C100 Architectural Common Component Design
Escalator Tunnel Lighting Study

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Purpose of this Report

A recent contractor-led change to the escalator task lighting has prompted a review of the overall lighting strategy for the escalator tunnel by the C100 design team. Removing the ESC-101 luminous side panels of the escalators is a significant design change which will have an impact on how the escalator tunnels are perceived by passengers. The possible impact on operational decision making and evaluation of the surrounding environment has been considered in this report and recommendations made for modifications to the existing escalator deck uplighter design in order to mitigate possible adverse impacts.

Escalator Lighting Overview

Lighting Components

The escalator tunnel is to be lit by two major components: indirect architectural lighting from uplights (SPL-502) recessed into the face of the escalator deck, and diffuse direct task light to the step treads from a balustrade-integrated source - the latter component being part of the contractor fit-out.

Achieving the required levels of illuminance on the escalator itself will depend on the specification and design of the second component which will be the responsibility of the escalator supplier. This report will consider the design of prototype SPL-502 only.

Space Dimensions

The generic escalator environment is a symmetric three-escalator tunnel. There is a second, larger version which includes an inclined lift compartment alongside three escalators, however since this occurs only at Farringdon Station this report considers the lighting for the C100 generic station escalator tunnel.

The SPL-502 deck uplights will illuminate the vaulted ceiling of the generic escalator tunnel of height circa 5.5m AFFL and width circa 6.5m. The luminaires will be installed in the inclined escalator deck at 1m height AFFL (refer to drawings).

Materials

The internal surfaces of the escalator tunnels are clad in GFRC panels of light grey colour. Reflectance values for the acoustic panels have been estimated at 42% while for the light grey, solid soffit GFRC panels it has been estimated as circa 52%. For the escalator treads a typical stainless steel finish should has been assumed.

Luminance Levels on Tunnel Soffit

General illuminance levels are taken from London Underground Standards, Lighting of London Underground assets, 1-066 Revision A2. However the illuminance levels on the escalator treads are mainly dependent on the balustrade-integrated task lighting. Therefore the reference lighting levels for the architectural lighting of the escalator tunnel are defined as luminance levels on the tunnel soffit GFRC panels overhead, expressed as cd/m2. The escalator deck uplights primarily contribute to the illumination of the soffit, creating a feeling of a comfortable space and linking to the lower concourse.

General Illuminance (**E**) Levels according to London Underground Standards:

Average Illuminance:	150lux on stair tread
Uniformity*:	0.8
Glare Rating:	-
Colour Rendering:	>80
Colour Temperature:	-

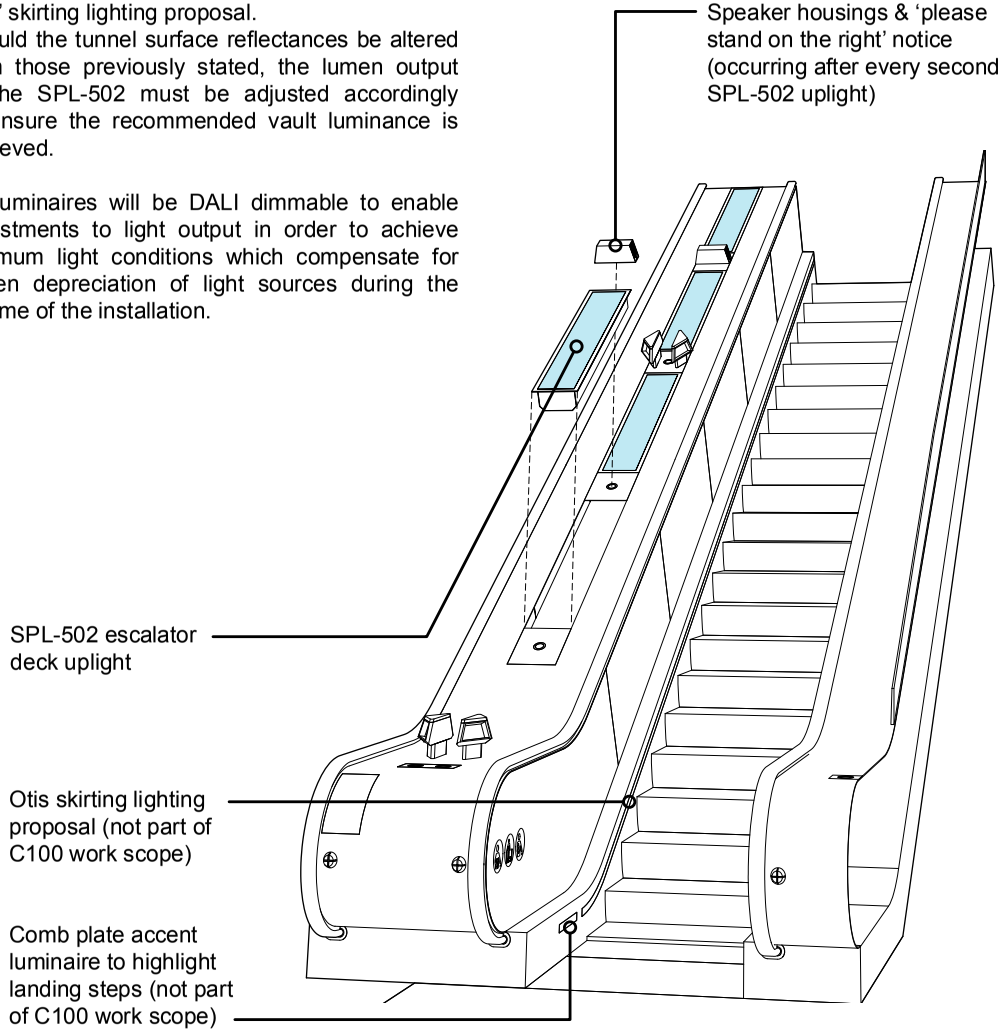
* excluding a boundary zone 100mm wide from any wall, pillar, column or other hardware mounted in the space.

Luminance (**L**) levels on tunnel vault recommended by C100:

Average Luminance:	20 cd/m^2 min 50 cd/m^2 optimum
Uniformity:	0.8
Colour Rendering:	>80
Colour Temperature:	5000K

The tier 1 station design teams responsible for completing the stage F2 detailed design for each station should consider the space dimensions and tunnel cladding reflectance to achieve an optimum Average Luminance of 50 cd/m^2 for the tunnel soffit contributed solely by SPL-502 uplights. This recommendation is an increase on the minimum luminance 20 cd/m^2 originally proposed for the SPL-502 uplighting and is intended to compensate for the loss in luminous flux contributed to the escalator environment as a result of as a result of the omission of ESC-101 and replacement with Otis' skirting lighting proposal.
Should the tunnel surface reflectances be altered from those previously stated, the lumen output of the SPL-502 must be adjusted accordingly to ensure the recommended vault luminance is achieved.

All luminaires will be DALI dimmable to enable adjustments to light output in order to achieve optimum light conditions which compensate for lumen depreciation of light sources during the lifetime of the installation.

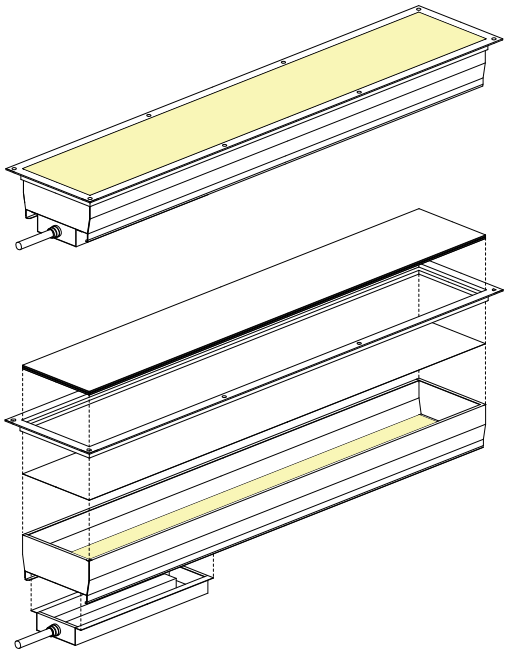


Where we were

Diffuse direct light to the step treads was to be delivered originally by ESC-101 in the form of uniformly lit backlit balustrade panels.

