

Master Specification

Part TUN-ME-DC3

Tunnel Carriageway and Underpass Lighting

September 2024



Government of South Australia
Department for Infrastructure
and Transport

Build.
Move.
Connect.

Document Information

Document Information

K Net Number:

Document Version: 1

Document Date: 30/09/2024

Document Amendment Record

| Version | Change Description | Date |
|---------|--------------------|------------|
| 0 | Initial issue | 31/08/2023 |
| 1 | Updated cover page | 30/09/2024 |

Document Management

This document is the property of the Department and contains information that is confidential to the Department. It must not be copied or reproduced in any way without the written consent of the Department. This is a controlled document and it will be updated and reissued as approved changes are made.

Contents

| | |
|--|----|
| Contents | 3 |
| TUN-ME-DC3 Tunnel Carriageway and Underpass Lighting | 4 |
| 1 General | 4 |
| 2 Documentation | 5 |
| 3 Technical requirements | 6 |
| 4 Control and monitoring requirements | 12 |
| 5 Design Life requirements | 15 |
| 6 Maintainability | 15 |
| 7 Warranty | 15 |
| 8 Hold Points and Witness Points | 16 |
| 9 Verification requirements and records | 16 |

TUN-ME-DC3 Tunnel Carriageway and Underpass Lighting

1 General

- a) This Master Specification Part sets out the requirements for the design, supply, installation, testing and commissioning of Tunnel carriageway and underpass lighting 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 Design Life requirements, as set out in section 5;
 - v) the maintainability requirements, as set out in section 6;
 - vi) the warranty requirements, as set out in section 7;
 - vii) the Hold Point and Witness Point requirements, as set out in section 8; and
 - viii) the verification requirements and records, as set out in section 9.
- b) For the purposes of this Master Specification Part, "Tunnel carriageway and underpass lighting" includes the following subsystems:
 - i) lighting of the Tunnel carriageways; and
 - ii) lighting of underpasses.
- c) This Master Specification Part does not apply to the following:
 - i) Tunnel evacuation lighting, low level guidance lighting, or directional signage in Tunnel carriageway spaces, which is addressed in TUN-FIRE-DC2 "Tunnel Evacuation Systems";
 - ii) Tunnel egress lighting or directional egress signage which is addressed in TUN-FIRE-DC2 "Tunnel Evacuation Systems";
 - iii) Tunnel services buildings that are underground, above ground, or in cut-and-cover structure as addressed by AS 2293 Emergency lighting and exit signs for buildings;
 - iv) lighting of Tunnel rooms and facilities which is addressed in TUN-FAC-DC1 "Requirements for Tunnel Facilities";
 - v) lighting of Tunnel egress passageways, which is addressed in TUN-FAC-DC1 "Requirements for Tunnel Facilities";
 - vi) lighting of open road and public lighting as addressed in RD-EL-D1 "Design of Road Lighting", RD-EL-S1 "Supply of Luminaires and Lighting Components" and RD-EL-C1 "Installation of Road Lighting";
 - vii) smart lighting control systems for open roads;
 - viii) electrical switchboards (which are addressed in RD-ITS-S2 "Roadside Electrical Switchboards" and TUN-ME-DC4 "Tunnel Equipment Cabinets" (as applicable)); or
 - ix) pits and conduits (which are addressed in RD-EL-D3 "Conduit Design for Road Lighting, Traffic Signals and ITS" and RD-EL-C3 "Supply and Installation of Conduits and Pits").
- d) The design, supply, installation, testing, and commissioning of Tunnel carriageway and underpass lighting must comply with the Reference Documents, including:
 - i) AS/NZS 1158 Lighting for roads and public spaces;

- ii) AS/NZS 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules);
- iii) AS/NZS 3008.1.1 Electrical installations - Selection of cables, Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions;
- iv) AS/NZS 4282 Control of the obtrusive effects of outdoor lighting;
- v) AS 60529 Degrees of protection provided by enclosures (IP Code);
- vi) AS/NZS 60598 Luminaires;
- vii) AS/NZS 61000 Electromagnetic compatibility (EMC);
- viii) AS/NZS 62386 Digital addressable lighting interface;
- ix) Austroads Guide to Road Tunnels (AGRT);
- x) DiiA Specification DALI Part 251 - Memory Bank 1 Extension;
- xi) DiiA Specification DALI Part 252 - Energy Reporting;
- xii) DiiA Specification DALI Part 253 - Diagnostics & Maintenance;
- xiii) IEC 62262 Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code); and
- xiv) ISO 14025 Environmental labels and declarations - Type III environmental declarations - Principles and procedures.

