Evolution of the UK Escalator Industry

by Colin Craney

The focus of this edition is on escalators, and it may be of interest to consider the UK escalator sector and its evolution with reference to some key developments, together with a comparison between jurisdictions.

Table 1 compares some requirements of BS2655-4:1969 with those of EN 115-1: 2017 and ASME A17.1: 2016. Whilst a number of the differences reflect changes arising due to metrification and cultural/historical factors drawing upon local building codes, others are worthy of wider consideration.

BS2655-4:1969 was the first British Standard specific to escalators and included several engineering provisions that exceed those of today's standard. Specifically, a 4-mm maximum clearance between adjacent steps, as opposed to the current 6 mm, which is perhaps a reflection of the emergence of cleated step risers and meshing steps, and a step-to-skirt clearance, the sum of which should not exceed 6.5 mm (maximum 5 mm on one side) as opposed to the current 7 mm (maximum 4 mm on one side).

Whilst a different approach is taken to the determination of structural loadings, these do not differ significantly, with a BS2655 step contract load of 290 kg/m^2 against today's 60 kg, 90 kg and 120 kg per step; an overall structural load based upon 440 kg/m^2 on the exposed step tread against today's 510 kg/m^2; and a step static load of 580 kg/m^2 against today's 610 kg/m^2. However, factors of safety are reduced from the BS2655 safety factor of eight for the drive chain and step chain to five under EN 115, perhaps reflective of experience and improved manufacturing and quality assurance provisions.

Under BS2655, a safety factor of three applied to tracks based upon a step loading of 440 kg/m^2 and to step frames based upon a loading of 580 kg/m^2, and to the truss itself based upon a step loading of 440 kg/m^2. The current standard opts for a prescribed loading.

BS2655 required an additional brake on all escalators incorporating a chain or belt link between the drive machine and step band. The introduction of the opt-out to this requirement, based upon the use of multiplex or multiple chains, which was introduced in BS5656:1983 was, in my view, and in light of recent failures, a retrograde step. The change from a prescribed mitigating safety measure to one based upon factors of safety may, in the light of improvements in technology and quality control, have appeared attractive, though the approach is heavily reliant upon the quality of materials and manufacture, as well as appropriately planned maintenance. It seems to me that a realistic risk-based approach should have retained the prescriptive requirement for an auxiliary brake. Whilst the A17.1 code does not prescribe an auxiliary brake, its provisions relating to alternative drive chain safety provisions exceed those of EN 115-1 and are perhaps a better measure and mitigation of risk.

The question of unintended reversals or runaways is perhaps the most pressing issue currently facing the industry and is something I have previously written about in more detail. I see no plausible rationale that supports the EN 115-1 application of auxiliary braking only to installations exceeding 6 m in vertical rise, which is in fact a diminution from the BS2655 provision, and an area in which the A.17 code surpasses EN 115-1.

In the 1970s, aluminium die cast unisteps began to replace the traditional fabricated step. The effect was of a greater accuracy of step construction and a reduced overall load upon the truss, and an easier life for those of us undertaking step removal/replacement, in terms of the loads we were required to manually handle.

In 1979, a side of step entrapment injury to a child on a Birmingham department store escalator provided the initial impetus for the application of skirt deflectors, which was set out in HSE PM34 November 1983 and repeated in BS5656:1983; it became mandatory for new escalators in the UK ordered after 1 January 1984. Whilst initially resisted, it was eventual incorporated into EN 115:1995 by Amendment 2 2004 as a requirement for skirt deflectors on new escalators in Europe. PM34 also required that deflectors be fitted to existing escalators wherever reasonably practicable.