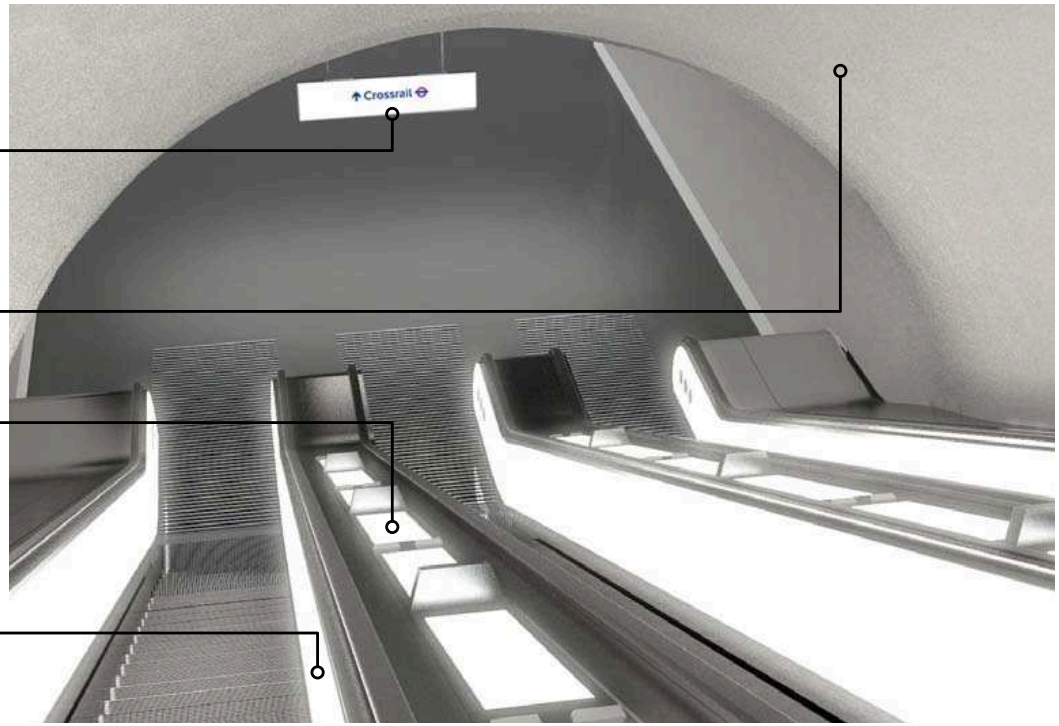
For consistent luminaire aesthetic, the backlit approach was previously proposed for SPL-502 uplight - namely a diffuse light source using LED linear boards covered by a microprismatic diffuser optic borrowing low-glare technology from the latest developments in office luminaires.

The image beside shows the visual intent at stage F1 development with the module arrangement and optics of the luminaire to be developed.



SPL-502 microprismatic diffuser backlit by LEDs

Original SPL-502 & ESC-101 escalator mock-up

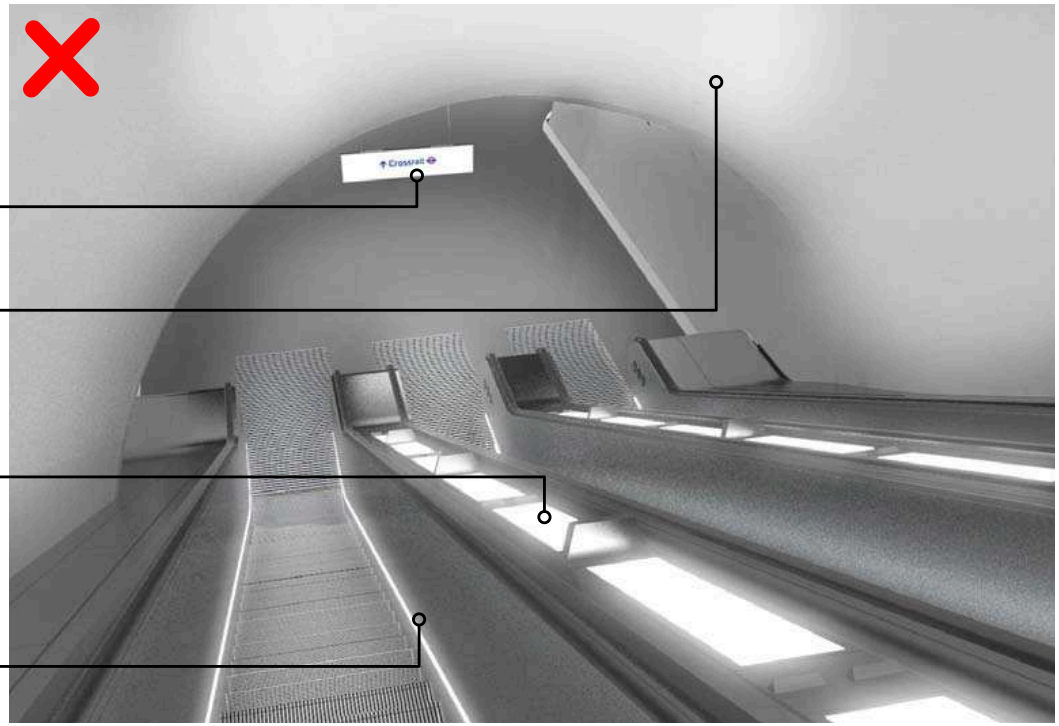


Original C100 design intent

Where we are now

The Crossrail escalator supplier has proposed an alternative task lighting solution which consists of a visually continuous linear profile which runs for the full extent of balustrade skirting to provide the diffuse direct light to step treads, albeit from a more localised, low-level position than originally proposed by the C100 team.

This change in form factor has an impact of the balance of the lit environment. The significantly reduced area of luminous balustrade surface is no longer complemented by the uniform luminance of the current SPL-502 escalator deck uplight proposal.



June 2014 - contractor-led skirting lighting (post-removal of ESC-101 balustrade lighting)

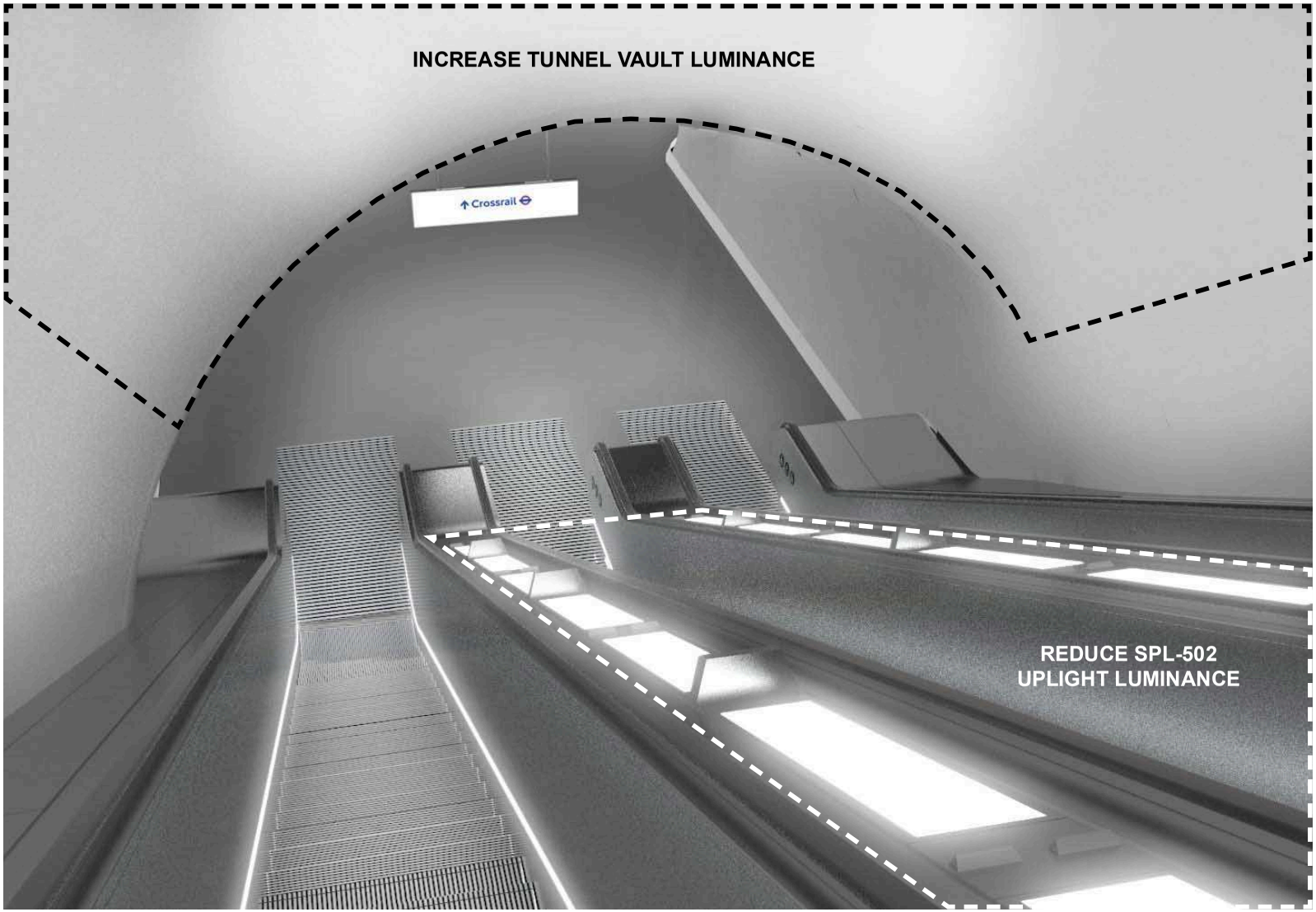
Moving forward

To restore visual balance to the escalator environment, it is proposed that the lit appearance of SPL-502 is revised.

