jet fans introduced to the population.

b) The PMCS must implement Tunnel carriageway ventilation axial fan duty sharing that balances operating hours across the axial fan population, without imposing excessive operation on new or restored axial fans introduced to the population.

c) The duty sharing required by section 4.2.6a) and section 4.2.6b) must only be applied when the PMCS is in normal mode.

4.3 Egress passageway pressurisation

When dedicated egress passageway ventilation systems are included in the Tunnel in accordance with section 3.2, the control and monitoring requirements of section 4.3 must apply.

4.3.1 Egress passageway VCAs

a) VCAs for egress passageways must be developed for the PMCS PLC that describe the automatic control of all ventilation equipment associated with each egress passageway.

b) VCAs for egress passageways must:

i) ensure safe air quality is maintained for people accessing the egress passageway;

ii) achieve and maintain the performance requirements of section 3.2; and

iii) provide any functionality required for maintainability of the ventilation system.

c) Upon detection of smoke within an egress passageway, VCAs for egress passageways must:

i) automatically shut down the associated ventilation system;

ii) raise an alarm to SCADA that the associated ventilation system has been shut down; and

iii) allow for manual reactivation of the associated ventilation system via SCADA.

d) The Contractor must confirm and augment the egress passageway VCAs required by section 4.3.1 based on the Contractor's Design Documentation.

4.3.2 Egress passageway ventilation manual controls

a) The following manual controls must be available from SCADA for each egress passageway ventilation system as a minimum:

i) stop the egress passageway ventilation system;

ii) run the egress passageway ventilation system; and

iii) adjust the airflow setpoint when the VCAs have airflow setpoint capability.

b) The manual controls required by section 4.3.2a) must:

i) be confirmed and augmented by the Contractor based on the Contractor's Design Documentation; and

ii) include any pre-defined activation response agreed with SAMFS during the consultation process defined by TUN-FIRE-DC3 "Tunnel Fire Engineering".

4.3.3 Egress passageway duty sharing

Egress passageway ventilation fan duty sharing must be implemented in the PMCS that automatically balances operating hours across the ventilation fan population, without imposing excessive operation on new or restored ventilation fans.

4.4 Services passageway ventilation

When service passage ventilation systems are included in the Tunnel in accordance with section 3.3, the control and monitoring requirements of section 4.4 must apply.

4.4.1 Services passageway VCAs

a) Services passageway VCAs must be developed for the PMCS PLC that describe the automatic control of all ventilation equipment for the following scenarios as a minimum:

i) normal operations scenarios; and

ii) fire scenarios.

b) The services passageway VCA for normal operations scenarios must:

i) achieve the performance requirements of section 3.3;

ii) be the default VCA for the services passageway; and

iii) be enabled when no other services passageway VCA is active.

c) The services passageway VCA for fire scenarios must:

i) achieve the smoke control performance requirements of section 3.3;

ii) be automatically enabled when a fire is declared for the area served;

iii) provide a user configurable time delay before the smoke control response is activated;

iv) allow an operator to cancel the smoke control response during the time delay; and

v) be automatically disabled when a fire alarm is cleared for the area served.

d) The Contractor must confirm and augment the services passageway VCAs required by section 4.4.1 based on the Contractor's Design Documentation.

4.4.2 Services passageway ventilation manual controls

a) The following manual controls must be available from SCADA for each services passageway ventilation system as a minimum:

i) stop the services passageway ventilation system;

ii) run the services passageway ventilation system; and

iii) adjust the airflow setpoint when the VCAs have airflow setpoint capability.

b) The manual controls required by this section 4.4.2 must:

i) be confirmed and augmented by the Contractor based on the Contractor's Design Documentation; and

ii) include any pre-defined manual smoke control response agreed with SAMFS during the consultation process defined by TUN-FIRE-DC3 "Tunnel Fire Engineering".

4.4.3 Services passageway duty sharing

a) Services passageway ventilation fan duty sharing must be implemented in the PMCS that automatically balances operating hours across the ventilation fan population, without imposing excessive operation on new or restored ventilation fans.

b) The services passageway ventilation fan duty sharing required by 4.4.3a) must only be applied when the VCA for normal operations is active.

4.5 Tunnel drainage sump ventilation

When Tunnel drainage sump ventilation systems are included in accordance with section 3.4, the control and monitoring requirements of section 4.5 must apply.

4.5.1 Tunnel drainage sump VCAs

a) Tunnel drainage sump ventilation VCAs must be developed for the PMCS PLC that describe the automatic control of Tunnel drainage sump ventilation systems.

b) The Tunnel drainage sump VCA must:

i) achieve the performance requirements of section 3.4;

ii) automatically alter the Tunnel drainage sump ventilation system in response to:

A. hydrocarbon instrument signals; and

B. foam suppression signals (when foam suppression is provided); and

iii) automatically stop the Tunnel drainage sump ventilation system in the event of a foam suppression release in the area being served (when foam suppression is provided).

c) The Contractor must confirm and augment the Tunnel drainage sump ventilation VCAs required by section 4.5.1b) based on the Contractor's Design Documentation

4.5.2 Tunnel drainage sump ventilation manual controls

a) The following manual controls must be available from SCADA for each Tunnel drainage sump ventilation system as a minimum:

i) stop the Tunnel drainage sump ventilation system;

ii) run the Tunnel drainage sump ventilation system; and

iii) adjust the airflow setpoint when the VCAs have airflow setpoint capability.

b) The Contractor must confirm and augment the Tunnel drainage sump ventilation manual controls required by section 4.5.2a) based on the Contractor's Design Documentation.