2 Documentation

2.1 Design Documentation

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

- a) the selection of the lighting category as required by section 3.1b);
- b) the maintenance factor calculations for Tunnel lighting systems as required by section 3.2b);
- c) the spacing of support brackets as required by section 3.6h);
- d) the information regarding the Contractor’s proposed luminaires, as required by section 3.10g);
- e) the photometer datasheets or manufacturer’s declarations and device certification as required by section 3.12f);
- f) the automatic lighting control strategy required by section 4.2a);
- g) the time-of-day lighting control strategy required by section 4.3; and
- h) the architectural lighting and landscape lighting control strategy required by section 4.6c).

2.2 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) valid and current test instrument calibration certificates (NATA accredited calibration provider) for test instruments;
- b) certificates of compliance provided by a suitably qualified electrical contractor for all LV electrical work at their completion; and
- c) the lighting test report, in accordance with section 9j).

3 Technical requirements

3.1 General design requirements

- a) The selection of lighting category must be determined in accordance with AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses.
- b) The selection of lighting category (as determined in accordance with section 3.1a)) must be documented in the Design Documentation.
- c) Lighting schemes under category TU1 and TU2 (as determined in accordance with section 3.1a)) must comply with section 3.2.
- d) Lighting schemes under category TU3, TU4 and TU5 (as determined in accordance with section 3.1a)) must comply with the requirements of section 3.3.
- e) The design of the lighting system must comply with WHS requirements and regulations for installation, modification, maintenance, and decommissioning.
- f) The design of the lighting system must minimise the whole-of-life costs to the Principal (taking into account the cost of construction, maintenance, repairs, energy consumption and replacement) and environmental impact.
- g) The design of the lighting system must take account of site-specific conditions and surrounding environment.
- h) The number of luminaires on each digital lighting interface (DLI) network must not exceed 80% of the maximum number of devices allowed on the network.

3.2 Design of Tunnel carriageway lighting

- a) The design of the Tunnel carriageway lighting system must comply with the requirements of AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses.
- b) The maintenance factors of the Tunnel carriageway lighting system must be calculated in accordance with Appendix F of AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses, and submitted as part of the Design Documentation.
- c) The calculation of Tunnel carriageway lighting must be performed using the luminance reduction curve method as specified in AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses.
- d) The Tunnel carriageway lighting design must be performed on TULIP software.
- e) Mains failure lighting must:
 - i) be provided for Tunnel carriageway lighting for category TU1 and TU2 in accordance with AS 1158.5 Lighting for roads and public spaces; and
 - ii) have an operation duration of not less than 90 minutes at any time during the life of the installation after a mains failure.

3.3 Design of underpass lighting

- a) The design of the underpass lighting system must comply with the requirements of AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses.
- b) The category TU3 and TU4 underpass lighting design schemes must have day-time lighting design performed on TULIP software.
- c) The category TU3, TU4 and TU5 underpass lighting design schemes must have night-time lighting calculations performed in accordance with the requirements of RD-EL-D1 "Design of Road Lighting".

3.4 Design of architectural lighting and landscape lighting

- a) Architectural lighting and landscape lighting for Tunnels and underpasses must be provided in accordance with the urban design requirements of the Contract Documents.
- b) Where the luminaires for architectural lighting and landscape lighting are visible from the environment outside of the Tunnel structure, the architectural lighting and landscape lighting designs must comply with AS/NZS 4282 Control of the obtrusive effects of outdoor lighting.

