The Investigation of Efficacy and Fire Resistance Characteristics of Fire Barrier in the Lift Industry Applications

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Abstract. Although it would be preferable for the lift well to be located in the fire-protected area of the building, it is not always possible. Therefore, most newly installed lifts are required to have adequate fire resistance for the length of time corresponding to the fire rating of the building in which they are fitted. The national and international regulations specify such fire rating requirements. However, the regulations fail to address the scenarios that involve lift service or installation periods. In most cases, the lift shaft is then fully or partially open with an exposed area of the entrance creating a significant hazard in time of a fire. In this paper, a novel solution is presented to this problem by considering the design standards, regulations and fire resistance testing procedures. The flow simulation and computational fluid dynamics software are used to simulate and validate the suitability of the proposed solution. It is shown that the development of a temporary fire barrier covering the lift well is feasible. However, further testing and full certification are needed to produce a final, commercially viable product.

1 INTRODUCTION

When designing a hoistway with all its components, multiple factors are taken into consideration. The material of door leafs, the architraves, and the other components associated with the lift entrance must be chosen and engineered with strength, longevity, and fire protection in mind. Fire protection is most commonly achieved by using components with known fire resistance and insulation properties. As most of the lift panel components are made of sheet metal, specialised techniques are used to account for and, in some cases, take advantage of metal thermal expansion. For example, when heated by fire, a door panel jams itself in between the sill and top header, sealing any previous gaps at the bottom and the top area. Another instance is the use of overlapping smoke fillets to prevent the formation of excessive gaps between panels (Fig. 1).

British and international regulations form a series of standards concerning the safe design and testing of passenger and goods passenger lifts [1–3]. Therefore, if the lift construction fire rating is certified and fully compliant with the building fire regulation, it becomes part of the building fire rating [2], [4], [5]. In other words, the whole building's fire rating is compromised if the lift entrance is no longer fire-protected.

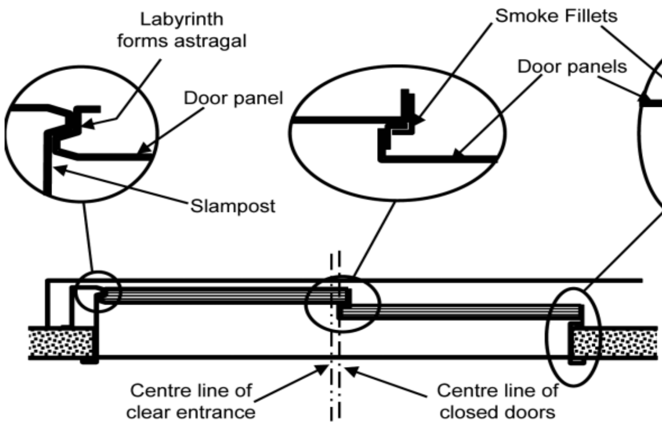

Figure 1 Smoke Fillets

Amongst many aspects, the stack effect, also known as the "chimney effect", is one of the most dangerous fire propagation phenomena when the lift shaft entrance fire resistance is compromised. This happens primarily while the lift entrance is being serviced or during its installation when part or the whole of the hoistway is open. Although it is most prominent in tall multi-story buildings, its impacts can be observed even in the two or three floor lift shafts [6]. In principle, the stack effect occurs when high-temperature gases rise inside the lift shaft, causing a change in the pressure relative to the neutral pressure plane [7]. As a result, it generates movement of the air in the lift shaft, changes the density of the air inside it and, in many cases, sucks in the fresh air into the fire room.

This paper looks at the current applicable construction and fire regulations and testing methods. It explores possible methods of developing the temporary fire barrier and using the simulation software to analyse the fire propagation thwarting characteristics of the found solution.

2 STANDARDS, FIRE TESTING AND SIMULATION SOFTWARE

2.1 Regulations

In the UK, the primary standards employed in the lift industry relevant to this study are EN 81-20[2] and EN 81-58[3], with EN 81-50[1] and EN 1634[8]/ BS EN 1363-1[9] defining testing procedures to implement them accordingly.

EN 81-20 sets out safety requirements for construction and installation, while EN 81-50 sets out test and examination requirements for specific lift components. In addition, the standards contain several requirements with the aim of improving passenger safety.

The landing and car door section of EN 81-20 (paragraph 5.3) explicitly defines rules on how the door should be designed and installed, with details ranging from the dimensions and clearances to its mechanical strength and movement. In this regulations segment, we learn that the strength of the landing door must be assessed with static load and a pendulum shock test with the given criteria for acceptance. We can also find the critical rule concerning the fire safety of the door. The section defining door behaviour under fire conditions states, "Landing doors shall comply with the regulations relevant to the fire protection for the building concerned. EN 81-58 shall be applied for the testing and certification of such doors"[2].