The events surrounding the development of the UK and EU application of skirt deflectors are of interest. Whilst there are those who might dispute whether the 1983/4 requirement was mandatory, I refer them to CEN's Introduction to the 2008 Amendment A2 to EN115:1995, which refers to discussions on the "mandatory introduction of deflector devices" and seems pretty clear to me. Enforcement was achieved by way of HSE liaison with the industry and through the PM34 onus upon purchasers of escalators to ensure compliance. Provision for enforcement already existed in Sections 3 and 4 of the HSWA. Whilst enforcement relating to existing escalators was

<table>
<tr><th></th><th colspan="2">BS2655-4</th><th colspan="2">EN 115-1</th><th colspan="2">ASME A17</th></tr>
<tr><td>MAXIMUM SPEED</td><td colspan="2">0.75 m/sec</td><td colspan="2">0.75 m/sec</td><td colspan="2">0.5 m/sec</td></tr>
<tr><td>STEP STATIC LOAD</td><td colspan="2">580 kg/m^2</td><td colspan="2">6000 N/m^2 and prescribed static and dynamic tests</td><td colspan="2">Based on 135 kg on an area 150 mm x 250 mm and safety factor not less than 5. Prescribed form of fatigue testing.</td></tr>
<tr><td>STEP DIMENSIONS</td><td colspan="2">Width - 0.6 m to 1.05 m;
Depth - Not less than 0.4 m;
Height - Not exceeding 0.24 m.</td><td colspan="2">Width - 0.58 m to 1.1 m;
Depth - Not less than 0.38 m;
Height - Not exceeding 0.24 m.</td><td colspan="2">Width - 0.56 m to 1.20 m;
Depth - Not less than 0.4 m;
Height - Not exceeding 0.22 m.</td></tr>
<tr><td rowspan="3">NUMBER OF FLAT STEPS/ DISTANCE</td><td colspan="2">Up to 0.45 m/sec - 400 mm</td><td colspan="2">Up to 0.5 m/sec - 800 mm</td><td colspan="2" rowspan="3">Minimum of two steps;
Maximum of four steps.</td></tr>
<tr><td colspan="2">0.45 to 0.65 m/sec - 535 mm</td><td colspan="2">0.5 to 0.65 m/sec and/or rise >6 m - 1200 mm</td></tr>
<tr><td colspan="2">0.65 to 0.75 m/sec - 1220 mm</td><td colspan="2">0.65 to 0.75 m/sec - 1600 mm</td></tr>
<tr><td>CONTRACT LOAD</td><td colspan="2">290 kg/m^2 on area of exposed step treads</td><td colspan="2">Related to step width - 60 kg; 90 kg; 120 kg per step</td><td colspan="2">Based on loading factors of 210 kg/m^2 static, and 360 kg/m^2 running.</td></tr>
<tr><td>STRUCTURAL STATIC LOAD</td><td colspan="2">440 kg/m^2 on area of exposed step treads</td><td colspan="2">5000 N/m^2 distributed over width of step band and between supports</td><td colspan="2">In accordance applicable design code and calculated maximum static load</td></tr>
<tr><td>PERMITTED ANGLE OF INCLINE</td><td colspan="2">35˚ Permitted up to 6m vertical rise & 0.5 m/sec</td><td colspan="2">35˚ Permitted up to 6m vertical rise and 0.5 m/sec</td><td colspan="2">30˚ Maximum (+1˚ tolerance)</td></tr>
<tr><td>AUXILIARY BRAKE REQUIREMENT</td><td colspan="2">Additional brake required on all escalators</td><td colspan="2">Auxiliary brake required on escalators in excess of 6m vertical rise</td><td colspan="2">Required on all chain driven escalators, with alternative of multiple and separate chains with monitoring devices.</td></tr>
<tr><td>OVERALL STRUCTURAL LOADING</td><td colspan="2">440 kg/m^2 on area of exposed step treads</td><td colspan="2">5000 N/m^2 to ensure maximum deflection 1/750 between supports</td><td colspan="2">270 kg/m^2 over horizontal projection of entire truss</td></tr>
<tr><td>TRUSS SAFETY FACTOR</td><td colspan="2">Safety factor of 3 (based on 440 kg/m^2)</td><td colspan="2">Prescribed design loadings and deflections</td><td colspan="2">In accordance applicable design code and calculated maximum static load</td></tr>
<tr><td>TRACK FACTOR OF SAFETY/ LOADING</td><td colspan="2">Safety factor of 3 for tracks and step frames (based on 290 kg/m^2 and 580 kg/m^2)</td><td colspan="2">6000 N/m^2 and to withstand all possible loading and distortion effects imposed during normal operation.</td><td colspan="2">In accordance applicable design code and calculated maximum static load.</td></tr>
<tr><td>DRIVE AND STEP CHAIN SAFETY FACTOR</td><td colspan="2">8 (based on 290kg/m^2)</td><td colspan="2">5 (based on 5000 N/m^2 distributed over width of step band and between supports).</td><td colspan="2">Based on a loading factor of 210 kg/m^2 on the exposed footprint and not less than 10.</td></tr>
<tr><td>MAXIMUM STEP TO STEP CLEARANCE (mm)</td><td colspan="2">4 mm</td><td colspan="2">6 mm</td><td colspan="2">6 mm</td></tr>
<tr><td rowspan="2">MAXIMUM SIDE SKIRT CLEARANCE (mm)
5 mm</td><td>Single Side</td><td>Total</td><td>Single Side</td><td>Total</td><td>Single Side</td><td>Total</td></tr>
<tr><td>6.5 mm</td><td>4 mm</td><td>7 mm</td><td>To applicable code, defaulting to 4 mm max. and 5 mm max under prescribed loading.</td><td>To applicable code, defaulting to 7 mm max.</td><td></td></tr>
<tr><td>SIDE SKIRT PROTECTION</td><td colspan="2">Skirting to be firm & unyielding with low coefficient of friction at surface.</td><td colspan="2">Skirt deflectors all UK installations after 1st Jan 1984 & under EN115 in Europe after 31st January 2005.</td><td colspan="2">Prescribed Force/deflection limit & smooth surface. Step/ skirt Performance index. Skirt deflectors permitted. Skirt obstruction device required.</td></tr>
<tr><td>STEP RISER PROTECTION</td><td colspan="2">Smooth surface with low coefficient of friction, or vertical grooves.</td><td colspan="2">Meshing vertical cleats with smooth surface. Prescribed load test.</td><td colspan="2">Meshing vertical cleats. Step demarcation.</td></tr>
<tr><td>HEIGHT OF HANDRAIL</td><td colspan="2">840 mm to 1040 mm</td><td colspan="2">900 mm to 1100 mm</td><td colspan="2">900 mm to 1000 mm</td></tr>
<tr><td>FIRE PROTECTION AND FLAMMABILITY</td><td colspan="2">Step frames and treads non-flammable. Landing plates of fire-resisting materials.</td><td colspan="2">Recognition of fire hazard risk and prescribed fire ratings/testing of materials together with fire management systems.</td><td colspan="2">In accordance applicable building code</td></tr>
</table>