3.5 Design of electrical services

- a) The electrical services for Tunnel and underpass luminaires must be designed in accordance with the requirements of:
 - i) TUN-ME-DC2 "Tunnel Power Systems"; and
 - ii) AS/NZS 3000 Electrical installations.
- b) Where required by AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses, duplicated main power supplies for the selected lighting sub-category must be provided in accordance with TUN-ME-DC2 "Tunnel Power Systems".
- c) For a Tunnel with redundantly configured power supply, the power supply of Tunnel lighting luminaires must be interleaved such that the failure of one power supply does not result in the power loss on any 2 consecutive luminaires.
- d) The DLI devices must be supplied from the same distribution board as the luminaires the DLI device is connected to.
- e) Where required by AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses, UPS backup power must be provided for the selected lighting sub-category in accordance with TUN-ME-DC2 "Tunnel Power Systems".
- f) RCDs must not be used on the final sub-circuit supplying the luminaires and lighting control devices for Tunnel carriageway lighting and underpass lighting.
- g) Mains failure lighting must be supplied from the Tunnel essential power.

3.6 Installation of Tunnel carriageway and underpass lighting luminaires

- a) The installation of Tunnel carriageway lighting and underpass lighting luminaires must be in accordance with the requirements of this section 3.6.
- b) Steel support bracketry must be used to support cable ladders within the crown of the Tunnel.
- c) Support bracketry and fixing accessories must be capable of withstanding the corrosive environment from ground water ingress that may be present in the Tunnel space whilst avoiding dissimilar metal corrosion interfaces.
- d) The luminaires must be fixed underneath the cable ladder support brackets by fixtures designed to attach directly to the bracket.
- e) The weight of the luminaires, including the control gear, must be considered in the design of the support brackets.
- f) Fixtures to attach the luminaires to the support brackets must provide sufficient clearance between the underside of the support bracket and the top of the luminaire to clear any support mechanisms for the cable ladders.
- g) Fixtures to attach the luminaires to the support brackets must provide a gap for cooling air flow over the top of the luminaire.
- h) The spacing of support brackets installation must be included in the Design Documentation at Detailed Design.

3.7 Installation of architectural and landscape lighting luminaires

Luminaires for architectural lighting and landscape lighting must:

- a) be installed with mechanical and vandal-resistant fixing and mounting accessories;
- b) not use adhesive fixing or mounting; and
- c) be removable for maintenance and without damaging luminaires and mounting surfaces.

3.8 Installation of lighting control equipment

The installation of the light diffusing face of the enclosure for in-Tunnel illuminance photometers must be aligned with the Tunnel wall surface.

3.9 Installation of electrical services

The electrical reticulation for Tunnel and underpass luminaires must be installed in accordance with:

- a) AS/NZS 3000 Electrical installations; and
- b) TUN-ME-DC2 "Tunnel Power Systems".

3.10 Supply of Tunnel carriageway and underpass luminaires

- a) The supply of Tunnel carriageway and underpass lighting luminaires must be in accordance with this section 3.10.
- b) A warranty must be provided for all luminaires supplied for the Tunnel carriageway and underpass lighting systems in accordance with the requirements of section 7.
- c) Luminaires must comply with the following optical requirements:
 - i) the luminous efficacy of the luminaire must be greater than 140 lm/W;
 - ii) the luminaire must be rated to have 90% initial luminous output level over 90% of luminaire population after 100,000 hours of operation (i.e. rated to 100,000 hours L90 B10 lifespan);
 - iii) the luminaire must have a correlated colour temperature of 4000K with standard deviation colour matching not more than 3;
 - iv) the luminaire must retain a colour rendering index (Ra) of more than 70 through its Design Life; and
 - v) the photometric distribution must be symmetrical type.
- d) Luminaires (including drivers) must comply with the following electrical requirements:
 - i) rated operating voltage must be 230 V single phase with 50 Hz frequency;
 - ii) total current harmonic distortion must be not more than 10% at 100% dimming level;
 - iii) power factor must be not less than 0.9;
 - iv) the luminaire must be provided with built-in surge protection rated to an impulse level not less than 20 KV to protect drivers and LED arrays; and
 - v) the luminaire must be fitted with a driver that is:
 - A. compliant with the requirements of AS/NZS 62386 Digital addressable lighting interface;
 - B. certified by the DiiA DALI-2 and DiiA D4i certification program; and
 - C. certified by the DiiA DALI+ certification program if an alternative wired system is used.

