Design, Manufacture, and Installation of The Great Glass Lift, Lift 109 at Battersea Power Station

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Abstract. This paper describes the unique engineering challenge posed by putting a panoramic lift into a chimney of the redeveloped Battersea Power Station. The engineering solution is discussed with a particular focus on how passengers would be rescued from the lift and how the conformity assessment of the whole system is in accordance with relevant new equipment regulations. This paper will describe how the following challenges were met.

1 INTRODUCTION

1.1 The concept

Eight years ago, as part of the overall redevelopment of the Battersea Power Station site, the lift industry was challenged through a design competition, to develop a unique, one-of-a-kind attraction. This would be a bespoke lift that could travel to the top of one of the iconic chimneys and provide an unobstructed, 360-degree panoramic view at a height of 109m (hence the name Lift 109) of the London skyline. The system also had to ensure that visitors could return to the ground safely in the unlikely event of power failure or another emergency.

Otis proposed a unique 'three lifts in one', comprising a double-deck lift (panorama lift), a platform lift and a rescue lift (MIP lift).

The panorama lift contains a top cabin and acts as the panoramic platform that protrudes out the top of the chimney and a lower cabin that contains plant equipment and a docking area, with the platform lift linking the two cabins together in case of rescue. Finally, the MIP lift, a dual-purpose lift that could travel within the same chimney and to wherever the panorama lift may have stopped.

Due to the entire lift system needing to be contained within the chimney, the only position for the controls and machines was at the base of the chimney. Environmental conditions required extra protection of the electrical and mechanical systems. The need for the car to have a greater travel distance than the counterweight meant an elaborate special roping arrangement.

The panorama lift is rated for 40 people and travels at 1 m/s which allows passengers to enjoy an eye-catching light show and immersive sound experience as they approach the rim of the chimney.

1.2 The challenge

- How to design, manufacture, install and commission a 40-person London experience that provides 360° panoramic views, travelling within one of Battersea Power Station's iconic chimneys (see Figure 1).
- How to safely evacuate passengers from the viewing platform at potentially any point within the chimney, above the entry floor where there is no alternative exit level.
- Combining 3 independent units (Panorama Lift, Access Platform within Panorama Lift and Mobility Impaired Passenger (MIP)/Rescue Lift) into a single unified machine.

- Having a lift with only one defined landing level and therefore not fully meeting the scope of BS EN 81-20 [1], and the subsequent complexities of certifying a unique, one-of-a-kind machine through a Type Examination process via Otis UK's Approved Body.
- The design required the panorama lift to emerge from the top of the chimney and therefore become fully exposed to the external environment. Whilst the MIP lift remained within the structure of the chimney, some elements still needed to be considered. In addition to the inevitable rain, sleet and snow that will enter the chimney there are also other factors such as high winds, lightning, pollution and the proximity to salt water from the river. During cold periods there is the risk of ice build-up within the chimney. All of these factors had to be considered in the design process.

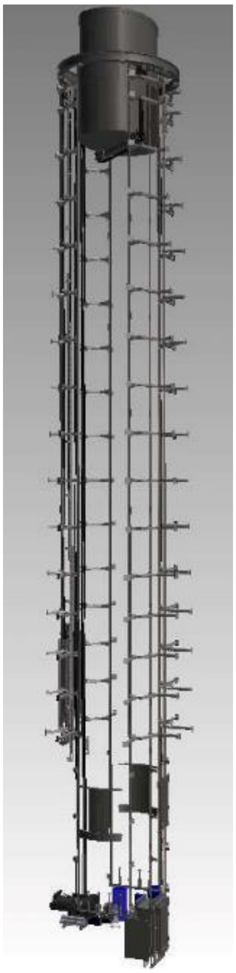

Figure 1 Lift schematic

2 REQUIREMENTS AND KEY CHALLENGES

After many years of service, Battersea Power Station (Grade II* listed), including its four iconic chimneys, was rebuilt between 2015 and 2017. Due to their state of disrepair, they were painstakingly reconstructed using the exact same methods utilised in the original build more than 60 years ago.