Most manufacturers have adopted EN 81-58 fire test methods with the corresponding testing procedures of EN 1634 as it allows the door design to be recognised as suitable in all European countries. The typical duration of the fire-resistance rating is 30, 60, 90, and 120 minutes, with most manufacturers aiming for the two-hours rating as standard.

Criteria of performance as defined by the EN 81-58:

Integrity (E) - The main criterion for judging the performance of the test specimen is the integrity. For lift landing doors, as long as the leakage rate per meter width of the door opening does not exceed 3.0 $m^3/(min \cdot m)$, the integrity criterion is satisfied. This is not taking into account the first 14 minutes of the test.

Thermal insulation (I) - If insulation requirements apply, the insulation criterion l is no longer satisfied when the average temperature rise exceeds 140 K. The maximum temperature rise on the door leaf, over panel and side panel with a width ≥ 300 mm shall not exceed 180 K.

Radiation (W) - If radiation requirements apply, the radiation criterion is satisfied until the measured radiation exceeds the value of 15.0 kW/m^2, measured as specified in EN 1363-2[9].

Direct field of application:

Test results in terms of Integrity (E) and Thermal Insulation (I) are considered to be applicable to doors of sizes different from those of the test specimens, all other constructional details being the same, within the following limitations:

- without correction to be applied on the measured leakage rate.
    1. a similar door of lower height than the tested specimen.
    2. a similar door with a door opening or an opening width in the wall equal to the one tested within a range of +/- 30%.
- after correcting the measured leakage rate as a function of the increase in height, as specified in "Interpreting the leakage rate curve".
    1. a similar door with an increased height of up to 15%.

Criteria of performance as defined by the EN 1634[6]/ BS EN 1363-1[7]:

Integrity (E) – Unless otherwise specified in the relevant test method, the integrity of separating elements shall be evaluated throughout the test by cotton wool pads, gap gauges and monitoring the test specimen for evidence of sustained flaming.

Gap gauges -

a) whether the 6 mm gap gauge can be passed through the test specimen, such that the gauge projects into the furnace, and can be moved a distance of 150 mm along the gap; or

b) whether the 25 mm gap gauge can be passed through the test specimen such that the gauge projects into the furnace.

Thermal insulation (I) - If insulation requirements apply, the insulation criterion l is no longer satisfied when the average temperature rise exceeds 140 K. increase at any location (including the roving thermocouple) above the initial average temperature by more than 180 K.

Direct field of application:

Unlimited size reduction is permitted for all types except insulated metal doors where a reduction to 50% width and 75% height of the tested specimen is the limit of variation. The size increase is permitted only for those which are required to satisfy integrity or integrity and insulation and then only up to:

- 15% height, 15% width and 20% area

Considering the above, when designing the temporary fire barrier, it is clear that not all of the rules applicable to the permanent hoistway construction are transferable. Consequently, if the solution is to be deployed within a short time and made easy to use, some compromises must be made. Therefore, priority is given to the fire safety and strength of the entrance gate. Thus, creating a physical barrier capable of stopping anyone from falling into the shaft, preventing access to the lift shaft for an unauthorised person, and being able to withstand 120 minutes fire scenario are the main objectives which are considered to develop the prototype.

2.2 Fire testing, preparation and procedures

A number of scaled-down components have been tested in the glow plug laboratory furnace (Fig. 2) in preparation for the official fire testing. The process eliminated the unsuitable components and narrowed down the list of the most appropriate materials. It became clear that composite materials offer the best possible solution. The construction with only metals leads to very high levels of thermal expansion, increases weight and adds difficulty and complexity to secure the structure in place under fire conditions.