- e) Luminaires must demonstrate electromagnetic compatibility compliance with AS/NZS 61000 Electromagnetic compatibility (EMC).
- f) Luminaires must comply with the following physical requirements:
 - i) the luminaires must have an IP rating of not less than IP66 as measured in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code);
 - ii) the luminaires must have a mechanical impacts protection rating of not less than IK07 as measured in accordance with IEC 62262 Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code);
 - iii) the operating temperature range of the luminaires must be not less than -15°C to +55°C;
 - iv) the luminaires must comprise a multi-service (power and control) plug and socket arrangement with pre-manufactured or terminated wiring harnesses using LSZH cable;
 - v) the luminaire sub-components must be replaceable in situ;
 - vi) the luminaire front optical must be constructed with tempered glass;
 - vii) the luminaire front optical must not be polycarbonate;
 - viii) the luminaire front optical must be sealed with a long-life ethylene propylene diene monomer (EPDM) gasket utilising continuous over-centre clamping;
 - ix) the luminaire body must be constructed with either:
 - A. extruded aluminium; or
 - B. stainless steel;
 - x) the luminaire surface finish must be completed with either:
 - A. electro-static powder coating; or
 - B. anodising (aluminium); and
 - xi) mounting brackets must include dissimilar metal segregation where required.
- g) The Design Documentation must include the following information regarding the proposed luminaires to be supplied for the Tunnel carriageway and underpass lighting systems:
 - i) luminaire data sheets, including rated operating voltage, frequency, power factor, total harmonic distortion (THD) and operating temperature;
 - ii) the luminaire photometric files (in both IESNA (.ies) and CIE (.cie) format) associated with the LM-79 test required by section 3.10h);
 - iii) the following test reports, following tests undertaken by a NATA accredited testing facility in Australia in accordance with section 3.10h):
 - A. LM-79;
 - B. LM-80;
 - C. TM-21; and
 - D. in-situ temperature measurement testing for the luminaires (ISTMT);
 - iv) details and schedule of previous installation sites of the proposed luminaire type, to demonstrate successful prior use of the luminaire type in similar environmental and site conditions;
 - v) details of local support arrangements and nominated local support representative in South Australia;

- vi) Environmental Product Declaration quantifying the life-cycle environmental impact including life-cycle carbon footprints of the proposed luminaires as provided by the luminaire manufacturer;
- vii) the Environmental Product Declaration required by 3.10g)vi) must:
 - A. comply with ISO 14021 Environmental labels and declarations - Self-declared environmental claims; or
 - B. comply with ISO 14025 Environmental labels and declarations - Type III environmental declarations - Principles and procedures if required by the Contract Documents; and
- viii) a checklist confirming the Contractor's compliance with the requirements set out in this Master Specification Part relating to luminaires, including a report detailing compliance with AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses, including all necessary calculations and documents listed in Appendix J of AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses.
- h) The LM-79 test required by section 3.10g)iii)A must be carried out by a NATA accredited testing facility in Australia and include the following parameters:
 - i) total luminous flux in absolute measurement;
 - ii) luminous efficacy (lm/W);
 - iii) luminous intensity distribution polar diagram (candela);
 - iv) correlated colour temperature (CCT);
 - v) colour rendering index (CRI); and
 - vi) chromaticity coordinates.

3.11 Supply of architectural and landscape lighting

- a) The requirements of this section 3.11 must apply to the supply of luminaires for architectural and landscape lighting installed:
 - i) within Tunnels;
 - ii) on structures attached to or at the Tunnel portals; and
 - iii) within underpasses.
- b) Luminaires for architectural and landscape lighting must:
 - i) comply with PR-LS-D1 "Landscape and Urban Design";
 - ii) have a luminous efficacy which is greater than 110lm/W for white light luminaire, including colour changing luminaires in white light mode, with correlated colour temperature between 2200K to 6700K;
 - iii) have a luminous efficacy which is greater than 60lm/W for colour changing luminaire in red, green, and blue (RGB) mode; and
 - iv) have a L90/B10 lifespan not less than 100,000 hours in all colour modes.