The northwest new chimney was designed to absorb up to 1 million newtons of force if the lift ever needed to come to an emergency stop. Part of the redesign included the ring beam, which was supported on corbels embedded into the chimney structure. The ring beam was to serve as the support for the pulleys, ropes, hitches and counterweight of the Panorama lift as well as those of the MIP lift with counterweight.

For chimney exterior maintenance, a walkway was also included in the ring beam taking the total weight of the ring beam to 11 tonnes (see Figure 2).

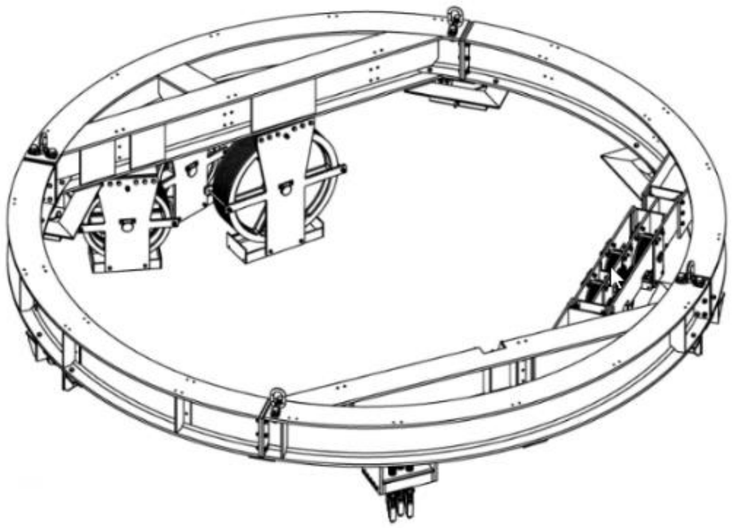

Figure 2 Schematic of ring beam

3 LIFT 109 - THE ENGINEERING SOLUTION

The Lift 109 project evolved constantly over its eight years of development and was a global effort to create a truly unique and innovative lift experience.

The lower cabin was built by Otis in Northern Germany, whereas the upper cabin was made in Southern Germany. Although both cabins were fully assembled in their factories, they weren't joined together until they arrived in the UK and installed inside the chimney itself.

Otis Berlin was responsible for the bespoke software and controls. The structural calculations and simulations for the ring beam were developed in Shanghai and USA.

3.1 Key figures – Panorama Lift

- Car weight: 16 tonnes
- Counterweight: 26 tonnes
- Combined weight: 42 tonnes
- Floor area: 12.7 m^2
- 6.6m car height: 3m for the panoramic cabin and 3.6m for the lower
- Rated load: 3000 kg
- No of persons: 40
- No of floors served: 1
- Number of entrances: 2 x Curved.
- Speed: 1.0 m/s
- Rise: 39 m
- Roping: 8 x 20 mm steel core (see Figure 3)
- Roping Arrangement: Car – 2:1
- Roping Arrangement: CWT – 3:1
- Guide Rails: 4 x 28 mm, with 2.5 m pitch between brackets

- Machine: Bottom drive – Wittur
- Pony Machine: Siemens
- Controller: GCS222MMR
- Drive: 280 amp
- Car Safety Gears: 4x Cobianchi
- CWT Safety Gears: 2x Cobianchi
- Parking Clamp Device: 4x Cobianchi
- Car Buffers: 8x Henning
- CWT Buffers: 9x ACLA
- Pulleys Specification: See Table 1

Table 1 Panorama Lift pulley specification

	Pulley 1	Pulley 2	Pulley 3	Pulley 4	Pulley 5	Pulley 6
Fixed to	car	car	ring beam	ring beam	cwt	ring beam
Diameter	Ø800mm	Ø800mm	Ø1150mm	Ø800mm	Ø800mm	Ø800mm
Weight	500kg	500kg	1300kg	500kg	500kg	500kg