The escalator soffit is a key surface as it appears directly in line of sight when passengers approach escalators from the station box. Design intent remains to provide a welcoming approach by washing the vault with soft-edged coverage of cool white light. It is important that greater emphasis is placed on the illuminated soffit overhead rather than the illuminated luminaires within the space. Given that there is no longer a visual language of large area luminous panels within the escalator tunnel a shielded low brightness solution for the escalator uplights is suggested instead.

The purpose of this report is to establish an appropriate new optical configuration for the SPL-502 which:

- achieves the proposed lit effect;
- conceals light sources from view at sight lines typically arising from escalator/concourse use;
- maintains low-glare performance to ensure visual comfort of escalator users.



Moving forward - objectives of SPL-502 redesign

Why retain escalator deck lights?

The Otis skirting lighting proposal will provide compliant task light for the escalator treads, however this does not automatically constitute a well-lit public circulation environment – particularly if the skirting-integrated light strip were to be the only source of light in the escalator tunnel.

Lighting within the escalator must also provide good facial recognition which is essential for passengers' sense of security and for effective CCTV operation. These lighting conditions cannot be achieved by the low-level step lighting alone - particularly during peak periods when escalators are heavily populated and much of the upward light emission from the skirting profile would be obscured by the dense passenger volume.

The SPL-502 escalator deck uplight will achieve good quality indirect lighting - reflected off the vault to provide vertical illumination which defines the space and enables passengers to perceive each other and their surroundings.

Omission of original SPL-502 deck uplight would severely compromise optimum lighting conditions

Why not dim existing SPL-502?

The change in form factor of ESC-101 has an impact of the aesthetic balance of the lit environment. The significantly reduced area of luminous balustrade surface is no longer complemented by the uniformly luminous diffuser panel used in the current SPL-502 escalator deck uplight design. If the existing deck uplight were to be installed it would be the brightest element of the space and would be visually overpowering. As stated previously, the intention is for the vaulted tunnel soffit to be the brightest element within the passengers field of view.

Dimming the existing deck uplight to reduce its surface luminance would in turn reduce the luminance of the vault overhead by a directly proportional measure. Therefore the same imbalance would still exist – the deck uplight still being perceived as the brightest element. Meanwhile indirect light to the space would be diminished and the design intent to provide good facial recognition would be compromised.

The purpose of the proposed SPL-502 deck uplight redesign is to revise the optical assembly to address this imbalance. Consequently the brightness of the vault will be immediately apparent to the viewer while the appearance of the SPL-502 luminaire will be visually discreet with minimal visual impact.

SPL-802 Linear LED downlight integrated within suspended sign at top and bottom escalator thresholds

Wash of light to vault diminishes in proportion with luminous intensity of SPL-502, as in turn does the indirect light contributed to the space essential for vertical illumination

Dimmed existing SPL-502 continues to dominate the space visually. Lit environment remains unbalanced.

Otis skirting lighting proposal comprises continuous linear profile in low level skirting

Dimming original SPL-502 deck uplight would severely compromise optimum lighting conditions

Why not recess existing SPL-502 uplight deeper into the escalator deck?

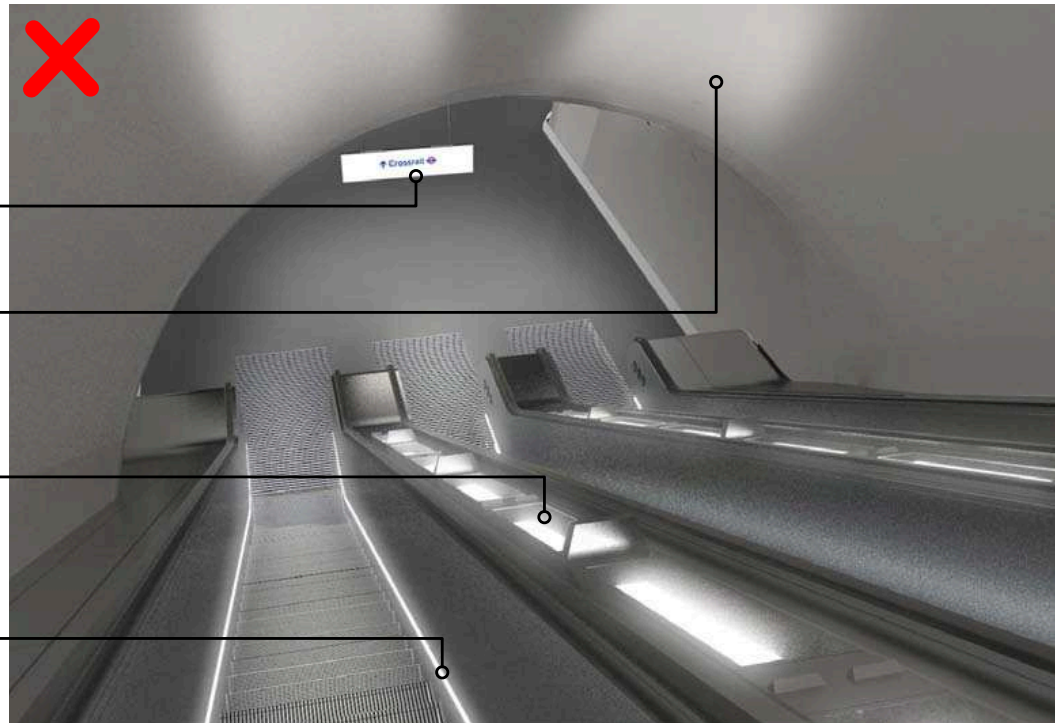
Recessing the existing SPL-502 downlight deeper into the escalator deck will not address the luminance imbalance within the space

Being circa 1500mm long and mounted on a 30 degree incline, a significant recess depth would be necessary to sufficiently conceal the luminous surface of the existing SPL-502 from view - particularly by passengers looking up on their approach from the concourse.

The lit appearance of the vault is an important factor. The wash of light should be diffuse with a soft, gradual run-off towards the sides of the vault.

Recessing the SPL-502 deeper into the escalator deck would create an excessively acute beam angle which would prevent light emission toward the sides of vault and create undesirably sharp cut-off shadow line on the soffit.

The proposed SPL-502 deck uplight redesign will employ optics which ensure that a reduced surface luminance for the uplight and optimum light coverage to the vault are simultaneously achieved - thereby negating a need to recess the luminaire deeper into the deck and compromise the lit effect.



Deep-recessing of original SPL-502 deck uplight would compromise soft-edge illumination of vault

Benefits of SPL-502 re-design

The revised optical design of the SPL-502 escalator deck uplight will achieve:

- a broad upward light distribution to the vaulted tunnel overhead;
- a soft-edged light distribution providing graduated coverage across the vault - brightest directly overhead;
- a 'darklight' appearance so that the luminaire is not recognised as a light emitter;
- minimised discomfort glare to passengers approaching and using escalators.

Proposed SPL-502 redesign

Soft-edged wash of light to vault is most prominent feature of escalator space

SPL-802 Linear LED downlight integrated within suspended sign at top and bottom escalator thresholds

Brightness of SPL-502 is minimised by appropriate optical control to conceal light sources. Balanced lit environment achieved

Balustrade upstands no longer appear dark in contrast to escalator deck

Tunnel uplighting precedents

Examples of existing lighting installations in underground escalator/platform tunnels where uplighting methods have been applied to illuminate the vaulted soffit.

Dupont Circle metro, Washington DC

London Piccadilly Line, 1960s

Abu Dhabi airport

Farragut West station, Washington DC

London Underground 1933

Lyublinskaya Line, Moscow metro

Kiev metro

Proposed SPL-502 redesign

SPL-502. Recessed luminaire in central escalator decks. Target luminaire body 1500mm (L) x 305mm (W) x 150mm (D) spaced at approximately 1870mm centres, to be coordinated with 'stand on right' signs, emergency stop buttons and speakers on the escalator deck.

Linear LED light engine set beneath a sealed optical arrangement comprising:

- a primary reflector (specular) with high-efficiency diffuse / beam-shaping cover with homogenous uniformly luminous lit appearance when viewed transversely by escalator users;
- a secondary reflector with black anodised baffles (25mm centres);
- a clear laminated safety glass cover with black back-painted perimeter with potential for graduated black line/dot fritting if necessary to soften beam edge on vault soffit.

The SPL-502 should feature an integral heat sink unit with linear LED light engine incorporated. Fixing of the heat sink body and LED light engine to optical chamber by screw and flange or by quick release lever clips. Fixing should prevent water and dust ingress into optical chamber. Front bezel with fixing screws to secure luminaire in escalator deck. Screws to be an anti-vandal Allen key or star head design.

Integral DALI dimmable driver in separate compartment from heat sink at base of luminaire body. DALI control will enable adjustments to light output in order to achieve maintained illuminance levels throughout the service life of the luminaire, to compensate for lumen depreciation of the LED light sources.