3.12 Supply of lighting control devices

- a) A warranty must be provided for all lighting control devices supplied as part of the Tunnel carriageway and underpass lighting systems in accordance with the requirements of section 7.
- b) The luminance photometers for the Tunnel portal areas and underpass portal areas must:

- i) include the optic specifically designed to view the L20 conical field and measure luminance within this field for Tunnel applications;
 - ii) include a sensor with a measurement variance not exceeding $\pm 3\%$;
 - iii) have housing which:
 - A. has a minimum IP rating of IP65 as measured in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code);
 - B. must be constructed with 316 stainless steel;
 - C. must have an operating temperature range of -15°C to $+55^{\circ}\text{C}$;
 - D. must be provided with separated IP65 plug and socket connections fitted on the housing for both mains input cable and signal output cable;
 - E. has a built-in surge protection device with rate discharge current rating of not less than 5kA (8/20 μs) and rated pulse voltage not less than 4kV; and
 - F. is provided with an internal heater to demist the viewing window;
 - iv) be provided with a sighting device for aiming the luminance photometer at the viewing point;
 - v) have a view angle of 20° with the option to alter the viewing angle between the ranges of 15° and 35° ;
 - vi) have a photodiode detector within the luminance photometer with a spectral response matching the CIE V lambda curve;
 - vii) have a 4mA to 20mA DC output signal and Modbus digital interface; and
 - viii) be supplied with a pan/tilt mounting bracket and pole mount bracket adaptor.
- c) The luminance photometers for the Tunnel portal areas and underpass portal areas must be dual range and:
- i) the high range must be user configurable between 0 and values ranging between 1,000 candela/m² and 10,000 candela/m²; and
 - ii) the low range must be user configurable between 0 and values ranging between 200 candela/m² and 500 candela/m².
- d) The illuminance photometer for in-Tunnel dirt depreciation measurement must:
- i) include a sensor with a measurement variance not exceeding $\pm 3\%$;
 - ii) have housing with a minimum IP rating of IP66 as measured in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code);
 - iii) have an operating temperature range must of -15°C to $+55^{\circ}\text{C}$;
 - iv) be provided with separated IP66 plug and socket connections fitted on the housing for both mains input cable and signal output cable (as measured in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code));
 - v) have a photodiode detector within the photometer with a spectral response matching the CIE V lambda curve;
 - vi) have a 4 to 20 mA DC output signal; and
 - vii) have a measurement range not less than 0-20,000 lux.
- e) The DLI devices for Tunnel and underpass lighting control must:
- i) comply with the requirements of AS/NZS 62386 Digital addressable lighting interface;
 - ii) be certified to DALI-2 and D4i by DiiA;

- iii) be certified to DALI+ if alternative wired system is used;
- iv) conform to the following DiiA specifications for monitoring and reporting functions:
 - A. DiiA Specification DALI Part 251 - Memory Bank 1 Extension;
 - B. DiiA Specification DALI Part 252 - Energy Reporting; and
 - C. DiiA Specification DALI Part 253 - Diagnostics & Maintenance; and
- v) have an operating temperature range of -15°C to +55°C.
- f) The following documentation must be included as part of the Design Documentation:
 - i) Tunnel portal area and underpass portal area luminance photometer datasheet or manufacturer's declaration to demonstrate compliance with the requirements of section 3.12d);
 - ii) in-Tunnel illuminance photometer datasheet or manufacturer's declaration to demonstrate compliance with the requirements of section 3.12c); and
 - iii) the DLI device certification of compliance as required by section 3.12e).