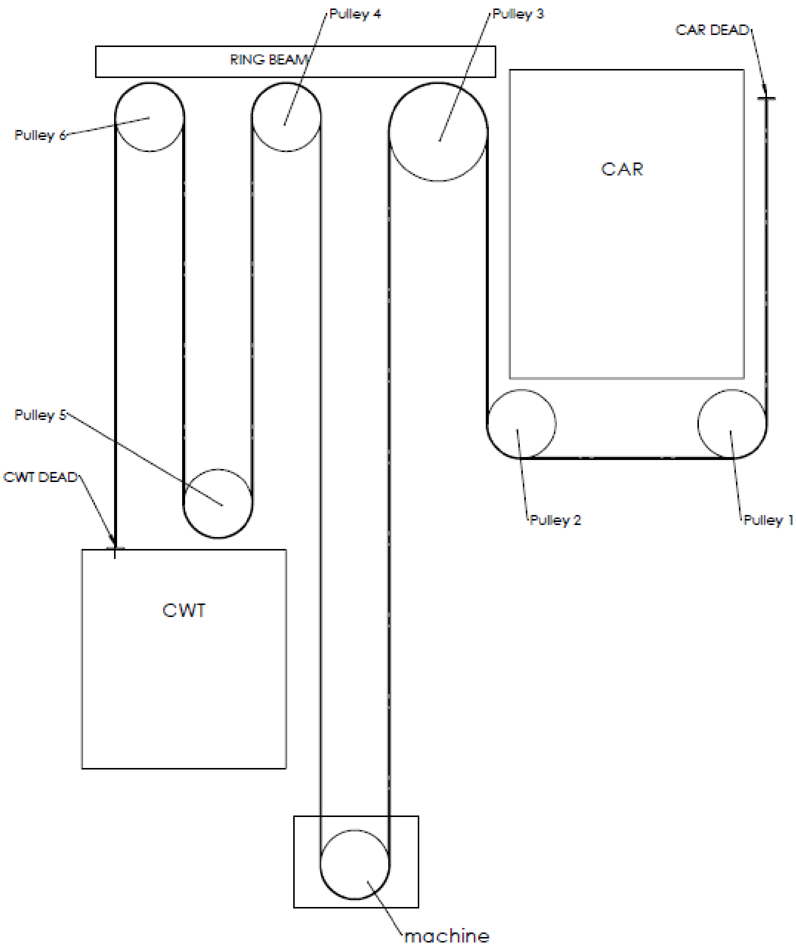

Figure 3 Panorama Lift roping arrangement

3.2 Key figures - MIP Lift

- Rated load: 600 kg
- No of persons: 8
- No of floors served: 2
- Dual entry: 2 x
- Speed: 0.5 m/s
- Rise: 6.5 m + variable to underside of Panorama lift
- Roping: 6x8 mm steel core (See Figure 4)
- Car: 2:1
- CWT: 2:1
- Guides: 2 x 16 mm guide rails, 2.5 m pitch between brackets
- Machine: Bottom drive - Wittur
- Pony Machine: Siemens
- Controller: GCS222MMR
- Drive: 60 amp
- Car Safety Gears: 2x Dynatech
- CWT Safety Gears: 2x Cobianchi
- Car Buffers: 2x ACLA
- CWT Buffers: 2x ACLA
- Pulley Specification: See Table 2

Table 2 MIP Lift pulley specification

	Pulley 7	Pulley 8	Pulley 9	Pulley 10	Pulley 11	Pulley 12
Fixed to	car	car	ring beam	ring beam	ring beam	cwt
Diameter	Ø330mm	Ø330mm	Ø410mm	Ø410mm	Ø410mm	Ø410mm
Weight	38kg	38kg	45kg	45kg	45kg	45kg