4.5.3 Tunnel drainage sump ventilation duty sharing

Tunnel drainage sump ventilation fan duty sharing must be implemented in the PMCS that automatically balances operating hours across the ventilation fan population, without imposing excessive operation on new or restored ventilation fans.

5 Reliability, Design Life, and functional safety requirements

The Contractor must ensure that the Tunnel ventilation systems satisfy the following reliability, Design Life, and functional performance requirements:

a) the Tunnel ventilation systems must be designed and provided to comply with the systems engineering requirements and the analysis for RAMS in accordance with PC-EDM6 "Systems Engineering Management"; and

b) the failure of any element of the Tunnel ventilation systems must not adversely impact the function or performance of the remainder of the Tunnel ventilation systems.

6 Maintainability

The Contractor must ensure that the Tunnel ventilation systems are:

a) designed for safe maintenance access; and

b) designed such that components are removable from their installed locations without the need to disassemble or reassemble components on Site.

7 Verification requirements and records

7.1 General

a) Tunnel ventilation systems must be tested and commissioned in accordance with:

i) PC-CN1 "Testing and Commissioning";

ii) all system component manufacturer and supplier recommendations;

iii) the Contractor's Fire Engineering design; and

iv) the requirements of this section 7.

b) The Tunnel ventilation systems must be tested and commissioned to demonstrate compliance with acoustic requirements.

c) For ventilation systems that operate for the normal operations, post-opening completion system tuning must be undertaken in accordance with PC-CN1 “Testing and Commissioning” and include as a minimum:

i) optimisation of the VCA performance;

ii) optimisation of energy consumption; and

iii) minimisation of false alarms associated with equipment monitoring.

7.2 Tunnel carriageway ventilation system

a) Testing of the Tunnel carriageway ventilation system must be undertaken to determine by measurement the pressure loss factor for each Tunnel without any vehicles present.

b) Testing of ventilation jet fan performance must be undertaken to assess the Tunnel flow delivered given the operation of different numbers of ventilation jet fans at different locations.

c) Ventilation axial fan flow must be tested individually, in different group patterns and at different speeds to:

i) prove required fan flow capacities are achieved; and

ii) enable the determination the total flow relationship to ventilation axial fan number and fan speed.

d) In-Tunnel air velocity testing and measurements must be undertaken:

i) for a range of velocities expected in the Tunnel;

ii) by measuring velocities using Tunnel cross section grid techniques at multiple locations;

iii) using Tunnel velocity instruments to compare to the grid measurements to determine instrument correction factors;

iv) to determine the correlation between Tunnel velocity instrument measurements and the Tunnel flowrate; and

v) to prove that accurate Tunnel flows can be determined with instrument failures.

e) For Tunnels where portal emissions need to be controlled, portal flow capture tests must be undertaken to demonstrate performance including as required by section 3.1.7e)i).

f) Tunnel carriageway ventilation smoke management tests must be undertaking including:

i) cold flow testing simulating multiple fire locations to:

A. demonstrate the correct integrated response of all systems; and

B. confirm the cold flow modelled flowrates can be achieved; and

ii) hot smoke testing in accordance with AS 4391 Smoke management systems - Hot smoke test to:

A. demonstrate the detection system response;

B. demonstrate the correct integrated response of all systems; and

C. allow a visualisation of smoke management for emergency operations.

g) Tunnel carriageway ventilation hot smoke tests must:

i) be undertaken in all Tunnels; and

ii) have locations and parameters agreed with the Principal and SAMFS.

h) Testing must be undertaken where a fire incident is declared in the Tunnel ventilation control system for every detection zone to demonstrate:

i) all required ventilation systems operate; and

ii) no incorrect airflow outcomes occur.

i) Tunnel carriageway ventilation system management tests must demonstrate the reduction in the Tunnel air flow with the required deluge operation response for the most onerous ventilation location within each Tunnel bore.

j) Post-opening completion system tuning must be undertaken in accordance with PC-CN1 “Testing and Commissioning” and include as a minimum:

i) optimisation of the Tunnel carriageway ventilation VCAs performance;

ii) optimisation of the time-of-day response tables based on measured traffic data;

iii) optimisation of Tunnel carriageway ventilation energy consumption; and

iv) minimisation of false alarms associated with equipment monitoring.

7.3 Egress passageway pressurisation

a) Testing and commissioning of egress passageway ventilation systems must demonstrate:

i) door opening forces are compliant with this Master Specification Part;

ii) open door velocities and airflows are compliant with this Master Specification Part; and

iii) open door self-closing functionality occurs.

b) Testing and commissioning to demonstrate the requirements of section 7.3a) must be:

i) undertaken for each Tunnel carriageway detection zone; and

ii) undertaken with the Tunnel carriageway ventilation system operating to mimic the Tunnel carriageway ventilation conditions for each Tunnel carriageway detection zone.

c) For egress passageways with dedicated pressurisation systems, testing must also be undertaken to demonstrate compliance with noise requirements.

7.4 Services passageway ventilation

Testing and commissioning of services passageway ventilation systems must demonstrate:

a) the minimum airflows for each operational response;

b) integrated operation with air monitoring instrumentation in the services passage; and

c) safe access and egress whilst the ventilation system is operational.

7.5 Tunnel drainage sump ventilation

Testing and commissioning of Tunnel drainage sump ventilation systems must demonstrate:

a) the minimum airflows for each operational response;

b) integrated operation of the vapour detection and ventilation response;

c) integrated operation with the foam suppression system; and

d) safe access and egress whilst the ventilation system is operational.

8 Appendix 1: PMCS modes mapped to ventilation operations, scenarios and responses