4 Control and monitoring requirements

4.1 General

- a) The Tunnel carriageway and underpass lighting control system must be a PLC-based control system.
- b) Each individual Tunnel carriageway and underpass lighting luminaire must be controlled and monitored by the PLC-based control system via a DLI protocol.
- c) The DLI device must convert the DLI protocol directly to a communication protocol that is interpretable by the I/O of the PLC-based control system without intermediate protocol.
- d) The DLI device must be a wired-type digital lighting control system compliant with the requirements of AS/NZS 62386 Digital addressable lighting interface.
- e) The system time of DLI devices must be set with an open protocol (such as NTP) that does not require manual configuration to establish or maintain.
- f) Lighting control input devices must be connected to the PLC-based control system.
- g) Where the Tunnel carriageway lighting or underpass lighting is used to illuminate an area that is monitored by automatic incident detection systems such as video incident detection cameras, the method and rate of dimming employed by the lighting control system must not cause the incident detection system to have false positive detections as a result of the change in dimming level.
- h) The DLI devices must be selected and configured to avoid data collision under all operation conditions.
- i) In the event of the loss of DLI or PMCS control signal, the luminaires for Tunnel carriageway lighting must be set to the following default levels:
 - i) maximum day-time lighting level in threshold zones and transition zones;
 - ii) day-time lighting level in interior zones; and
 - iii) night-time lighting level in exit zones.

4.2 Automatic lighting control strategy

- a) A lighting control strategy must be developed and submitted with the Design Documentation for the automatic control of Tunnel carriageway lighting systems and underpass lighting systems.

- b) The lighting control strategy required by section 4.2a) must:
 - i) provide lighting levels in compliance with AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses;
 - ii) utilise dimming via DLI protocol to provide lighting levels based on real-time portal luminance measurements;
 - iii) have a dimming profile, with fade-in/fade-out between each adjustment, that is either is continuous or has a minimum of 50 dimming steps;
 - iv) incorporate time delay and luminance change limits between adjustments in accordance with Appendix G of AS/NZS 1158.5 Lighting for public spaces, Part 5: Tunnels and underpasses;
 - v) automatically compensate lighting level loss due to:
 - A. luminaire output depreciation;
 - B. luminaire dirt depreciation; and
 - C. Tunnel wall surface dirt depreciation; and
 - vi) automatically reverse the compensation for the lighting level loss required in section 4.2b)v)B and section 4.2b)v)C after Tunnel washing activities.
- c) The dimming profile required by section 4.2b)iii) must be coordinated with:
 - i) other light-sensitive Tunnel equipment systems, such as CCTV or automatic incident detection cameras, to not adversely affect those systems by sudden changes in dimming levels; and
 - ii) the Tunnel power system to limit the adverse effects on the power quality caused by the dimming mechanism.

4.3 Time-of-day control strategy

- a) A lighting control strategy must be developed for the time-of-day control of Tunnel carriageway lighting systems and underpass lighting systems in the event the photometers fail.
- b) The time-of-day strategy required by section 4.3a) must:
 - i) provide user configurable lighting levels in compliance with AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses;
 - ii) utilise dimming via DLI protocol to provide lighting levels based on the time and date;
 - iii) include lighting levels with time intervals not exceeding 30 minutes;
 - iv) include user configurable seasonal adjustments for lighting levels;
 - v) have a dimming profile with fade-in/fade-out between each adjustment;
 - vi) automatically compensate lighting level loss due to:
 - A. luminaire output depreciation; and
 - B. luminaire dirt depreciation;
 - vii) automatically reverse the compensation for the lighting level loss required in section 4.3b)vi)B after Tunnel washing activities; and
 - viii) be submitted with Design Documentation for approval.
- c) The dimming profile required by section 4.3b) must be coordinated with:
 - i) other light-sensitive Tunnel equipment systems, such as CCTV or automatic incident detection cameras, to not adversely affect those systems by sudden changes in dimming levels; and

- ii) the Tunnel power system to limit the adverse effects on the power quality caused by the dimming mechanism.