Anticipating optical efficiency of the proposed SPL-502 redesign, luminous flux of 4,000 luminaire lumens is proposed to achieve the required luminance values on the vaulted escalator tunnel ceiling. It is envisaged that manufacturer tests at prototyping stage of the product will confirm the exact lumen output and light distribution required.

Secondary optic comprising:

- bead-blasted aluminium cross-blade louvres with black ano-dised finish - max thickness 1.5mm, spacing 25mm (pending testing)
- bead-blasted aluminium trough reflector with black anodised finish
- 2-ply glass laminate cover with black back-painted glass perimeter terminating flush with trough reflector (+ graduated black dot/line fritted pattern for softened beam edge)

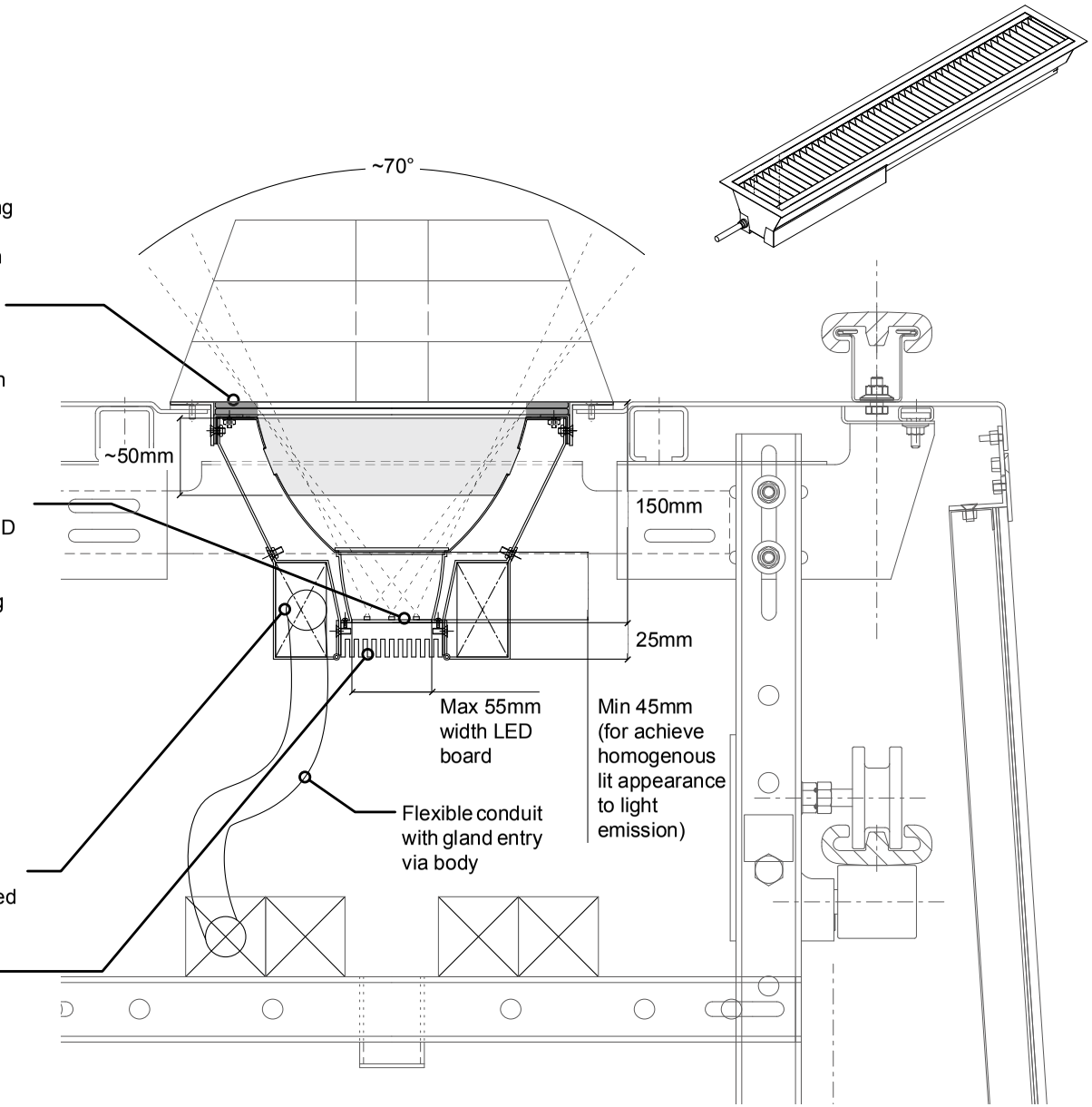
Primary optic comprising linear LED board in high-efficiency white reflector (>97% reflectance) with 2-ply glass laminate cover housing PET micro-lens film to achieve:

- ~70° beam-shaping
- LED chip concealment
- L0° peak intensity gain
- L65° glare suppression

(Both optics IP-sealed to prevent dust & moisture ingress)

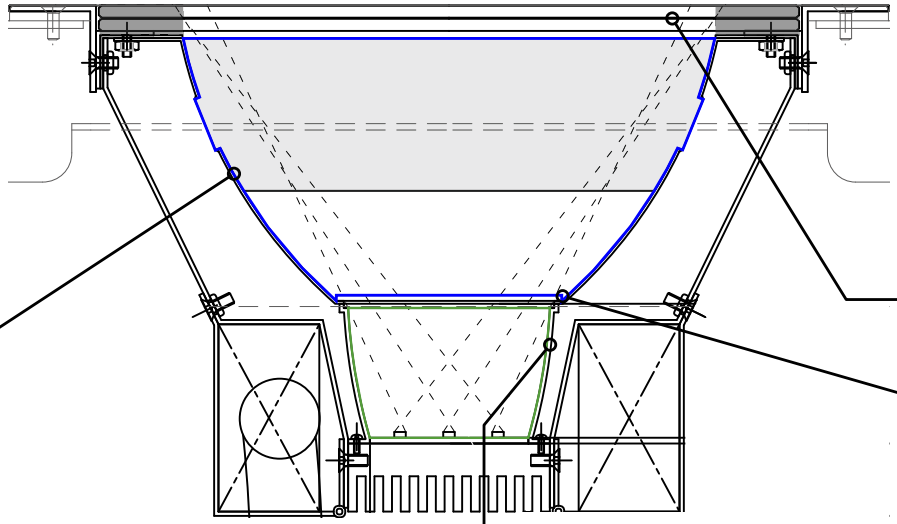
DALI dimmable control gear housed in separate compartment

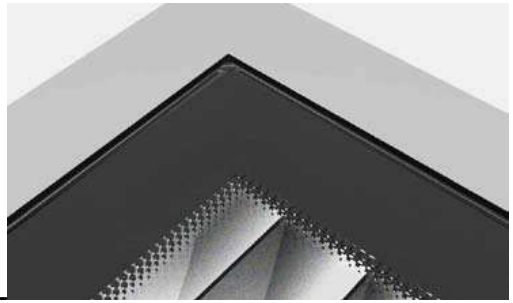
Passive heatsink



Proposed SPL-502 redesign - mock-up

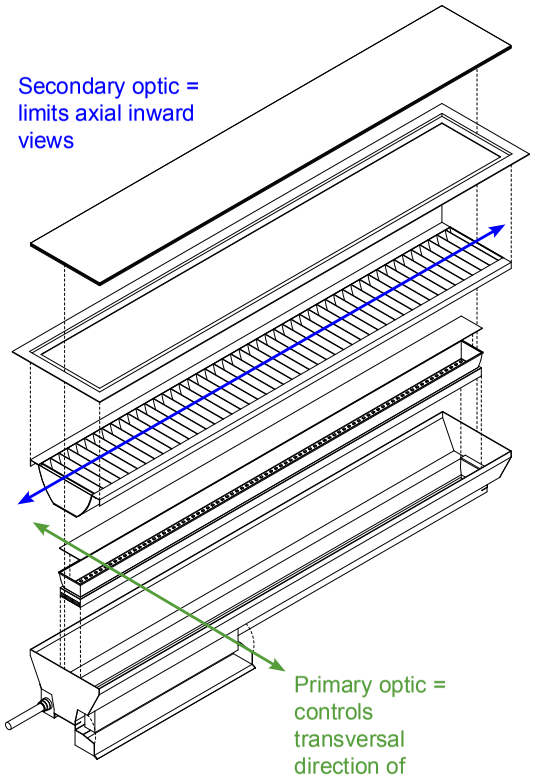
Examples of luminaire mock-ups and material samples illustrating the aesthetic and performance requirements previously outlined.