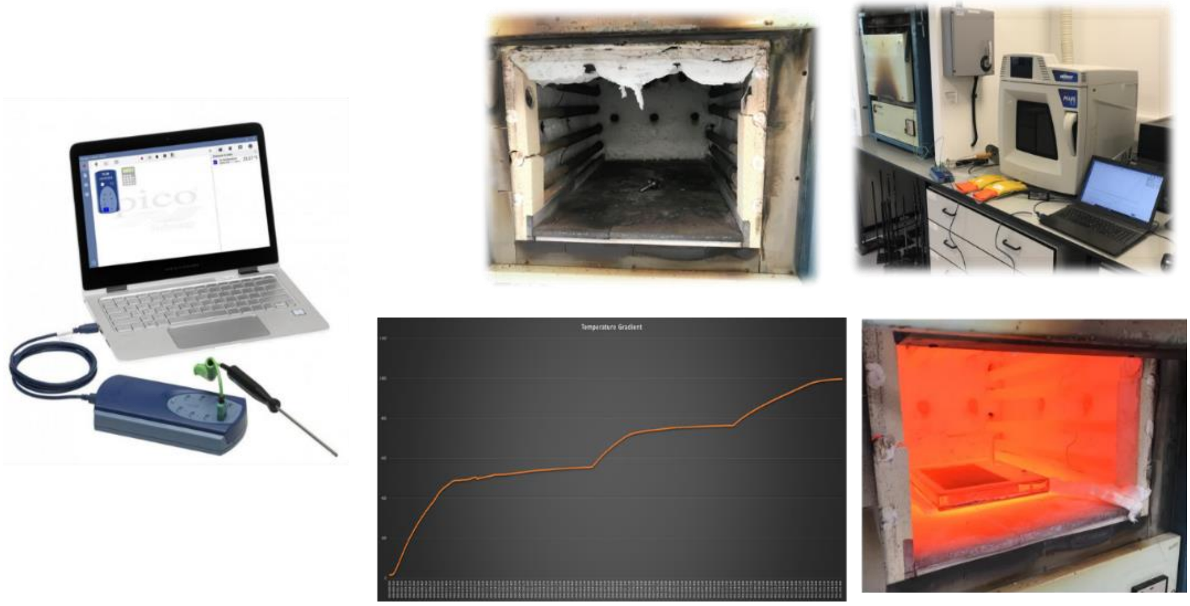

Figure 1 Testing of scaled-down components

Figure 2 Furnace Fire Testing

Lift landing doors are tested from one side only, unlike regular fire doors. In principle, the landing door specimen is mounted into a furnace wall. As the fire penetration is tested inwardly into the shaft, the landing side of the door set is the part facing the fire while in the controlled furnace. Figure 3 shows prototype fire testing at the BRE Global facilities. The temperature inside the furnace follows a specific heating curve given by the logarithmic function which is shown in Fig. 4.

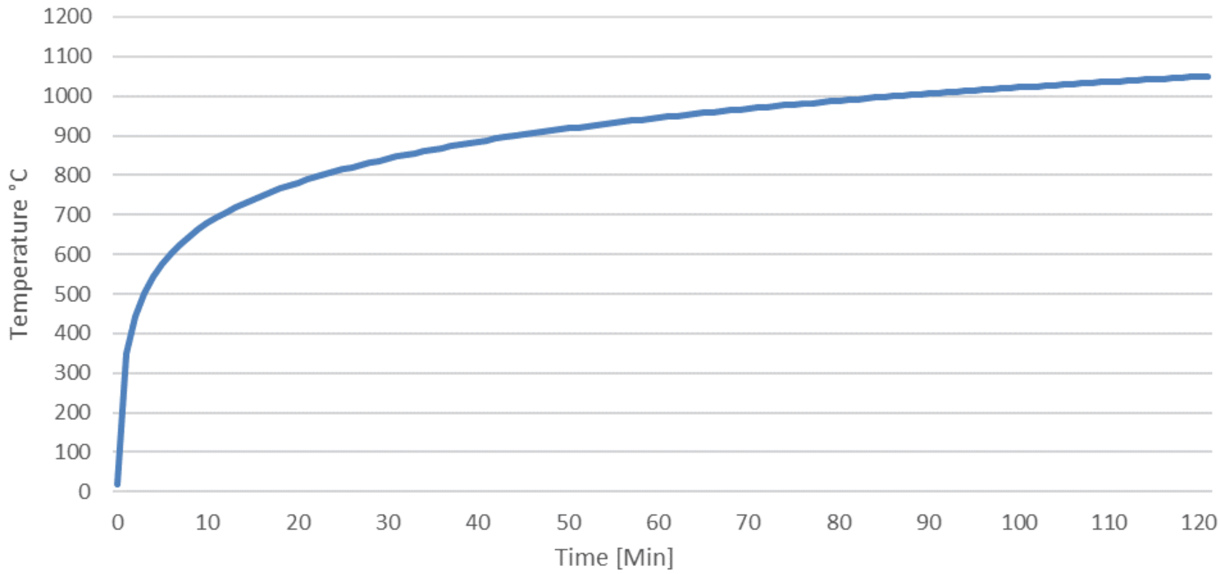

Figure 3 Temperature/Time Curve

The relationship between the average furnace temperature *T* and time *t* follows (Eq. 1):

$$T = 345 \log_{10} (8t + 1) + 20. \quad (1)$$

A set of thermocouples is deployed to monitor the temperature on the door's surface, and the data is saved for later analysis. Regular visual evaluations are performed throughout the test, and probe testing is performed if any potential gap development is spotted. The door set passes the Integrity (E) test if the number and size of gaps around the entrance do not exceed a specified limit [8].