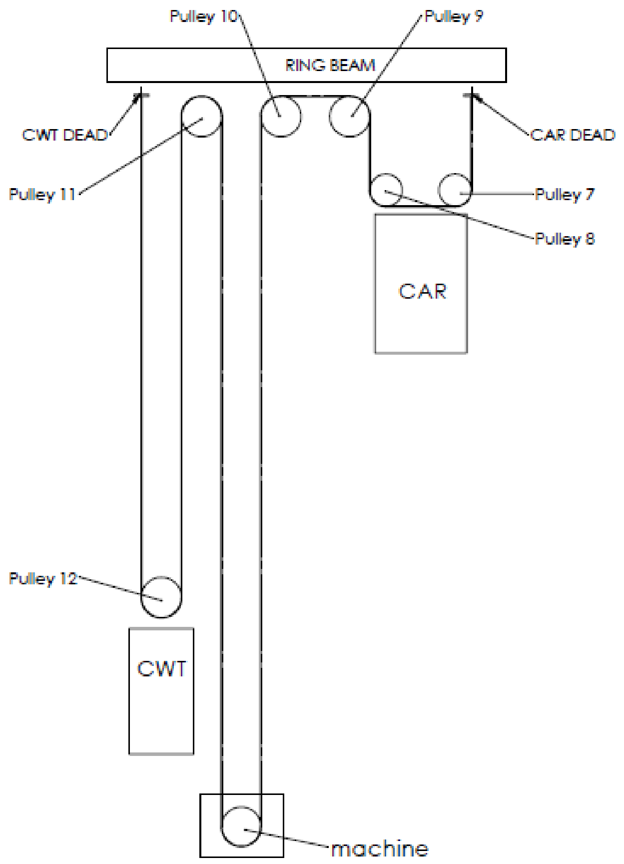

Figure 4 MIP Lift roping arrangement

3.3 Key figures – Platform Lift

- Rated load: 300 kg
- No of Persons: 2 persons or 1 person + wheelchair
- No of floors served: 2
- Entry: Single
- Speed: 0.03 m/s
- Rise: 2.9 m
- Drive: Screw jack with electric motor (see Figure 5).

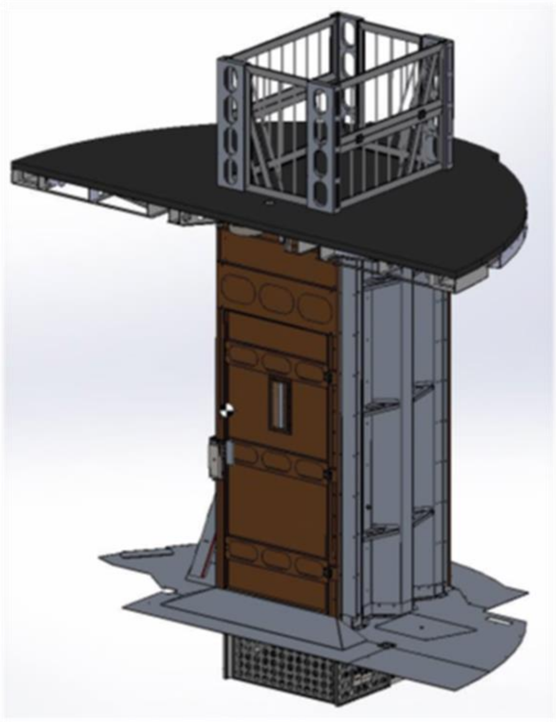

Figure 5 Platform Lift schematic

4 CONFORMITY ASSESSMENT

The risk assessment focused on two pieces of equipment both running in the same chimney. The first being the panorama lift and the second being a smaller passenger lift (MIP lift).

The MIP lift is also used to rescue any trapped persons in the panorama lift should it become stalled at any point in the lift chimney. It was crucial that the assessment of the Essential Health and Safety Requirements (EHSRs) determined the areas in need of specific analysis and then carried out those in order to ensure the design was safe.