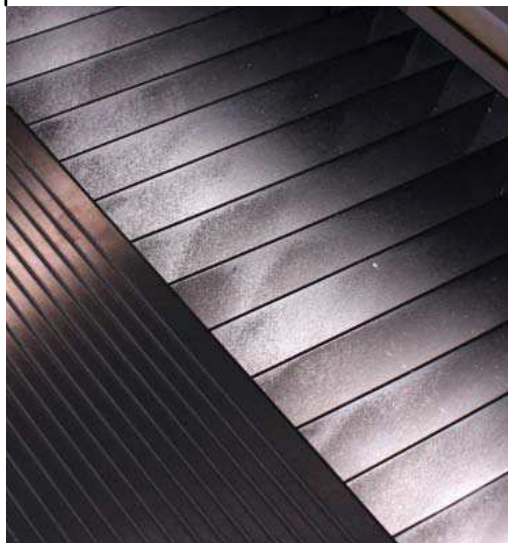




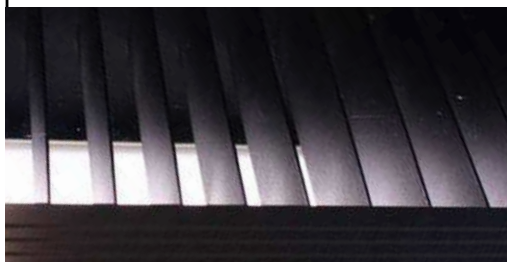
Back-painted glass perimeter & graduated black-dot/line frit

Linear LED board beneath diffuser

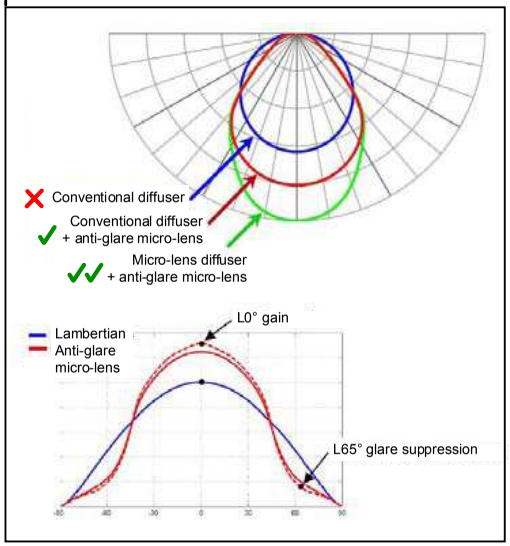




Secondary optic - trough reflector with cross-blade louvres for low luminance & low glare



Primary optic - visually comfortable light emitter, homogenous appearance when viewed side-on

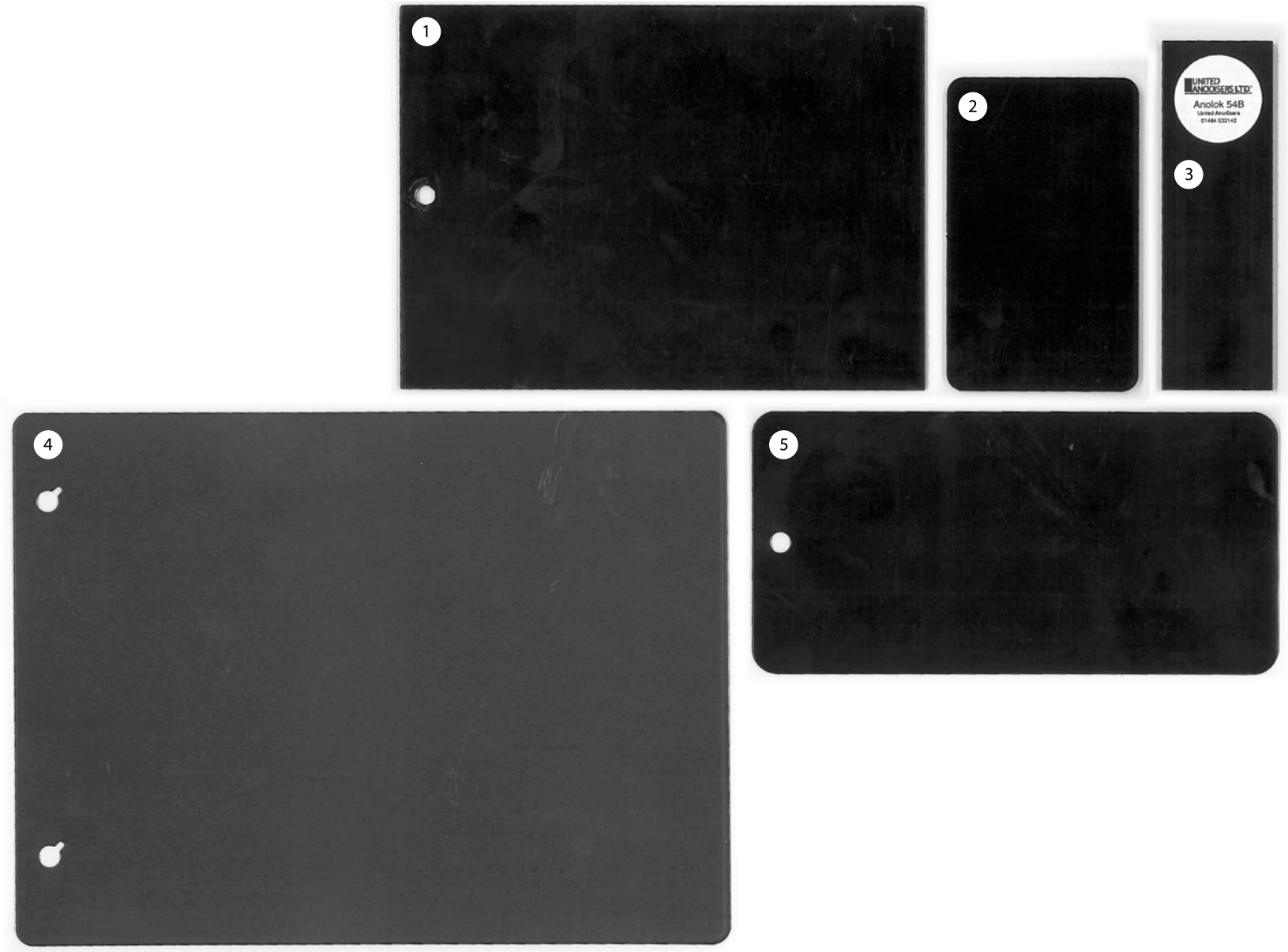


Micro-lens films in primary optic modify lambertian curve to suppress glare & increase peak intensity

Proposed SPL-502 redesign - materials

Samples of materials appropriate for consideration for the cross-bladed louvres and reflector forming the secondary optic:

1: Polyester Powder coat - Ral 9004 Semi Gloss
2: Anodic Finish Matt Black
3: Black Anodised Brush finish
4: Matt Black Powder Coat
5: Black Powder Coat Semi Gloss Satine



Proposed SPL-502 redesign - maintenance strategy

The finishes and detailing of the SPL-502 uplight have been designed to provide a product that is functional and simple to clean, access and maintain.

Materials & finishes

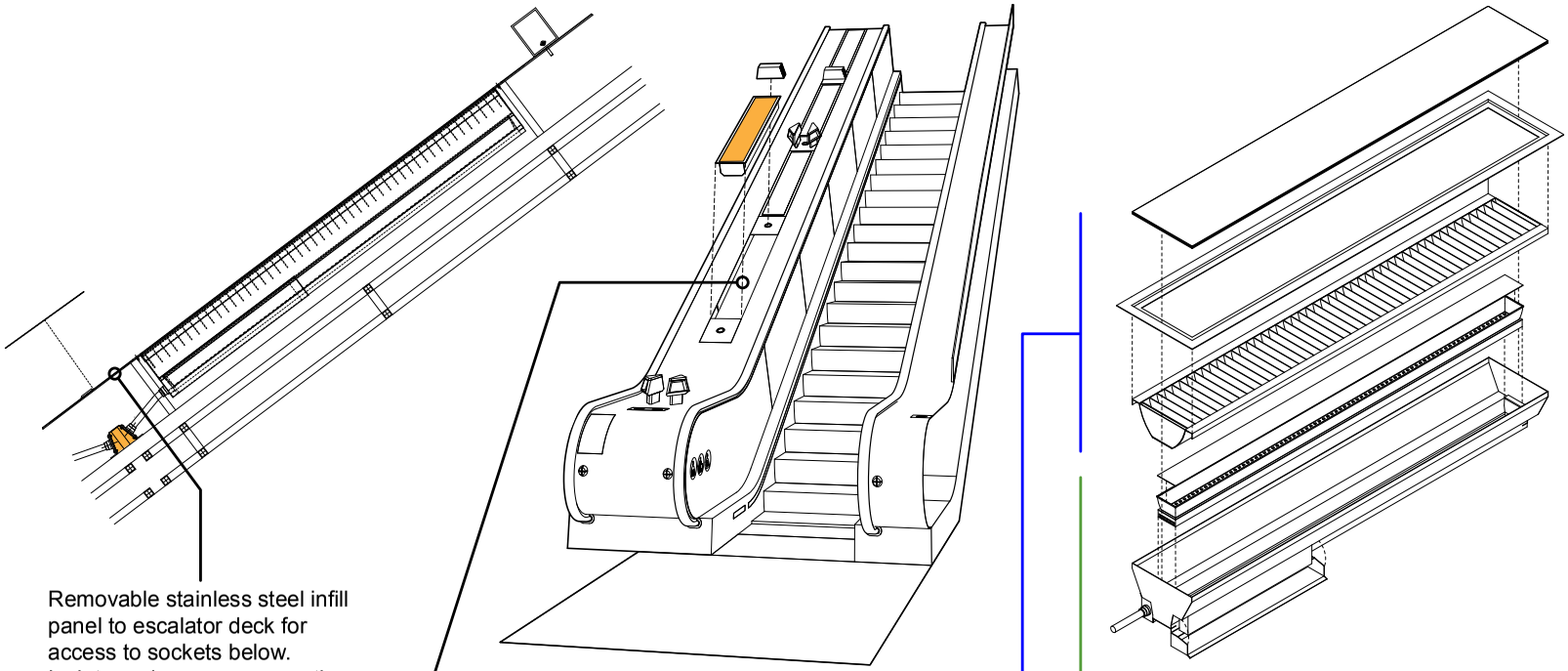
The selected materials are predominately glass and stainless steel. They provide a robust finish that is hard-wearing and can resist impact.