Table 1. Comparison between BS5655-4:1969; BS EN115-1: 2017; & ASME A17.1: 2016

Continued

somewhat less rigorous, the reasonable practicability measure of risk, coupled with the requirements s.4 of the HSWA, together with consistent industry advice, encouraged the great majority of escalator operators to retrofit their installations.

Whilst alternative solutions existed, mainly in the rail transport sector, the deflector brush emerged as the predominant solution, due mainly to its relatively straightforward application as a retrofit to existing escalators.

An important, if less obvious, improvement is the provision of maintenance controls. When I started in the industry, these were rare, with the start key switches used to control movement. A tragic fatal accident during a step chain replacement in 1980 provided the impetus for the retrofit of maintenance controls. This was successful to the extent that it is now rare to find an escalator without what is considered by today's standards, a basic safety provision.

The question of the most appropriate angle of inclination presents an interesting exercise in risk assessment. A maximum 30˚ incline applies in the U.S., whilst Europe permits a 35˚ incline for escalators of less than 6 m vertical rise. A straightforward intuitive approach indicates that a reduced angle of incline results in a lower risk of fall. So, in applying a 35^0 incline, we trade-off an increased risk of passenger fall, against an economic benefit in the form of a reduction in footprint. The theory underlying this trade-off, if indeed there is one, presents an interesting question in risk management.