2.3 Use of Ansys Fluent as simulation software

Ansys Fluent is used as the platform for numerical simulation. Its Computational fluid dynamics (CFD) code capabilities allow for modelling fluid flow, turbulence, heat transfer, mass transfer, and chemical reactions [10]. Manufacturers commonly use it to test design ideas and prototypes. The software is part of the Ansys products range, and its application capabilities are broad, as described above. Since the early 1930s, CFD techniques have been used extensively in the design and analysis of engineering systems, with simplified calculations executed by scientists and engineers. Initially, fluid flow calculations were limited to 2 dimensional due to the lack of computational power. However, the advancements in technology and software made the use of simulation tools like Ansys more powerful and essential to designing a new product.

The data collected during the full-scale fire testing, combined with the temperature and physical behaviour information of particular components gathered in the small-scale furnace tests, would be used to validate the CFD model. Once the model is defined and validated, then it can be used to simulate different scenarios in various building combinations.

3 CONCLUSION

In this research, it is shown that the development of the temporary fire safety-compliant hoistway barrier is feasible. From the initial findings, it can be concluded that the composite materials offer the most appropriate solution for the prototype. The composite materials used in this work present reliable strength and fire resistance properties while maintaining a low weight. However, further investigation is required to finalise the product design and overcome manufacturing limitations. In addition, full compliance with the regulations and successful fire rating tests are essential factors before it can be brought to the market.

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BIOGRAPHICAL DETAILS

Mateusz Gizicki has a bachelor's degree in mechanical engineering from the University of Northampton and is currently working towards achieving his doctorate in the area of multi-physics and computational fluid dynamics. He is a member of the Institution of Mechanical Engineers. He has experience in research and development in the industry environment as well as academia. In addition, he has recently completed the Knowledge Transfer Partnership project, which combined management skills with complete product development as an associate.

Stefan Kaczmarczyk has a master's degree in Mechanical Engineering and he obtained his doctorate in Engineering Dynamics. He is Professor of Applied Mechanics and Postgraduate Programme Leader for Lift Engineering at the University of Northampton. His expertise is in the area of applied dynamics and vibration with particular applications to vertical transportation and material handling systems. He has been involved in collaborative research with a number of national and international partners and has an extensive track record in consulting and research in vertical transportation and lift engineering. Professor Kaczmarczyk has published over 90 journal and international conference papers in this field. He is a Chartered Engineer, being a Fellow of the Institution of Mechanical Engineers, and he has been serving on the Applied Mechanics Group Committee of the Institute of Physics.

Brian Henderson has made elevators a career having been in the Lift Industry while completing a dual trade apprenticeship with EPL KONE in Australia over 35 years ago. Winner of the Australian Apprentice of the Year in 1990, he subsequently worked internationally with KONE and its subsidiaries. His keen interest in business resulted in multiple new start business operations in Australia, Asia, the UK and the EU covering a number of industries. One of those businesses was Elevator Engineering Services UK Ltd which enters its 20th year of operations in 2023, providing research, development, engineering and manufacturing solutions to the medical, food, automotive and lift industries amongst others and also developed the KTP project subject matter.

Neil Clark has 28 years of experience in Fine Limit Sheetmetal work. He worked for several years in control panel manufacturing and the lift Industry. Joined EES UK Ltd in 2009 as a workshop supervisor and helped to bring all the EES UK's manufacturing 'in-house'. He currently holds the production manager position, overseeing design, manufacturing and production. He specialises in finding and implementing bespoke fabrication solutions for customers from various industry sectors, ranging from lifts and escalators, motorsport, construction, and food packaging to control panels.

Dr Rasoul Khandan’s work experience in higher education span over 15 years with a specific interest in Mechanical and Manufacturing Engineering. Currently, he is the programme director of MSc Professional Engineering at Aston University. Before joining the University of Aston in December 2021, he was a Senior lecturer in the Technology department at University of Northampton for over 4 years. He has also worked in other higher education institutes such as Loughborough, Swansea and Bournemouth universities since 2008. Dr. Khandan's research interests are: Advanced and Digital manufacturing, Lean Manufacturing, Digital Twin and Industry 4.0.