All interior materials which are fragile or require a maintained environment are sealed with IP rated units which are only opened off site.

Accessibility and maintenance

The key access and maintenance requirements are:

- An IP65 sealed secondary optic unit comprising facing laminated glass, luminaire frame, baffle unit and the diffusion optics fixed upon the lower face;
- An IP65 sealed primary optic unit containing linear LED board, reflector and heatsink, which is fixed to the luminaire carcass.
- Flush luminaire frame to be removed from escalator deck via hand-held glass lifting equipment. Once removed, LED drivers (contained within a compartment beside the primary optic unit and located on the exterior side of the luminaire carcass) are accessed via a hatch for ease of maintenance;
- Flush removable stainless steel infill panel to escalator deck, for access to CMS trunking and sockets below. Isolation and connection are located for ease of access;
- LU approved product connectors & braiding for ease of maintenance and compliance



Removable stainless steel infill panel to escalator deck for access to sockets below. Isolate and remove connection

Remove from escalator deck with hand-held glass lifting equipment

Secondary optic unit
(only replaced if parts damaged)

Sealed IP rated unit comprising:
- Glass
- Luminaire frame
- Cross-blade louvred reflector unit
- Diffusion optics on lower cover

Primary optic unit
(replaced on site - unit removed and serviced in clean space outside station environment)

Sealed IP rated unit comprising:
- primary reflector + glass cover
- heatsink
- luminaire carcass containing drivers
- LU approved connector + braiding

Comparison of light conditions

A preliminary DIAlux calculation study offers a tentative before/after comparison for the anticipated difference in luminance across the vaulted soffit of the generic escalator tunnel. The calculated scenes are identical - the only variable being the luminaire type:

1. Where we are now

The calculation uses photometry provided by manufacturer iGuzzini for the existing SPL-502 uplight prototype.

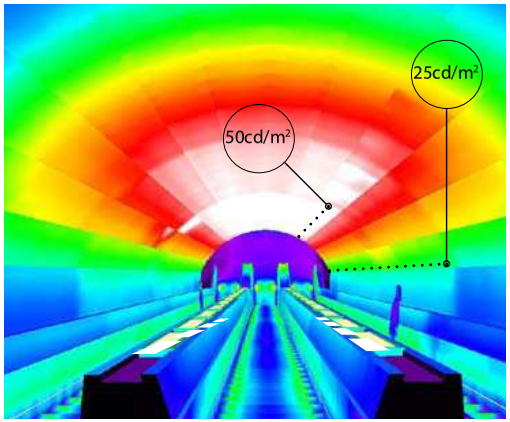
2. Proposed Alternative Design

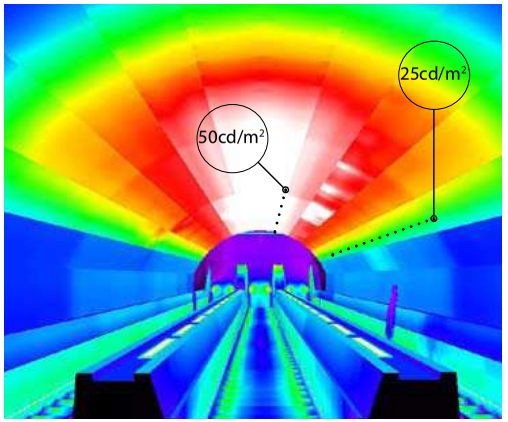
The calculation uses photometry for a louvred office luminaire - with single 35W T5 fluorescent lamp in a satin reflector - inverted to simulate an upward distribution closely resembling the emission proposed for the revised SPL-502 uplight. Lumen output and correction factor are adjusted to account for the estimated change in efficiency arising from the proposed optical control measures.

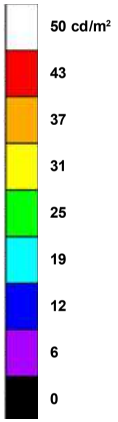
Note 1: This comparison is offered for illustrative purposes only. Accurate calculations will be produced by the manufacturer following development of the redesigned SPL-502 prototype and photometric testing to verify that the design achieves the required optical performance.

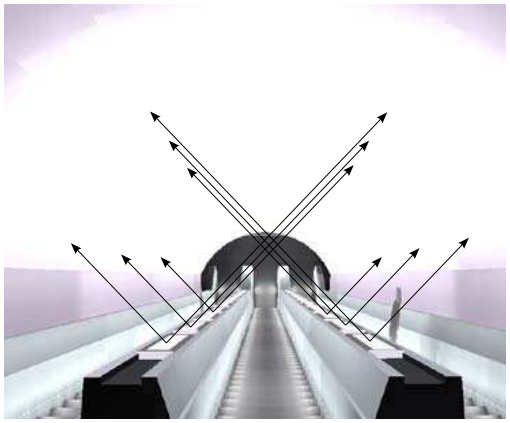
Note 2: CRL-nominated escalator manufacturer is responsible for ensuring that the skirting lighting proposal provided as part of the escalator contract complies with LUL 1-066.

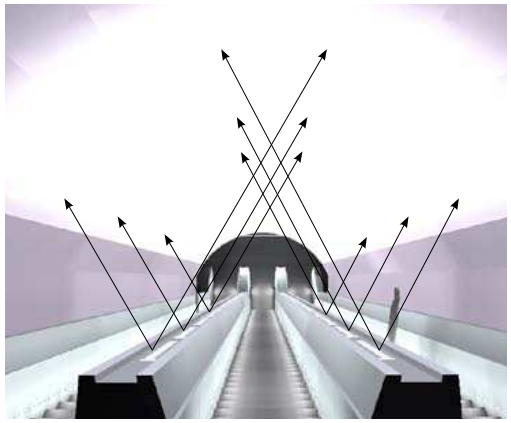
Note 3: For contribution of the suspended signage element SPL-801 at threshold zones refer to calculations in Stage F1 Lighting Report 'C100-ATK-A-RGN-CRG02-50060' Appendix I.











1. Where we are now:
Existing SPL-502 prototype with low-luminance diffuser

- Achieves >50cd/m² at the vault centre directly overhead and a broad distribution trailing off gradually to the sides

(-) Lighting unbalanced - deck brightness high compared to balustrades and vault. SPL-502 deck uplight design should be revisited to achieve more balanced lighting conditions to escalator tunnel

2. Proposed Alternative Design:
Simulation of proposed SPL-502 redesign with baffles

(+) Revised optical assembly ensures luminaire is less easily recognised as light emitter
(+) Lateral beam breadth only marginally reduced by cut-off angles essential for visual comfort
(+) Diffuse effect achieved from direct source - new optical design maintains soft beam edge
(+) >50cd/m2 still achieved at the vault centre

Reflectance values of GRFC acoustic cladding panels are taken from C100 material samples estimated at 52% for solid panels and 42% for perforated acoustic panels.