Glass balustrades, developed in the 1950s, became predominant during the late 1960s and through the 1970s, with the mullions originally included in the early designs disappearing in the quest for a wholly transparent balustrade and sightline, such that by the 1980s, this design was standard in the retail sector. However, it was in the early 1980s that the so-called slimline escalator made its debut. Whilst the change from opaque to glass balustrades had unavoidably (I use the term tongue-in-cheek in relation to Image 1) complicated the design of handrail systems, the problems arising were exacerbated due to the further reductions in space necessitated in the slimline design. Whilst the early issues relating to the stiffness of these balustrades have been more or less resolved, the reduced cross section of the slimline handrail and problems relating to these handrail drives still arise. Couple these aesthetically driven design changes with cost reduced (or value-engineered?) tracking and component mounting/bracket systems, and the result is a limited equipment life with reduced levels of resilience and reliability. So, whilst we have moved forward in terms of safety devices, we have, in my view, taken some backwards steps in terms of product engineering.

In 1987, the tragic fire at the Kings Cross underground station focused the industry upon the maintenance and cleaning of

Image 1. Glass Balustrade with Conventional Handrail Drive System (a design that did not catch on in the UK)

escalators and associated fire risks. I recall attending an incident in which a supermarket escalator had caught fire in the early hours of the morning. The fire brigade extinguished the fire, which was, in fact, a drive motor burn-out. Whilst the firemen used crowbars to remove the upper tank-trap, both I and the insurers questioned whether it really had been necessary to use a hydraulic breaker to separate the step chain and an axe to chop out 20 steps together with the side skirts and to cut the handrails. As the fire officer explained, whilst attempting to suppress the grin on his face, he couldn't be certain that the fire had not spread into the truss and had thought it best to take no chances. Having been called out at 2 a.m. on a cold and dark morning, I guess this presented a good opportunity for the guys to test out their training? Our investigation revealed that a motor driven floor-scrubber had been transported on the escalator, up from the lower floor (why else was this operational at 2 a.m.?) and a wheel of this had wedged between a step and the underside of the skirt decking, fracturing the step as this traversed the lower transition curve. The escalator continued for a time, until the step became dislodged and collided with the upper combs, locking the step band and causing the motor burn-out (no comb switches on this escalator).

Around the same time, I recall issues relating to the flammability of materials and the performance of these under fire conditions and contracts involving balustrade panel replacement. Another involved a step design, which incorporated a plastic step tread that, when ignited, produced toxic fumes, and the replacement of these with modern unisteps.

My more recent fire-related investigations have involved lighting ballasts, which, having exceeded their shelf life and been allowed to deteriorate to an unacceptable condition, ignited. In one case, a contractor manager advised that the circuit had been isolated at the time. If this were to have been believed (it wasn't), the incident could only have been attributed to spontaneous combustion, rather than to the deteriorated handrail lighting, electrical wiring and ballast units, as was in fact the case.

In regulatory terms, we are, in general, well served by the product directives and the standards in terms of new equipment. We are less well served, I think, in specific domestic regulation, which is limited to Section 19 of the Workplace (Health, Safety & Welfare) Regulations 1992. Whilst the requirements of s.19 are wide and far reaching, these provide little by way of specific guidance, and in that sense, we rely upon references to the standards and the SAFed Guidance, which can prove problematic when considered in Court.

In terms of technological development, we have seen no successful radical innovation in escalator design, although we have witnessed a few crash-and-burn product releases. We continue to employ chain technologies, coupled with the basic

Continued

geometric form of the step design, metal track systems and rubber/polymer handrails.

Technological development has been incremental, with the development of existing system elements, rather than radical innovative leaps. The development of handrail drives has been a particular focus for attempts at innovation and improvement, some of which has worked well, others not so well. Microprocessors have replaced the traditional relay panels (Outside of monitoring, I doubt the need for these on an escalator.) and energy saving drives, both of which are technologies drawn from other sectors.

My experience of so-called "green" or lubrication-free chains has been negative, with these products failing to live up to expectations in terms of performance and longevity.

Overall, the diminution of engineering standards arising due to the reduced factors of safety introduced in the BS5656:1983 Standard over those of the BS2655-4 Standard has contributed to the emergence of a less robust and safe product. I am strongly of the view that we shall soon revert back to a universal application of auxiliary brakes. I doubt, though, that the drafters of the BS5656:1983 Standard foresaw the unintended consequence of their work in the 'value-engineered' designs now prevalent and enabled by way of the proliferation of computerised engineering, design and manufacturing systems.