4.4 Tunnel carriageway lighting control and monitoring

- a) For Tunnel carriageway lighting the Contractor must ensure that the control and monitoring of the Tunnel carriageway lighting system complies with this section 4.4.
- b) For Tunnel carriageway lighting the PLC-based control system must be a PMCS in accordance with TUN-PMCS-DC1 "Tunnel Plant Monitoring and Control Systems".
- c) The PMCS must perform all lighting control and monitoring functions including reporting of status and alarms as specified in TUN-PMCS-DC1 "Tunnel Plant Monitoring and Control Systems".
- d) The I/O from the DLI device must communicate with the PMCS PLC via high level interface (HLI).
- e) Lighting control protocols used between the luminaire control gear and the PMCS must be open-source protocol without restricting the device selection and system integration to a specific vendor.
- f) Lighting control input devices must be connected to the PMCS PLC.
- g) The communication protocol utilised by DLI device to communicate with PMCS PLC must be an industrial ethernet protocol that is directly interpretable by the PLC or I/O module of the PMCS without additional conversion hardware or software.
- h) An automatic testing facility must be implemented in PMCS to perform periodic functional test and duration test to mains failure lighting required by section 3.2e).
- i) The automatic testing facility required by section 4.4h) must:
 - i) utilise DLI lighting control protocol;
 - ii) monitor the operational status of the mains failure lighting luminaires and associated control gear;
 - iii) monitor the operational status of electrical circuits and communication paths associated with mains failure lighting;
 - iv) monitor the operational status of emergency power sources for mains failure lighting;
 - v) perform function test and duration test on emergency power sources as part of the UPS routine test; and
 - vi) maintain electronic records of results from each test.
- j) The automatic testing facility required by section 4.4h) must have a user-configurable means for the test initiation via SCADA, including:
 - i) manual initiation of testing by an operator; and
 - ii) automatic initiation of testing on a periodic basis with a user-configurable time interval aligned with the emergency lighting test required by TUN-FAC-DC1 "Requirements for Tunnel Facilities".
- k) Testing of any mains failure lighting luminaire must not impact the operation of any other mains failure lighting luminaire or Tunnel carriageway lighting luminaire.

4.5 Underpass lighting control and monitoring

- a) Where the underpass lighting can be controlled and monitored by a PMCS or required in the Contract Documents to be controlled and monitored by a PMCS, the underpass lighting system must be controlled and monitored in accordance with section 4.1a).

- b) For underpass lighting not controlled and monitored by a PMCS the Contractor must ensure that the control and monitoring of the underpass lighting system complies with this section 4.5.
- c) The underpass lighting PLC-based control system must control the lighting levels in accordance with AS/NZS 1158 Lighting for roads and public spaces using input from the underpass portal area luminance photometer.

4.6 Architectural and landscape lighting control and monitoring

- a) Architectural lighting and landscape lighting must:
 - i) be individually controlled and monitored via a digital lighting control protocol; and
 - ii) be provided with remote switching and fault monitoring by the PMCS.
- b) The Contractor must develop an architectural lighting and landscape lighting control strategy to satisfy the requirements of urban design.
- c) The architectural lighting and landscape lighting control strategy required by section 4.6b) must be submitted with Design Documentation for approval.

5 Design Life requirements

The Tunnel carriageway and underpass lighting system components must satisfy the Design Life requirements of the Contract Documents.

6 Maintainability

- a) The Tunnel carriageway and underpass lighting system must be designed such that it requires minimal maintenance and can be easily maintained and serviced without the requirement for specialised training or tools.
- b) The Tunnel carriageway and underpass lighting system must be installed such that it can be easily maintained and serviced in accordance with the requirements of Appendix F of AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses.
- c) The Tunnel carriageway and underpass lighting system must be installed such that it can be easily maintained and serviced as required to:
 - i) clean the luminaires;
 - ii) replace failed LED luminaires;
 - iii) replace electronic control gear;
 - iv) inspect and replace seals; and
 - v) clean and calibrate luminance photometers.

7 Warranty

For the purposes of PC-CN3 “Construction Management”, the Contractor must obtain a manufacturer’s warranty of at least 10 years from the date of installation for all luminaires and lighting control devices, which satisfies the requirements of PC-CN3 “Construction Management”.