Preliminary optical design analysis

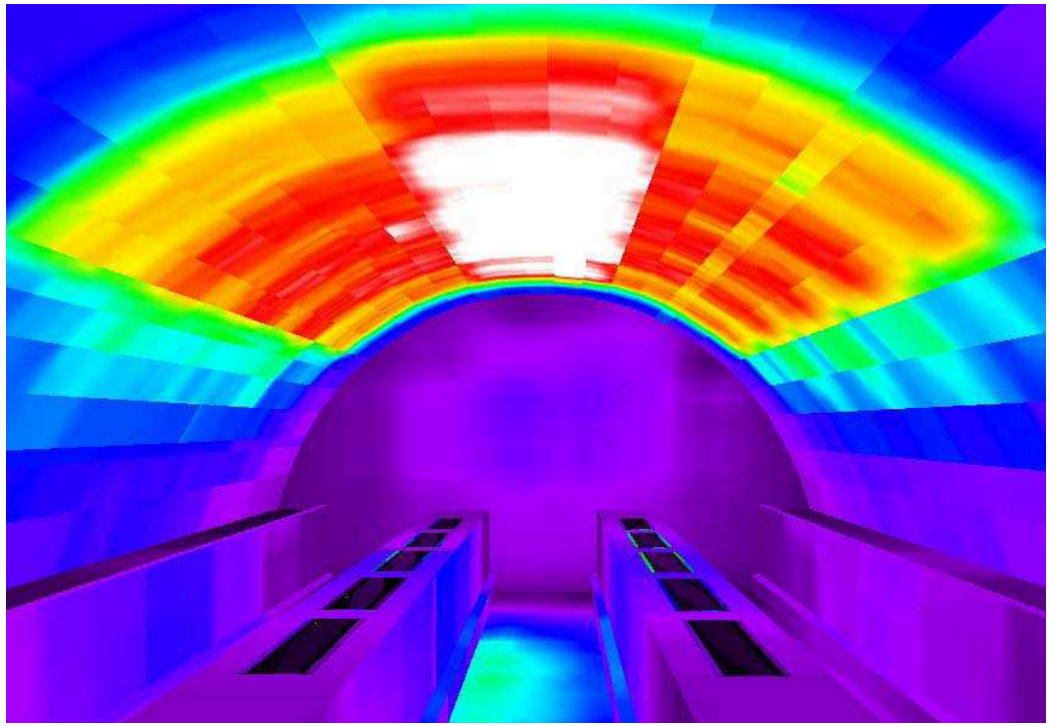
A preliminary DIALux calculation has been undertaken to indicate the light distribution that can be achieved across the vault through the use of suitable reflectors and louvres.

The calculation uses photometry for a bare linear LED board inserted into a 3D model of the proposed SPL-502 luminaire. Each component of the 3D model was assigned appropriate material reflectances to simulate the optical properties as faithfully as possible.

Results show light projected above passenger head-height to minimise potential discomfort glare.

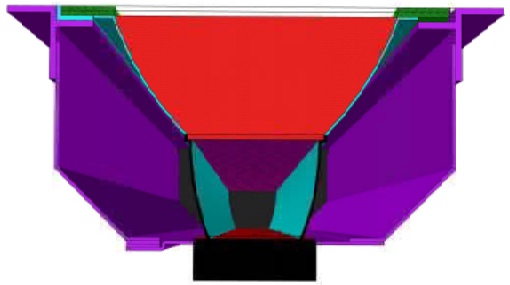
Note 1: DIALux software does not account for the light diffusing properties of the proposed primary and secondary optical covers, so the calculation result displays a sharp cut-off to the beam periphery. For the final installation, the edge of the light beam will be softer and the contribution from each individual SPL-502 uplight will blend together to create a more uniform light coverage across the escalator tunnel vault.

Note 2: This comparison is offered for illustrative purposes only. Accurate calculations will be produced by the manufacturer following development of the redesigned SPL-502 prototype and photometric testing to verify that the design achieves the required optical performance.



Pseudo colour calculation demonstrating principle of pre-diffusion reflector cut-off angle

Dialux calc not accounting for diffusion - primary optic diffuser will blend beams & soften edges



3D CAD model inserted into Dialux for preliminary reflector distribution test

Method of glare evaluation

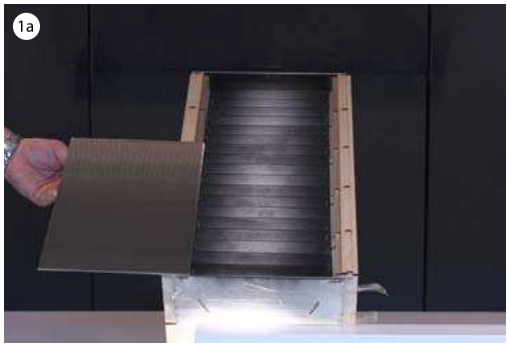
A broad beam angle must be achieved by the SPL-502 in order to illuminate the breadth of the vault.

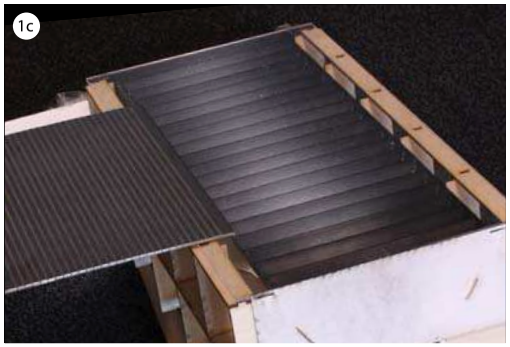
Given that the deck uplight is located below head height, optical design must include measures to prevent glare to escalator users.

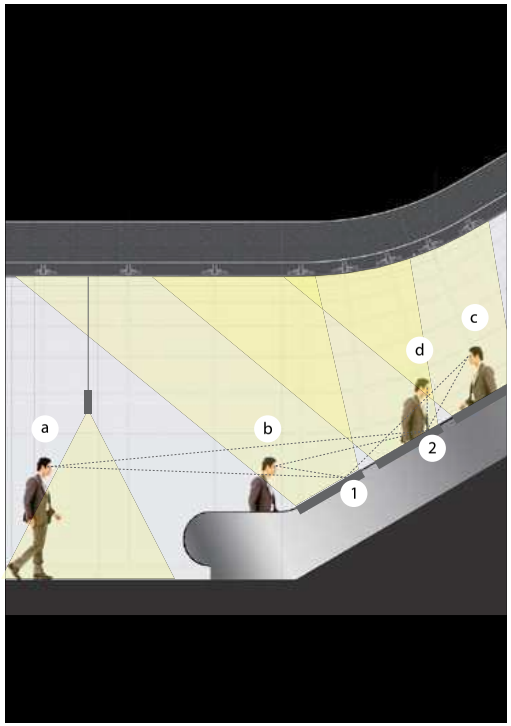
UGR calculations are applicable only to rooms which are standard (square), therefore to establish glare in a complex space such as the escalator tunnel is not viable. Detailed trials during luminaire development will therefore be necessary to ensure visual comfort is achieved as well as successful lit effect on the soffit.

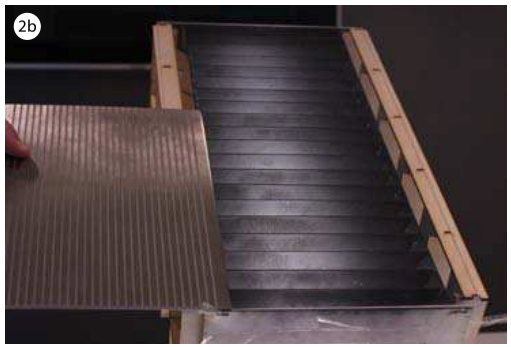
The following study of a preliminary luminaire mock-up demonstrates that application of the optical measures proposed for the redesigned SPL-502 can achieve a low-glare outcome.

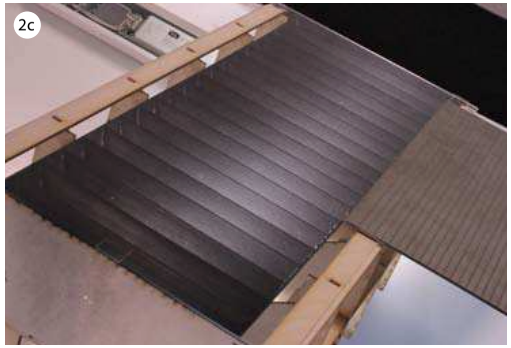
The C100 team would recommend that a fully detailed prototype luminaire is fabricated. The prototype luminaire should then be installed in a full scale mock-up to confirm that the proposed glare control measures are effective in the escalator tunnel environment (Installation of a prototype luminaire into the escalator deck will enable accurate evaluation of the various possible sight lines a passenger may encounter when navigating the space).