In conclusion, I see many more safety devices, all of which are welcome, with a wholly unwelcome deterioration in mechanical design, driven by aesthetics in terms of spatial reduction and what is often ill-considered cost reduction. I envisage there is further scope for the application of new technologies in terms of sensor-based safety devices and in a review of the EN 115-1 design provisions including a wider application of auxiliary brakes.

More recently, the key factor driving competition has been price, coupled to aesthetics, although the aesthetics factor appears, for the moment, at least, pretty well exhausted. The effects of globalisation have been such that the competitive forces driving unit price have shifted production from Europe to China (China has the largest domestic demand, which is a significant proportion of global demand, and therefore an inherent competitive advantage). I do, though, detect a welcome shift in emphasis from price to quality. The nature of escalators is that unplanned downtime is more often disruptive to business operations and significant in terms of commercial loss, to the extent that the additional capital cost of a superior product is outweighed by risks relating to commercial loss and business disruption resulting from operational failures over the equipment life.

Turning to current matters, I note an increased promotion of step-riser advertising, of which I remain sceptical. Questions arise in relation to the coefficient of friction of the material adhered to the step riser, and in relation to the consequence of the detachment of this, and possible failure or step pile-up. Some years ago, HSE, amongst others, undertook research into the visual perceptions experienced by escalator users in relation to the risk of falling due to disorientation. As far as I am aware, no similar research has been conducted into the effects of step advertising in relation to risks of passenger falls.

I note also the widespread marketing of handrail sanitisation equipment, more often based upon UV effects, in relation to COVID-19. I also note commentaries in social media questioning the efficacy of these products. Once again, supporting research appears sparse. Whilst I am no scientist, I would have expected to see scientific evidence in support of the functionality and effectiveness of these devices in terms of destroying the COVID virus. There are also concerns relating to the mechanical application of these devices and the possibility of the introduction of other hazards.

Whilst I have no inherent objections to these products or those promoting them, I take the view that more research is required in terms of the safety of step advertising. The current vogue in handrail sanitisation is of interest, if only in terms of how quickly firms have been able to design and produce UV devices, many of which come with extravagant claims as to their effectiveness. Whilst the need may be pressing, and the window of opportunity short (or we hope it will be), I harbour an underlying suspicion that simple regime of manual periodic cleaning, applying a suitable disinfecting agent, may prove at least, if not more, effective.

Colin Craney has 42 years of industry experience, initially in a number of field and management roles with Otis, followed by 17 years in consulting, currently for SVM Associates. Colin is a U.K. chartered engineer and fellow of CIBSE, European engineer, chartered safety and health practitioner, accredited consultant on the HSE Occupational Safety and Health Consultants Register and a member of the Chartered Institution of Occupational Safety and Health. Colin is a barrister, having been called to the bar by the Honourable Society of the Middle Temple. Colin is a Fellow of the Charted Institute of Arbitrators, an accredited mediator and a chartered manager and fellow of the Chartered Management Institute. Colin has been appointed in relation to hundreds of failure investigations, regulatory enforcement prosecutions, commercial claims and disputes. Areas of interest and expertise include the EC Directives, law and regulatory compliance applicable to the lift industry, management, health and safety in the lift industry, CDM 2015 principal designer, authorising engineer under NHS HTM 08-02, the modernisation of historical lift installations, lift and escalator related dilapidations and landlord and tenant disputes, competition and intellectual property law, incident and failure investigation, alternative dispute resolution and expert witness. Colin Craney is a forensic and consultant engineer, accredited mediator, management consultant and chartered safety and health practitioner with SVM Associates, a practice of independent lift and escalator and building services consulting engineers. He may be contacted at colin.craney@svma.co.uk.


"THE FUTURE OF VERTICAL TRANSPORTATION IN 2030"
IEES
INTERNATIONAL
ELEVATOR & ESCALATOR
SYMPOSIUM
DECEMBER 6-7
2021
AT
Hotel Okura
AMSTERDAM
ORGANIZED BY:
LIFTINSTITUUT SOLUTIONS
&
EW ELEVATOR WORLD
elevatorsymposium.org