8 Hold Points and Witness Points

- a) Table TUN-ME-D3 8-1 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-D3 8-2 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-D3 8-1 Hold Points

| Section reference | Hold Point | Documentation or construction quality | Review period or notification period |
|-------------------|------------------------------------|---------------------------------------|--------------------------------------|
| 9j) | Submission of lighting test report | Documentation | 15 Business Days review |

Table TUN-ME-D3 8-2 Witness Points

| Section reference | Witness Point | Documentation or construction quality | Review period or notification period |
|-------------------|--|---------------------------------------|--------------------------------------|
| 9g) | Tunnel road and Tunnel wall luminance measurements | Construction quality | 20 days notification |

9 Verification requirements and records

- a) Testing and commissioning procedures and documentation must comply with the requirements of PC-CN1 “Testing and Commissioning”.
- b) The Testing and Commissioning Management Plan required by PC-CN1 “Testing and Commissioning” must include a Luminance Measurement Plan.
- c) The Luminance Measurement Plan required by section 9b) must:
 - i) include the strategy for measuring the Tunnel carriageway road surface and Tunnel wall surface luminance levels to demonstrate the actual luminance levels comply with the designed luminance levels;
 - ii) include luminance measurement methods in accordance with the requirements of Appendix K of AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses;
 - iii) use a luminance measurement procedure that can be performed subsequently by the Principal at any time to compare the result against the initial testing results at commissioning;
 - iv) document the method of conversion of illuminance measurements used to derive luminance levels; and
 - v) include a test for each lighting zone within the Tunnel.
- d) The luminance measurement procedure must be undertaken as part of the System Integration Acceptance Testing (SIAT), as defined by PC-CN1 “Testing and Commissioning”, after the successful completion of SIAT of the Tunnel carriageway lighting system.
- e) The luminance measurement points for Tunnel carriageway road surface luminance levels must be:
 - i) spaced at not more than 5 times the calculation point spacing in the longitudinal direction;
 - ii) aligned with Tunnel carriageway road surface calculation points;
 - iii) evenly spaced in the longitudinal direction in each lighting zone; and
 - iv) evenly spaced in the transverse direction and have at least one luminance measurement point in each lane.

- f) The measurement points for wall luminance surface level must:
 - i) be spaced at not more than 5 times the calculation point spacing in the longitudinal direction;
 - ii) be aligned with Tunnel wall surface calculation points;
 - iii) be evenly spaced in the longitudinal direction in each lighting zone;
 - iv) be evenly spaced in the vertical direction; and
 - v) include 1 m and 2 m measuring heights as a minimum in the vertical direction.
 - g) The Principal must be invited to attend the measurement of the luminance levels, which will constitute a **Witness Point**.
 - h) Prior to undertaking the luminance measurement procedure the following surfaces must be confirmed clean and in an “as new” condition:
 - i) luminaire front glasses / optical elements;
 - ii) Tunnel carriageway road surface;
 - iii) Tunnel carriageway edge barriers; and
 - iv) Tunnel walls / wall panels (where installed).
 - i) Illuminance measurement method defined in Appendix K of AS/NZS 1158.5 Lighting for roads and public spaces, Part 5: Tunnels and underpasses must not be used on existing road and wall surfaces where the surfaces have been exposed to general traffic.
 - j) A lighting test report must:
 - i) include the following:
 - A. date and time of the tests;
 - B. testing method;
 - C. location of the luminance measurement points;
 - D. location of observer positions;
 - E. make and model of testing equipment;
 - F. level of dimming applied to the luminaires in the test area at the time of the tests; and
 - G. current readings from the Tunnel portal luminance meters at the time of the tests;
 - ii) include the results of the Tunnel carriageway road surface and Tunnel wall surface luminance measurement procedure, presented in:
 - A. luminance levels if luminance measurements are used; or
 - B. both illuminance levels and derived luminance levels, where the measurement is reliant upon illuminance measurement only;
 - iii) include a current calibration certificate issued by a NATA accredited laboratory for all testing equipment used; and
 - iv) be submitted as a part of the Quality Management Records, which will constitute a **Hold Point**.
-