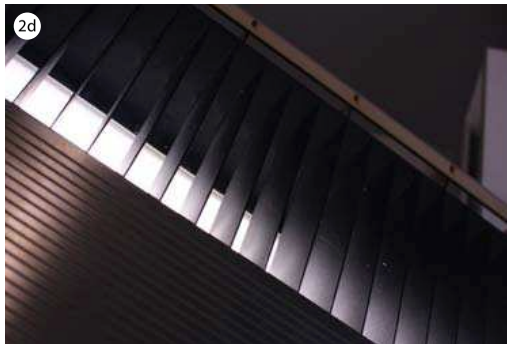












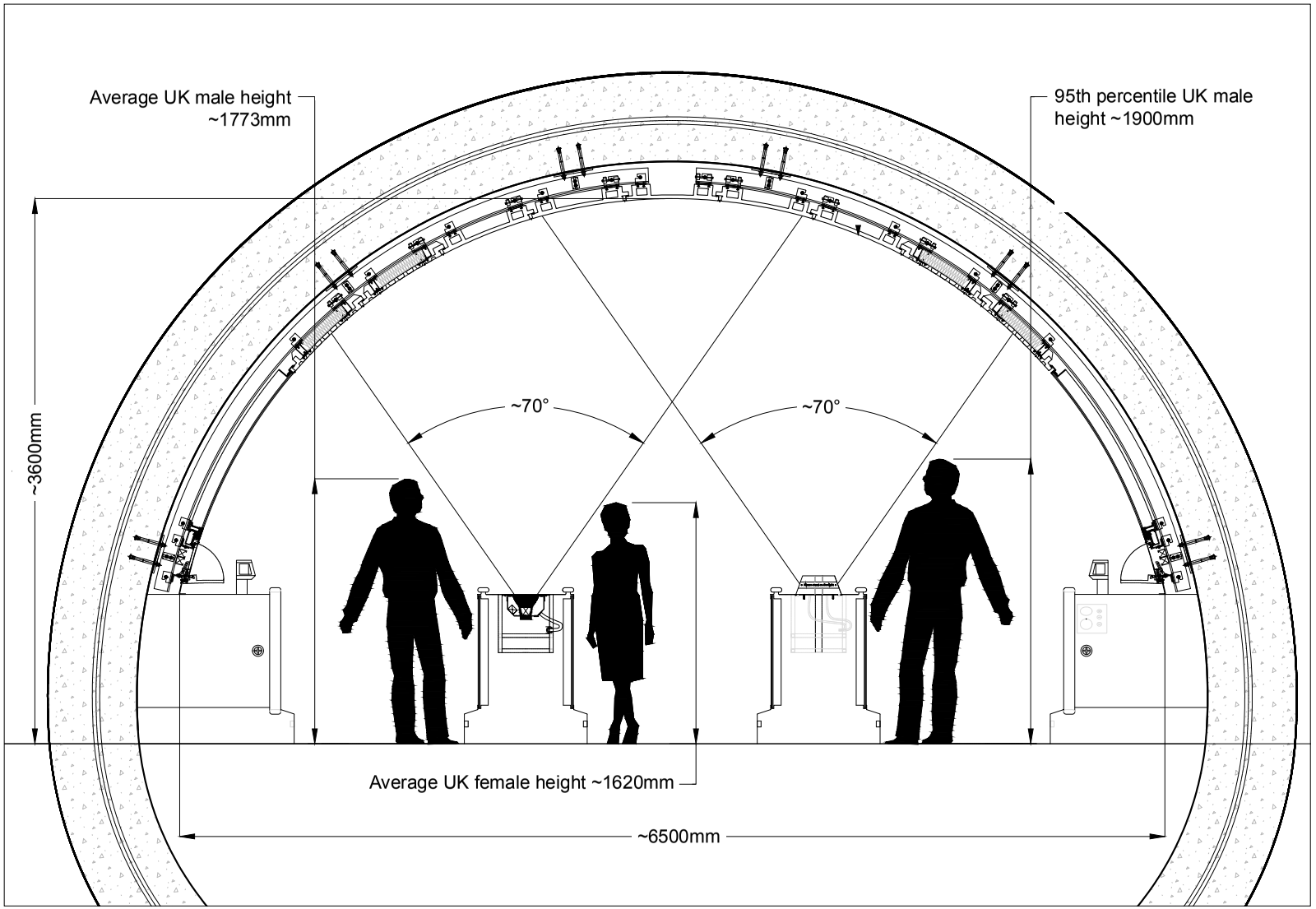
Methods of glare prevention

Passengers standing on the left or right of the escalator steps should not have a direct view of the LED light engine in the SPL-502 deck uplight.

The deep-set position of the primary optical assembly within the luminaire, together with the black anodized cross blade louvres forming the proposed secondary optical control element, should ensure the light source is not apparent to passengers ascending or descending the escalator.

In the event that a passenger leans over the escalator deck and experiences a side-on view, the proposed primary optical assembly will comprise a beam-shaping diffuse cover which ensures a homogenous appearance and controlled surface brightness rather than a view of individual, high brightness LED points.

The following section through the generic escalator tunnel illustrates an estimated 70° cut-off angle appropriate for direct view into the SPL-502 deck uplight when passenger height of 1900mm is considered based on current anthropometric data for the 95th percentile male.



Proposed redesign of SPL-502 luminaires - light projected above head height

Technical considerations

LED operating frequency

Stroboscopic effect can arise with LED's particularly when they are being dimmed – the lower the dimmed level, the more significant the issue can be. Many dimming sub-controllers on the market operate at a low hertz frequency. Drivers utilised in conjunction with the SPL-502 should operate with high frequency pulse width modulation (circa 1100-1200 KHz) to minimise flicker and strobe effects for comfortable dimming and interference-free video monitoring or recording by CCTV. This will also mitigate against the possibility of visible strobe effects for passengers.

Evaluating photosensitive risk

The black louvred secondary optic of the SPL-502 has been analyzed to ascertain whether, as passengers travel along the escalator, a stroboscopic effect of pulsing light from a potential contrasting light and dark geometric pattern could trigger epileptic seizures in users who suffer from photosensitive epilepsy.

Frequencies between 3-30Hz (flashes per second) are the common rates to trigger epileptic seizures but this varies from person to person, while some are sensitive at frequencies up to 60Hz *(source – Epilepsy Society)*.

The following calculation considers the minimum frequency of 'flashes' that could occur if a standing passenger traveling on the escalator were to look directly into the proposed SPL-502 luminaire:

Escalator velocity	= 0.75m/s
Louvre spacing	= 25mm = 0.025m
Louvres per m	= 40no.
Louvres per 0.75m	= 30no.

Frequency of 'flashes' = 30Hz (Note: frequency of flashes experienced by walking passengers would be higher)

The calculated figure sits on the upper threshold of aforementioned frequency range, however to establish whether this figure realistically represents a risk to passenger welfare, we must consider:

- what constitutes a 'flash'? i.e. whether the degree of contrast between the illuminated black louvre and diffuse light emitter is sufficient to create a photosensitive risk. The primary optic may sufficiently diffuse to avoid stroboscopic flashing;
- photosensitive risk is high when the pattern effect takes up your entire field of vision – meanwhile the SPL-502 optical design means the effect would not be experienced over typical sight lines – only when a concerted effort is made to lean over the deck and look directly into the luminaire;
- photosensitive risk is high when the effect is seen against a dark background – meanwhile the SPL-502 uplights will illuminate the space and reflected light from the vaulted ceiling overhead will ensure the stainless steel deck surrounding the luminaire is well lit;
- the 1500mm-long SPL-502 uplights are installed between 'stand on right' signs, emergency stop buttons and speakers – therefore the effect would not occur continuously being interrupted every 2 seconds by deck mounted equipment;
- geometric patterns with contrasts of light and dark such as stripes or bars are more likely to be a trigger if they are changing direction or flashing, rather than if they are moving slowly in one direction.

Comprehensive testing by the manufacturer is recommended at prototype stage. Should it be established that any risk is posed, only subtle optical modification to the proposed SPL-502 design would be necessary. A simple measure such as lightening the secondary optic finishes would reduce the perceived contrast between louvres and emitter and resultant patterning.

Application of a partially diffuse glass top cover (to reduce contrast between louvres & light emitter) would be another possible mitigation measure but is not preferred, as this would increase surface luminance of the SPL-502 and thereby increase contrast with escalator deck – opposing the objective of SPL-502 redesign to make the luminaire appear less prominent within the escalator tunnel.

Reducing spacing between louvres (to increase frequency of flashes per second) is not advised, as this measure would reduce the efficiency of the SPL-502 uplight and compromise the lighting conditions within the space.

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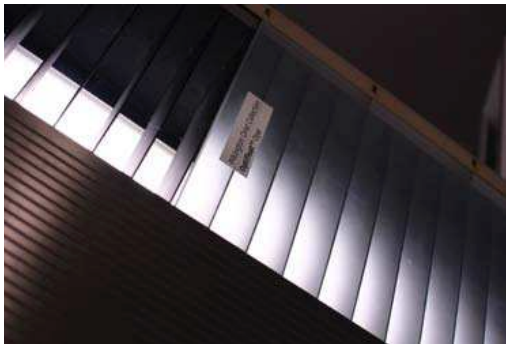
Contrast between illuminated black louvre and diffuse light emitter - potential for photosensitive risk to be evaluated at prototype stage

Lighter finish of secondary optic would reduce the perceived contrast between louvres and emitter and resultant patterning



Partially diffuse glass top cover would reduce contrast between louvres & light emitter, but surface luminance of SPL-502 increases contrary to design intent

Conclusion

The proposed low-brightness black anodised cross-blade louvre solution creates an aesthetically pleasing appearance to the deck mounted uplighter which achieves the stated objective of ensuring that the illuminated escalator tunnel cladding remains the brightest illuminated surface within a passenger's field of view. This shielded indirect lighting solution provides diffuse ambient light for the space which enhances facial recognition creating a suitable environment for CCTV.

The C100 team would recommend that the revised design of the escalator deck uplight is prototyped to further refine design detail and optimise lighting performance.