In considering the specific legislation of the Battersea Chimney project, there was a need to examine the panorama lift and MIP lift cars separately and how they follow the Regulations.

Where any one of the lifts, including the platform lift, was not able to function as it was designed, it would instantly make the other lifts inoperable or fail to give the required support with any rescue of passengers. For this reason, the system was treated as one machine for the conformity assessment under the SoMSR, verified under a Type Examination and listed on a single Declaration of Conformity.

4.1 Panorama Lift

In preliminary discussions, there were two interpretations possible regarding the panorama lift and the applicable legislation under which it could fall:

- The Supply of Machinery (Safety) Regulations (SoMSR) [2] since its primary use is to transport persons to an upper stop but not for them to leave the lift car, so not meeting the definition in the Lifts Regulations 1997 [3]*: "lift" means a lifting appliance — (a) serving specific levels*.

- The Lifts Regulations since the lift can also be used to allow the maintenance persons to reach the upper maintenance platform, this then could be considered as a permanent level of the building which the lift serves.

The burden of conformity lies on the installer of the lift under the Lifts Regulations and on the manufacturer under the Supply of Machinery (Safety) Regulations. To resolve the situation the HSE was consulted to determine which specific piece of legislation should apply.

In their response, they confirmed that the panorama lift could not fall under the Lifts Regulations. Instead, this lift was to be considered as a machine, under the Supply of Machinery (Safety) Regulations (SoMSR).

SoMSR has conformity assessment procedures for certain types of machines such as "devices for the lifting of persons or of persons and goods involving a hazard of falling from a vertical height of more than three metres". Since such a unique project would not follow a designated standard, the procedure from Article 12 of SoMSR required either a Type Examination (by an Approved Body) or a full quality assurance system to be used, with Otis opting for the Type Examination route.

4.2 MIP Lift

The MIP lift serves two defined landings in the building to transport persons from the main arrival level to the panorama lift loading level, and under rescue conditions also serves a further 3rd level of variable position of the panorama lift. However, since the headroom is restricted and will not be in accordance with refuge spaces listed in BS EN 81-20 [1], derogation from BEIS would be required against the Lifts Regulations. While the MIP lift might have been treated as a separate lift for conformity assessment, its operation was integral to the operation of the main lift.

The design of both lifts was based on EN 81-20 [1] and EN 81-50 [5], since these standards are already risk-assessed and in conformity with the Essential Health and Safety Requirements (EHSRs) of the Lift Regulations and those of the Machinery Directive.

4.3 Platform Lift

In the event of a rescue, mobility-impaired passengers travel from the upper cabin to the lower cabin of the panorama lift by a bespoke platform lift, considered under the SoSMR, using BS 6440 [4] as supporting documentation.

A combination of the appropriate parts within the BS 8486 test documents was used as a basis to commission the panorama and MIP lifts, and where sections within the BS 8486 [6] or BS 6440 [4] test documents highlighted deviations, the approved body listed these against the machine following a detailed risk assessment for each section deemed as being non-compliant.

5 OPERATIONAL MODES

5.1 Normal Mode

Normal operation of all the lifts in the chimney is controlled by attendants throughout the journey but follows a strict electrical and mechanical sequence. Whilst the main sequence is software-based, mechanical switches are located throughout the chimney to ensure that the software is backed up.

The sequence allows for the MIP lift to transport passengers from the main arrival level of the chimney to the loading level of the panorama lift only when the panorama lift is located at the upper level of the chimney (whilst allowing passengers to view the skyline of London). The time passengers are held at the upper level is signalled via a timer; when 2 minutes remain, a signal is given to the MIP lift to return to the lower floor level (entrance of the chimney level). If the MIP has already begun a journey to the panorama loading level, it continues that journey and then returns down after not accepting any further calls, holding the panorama lift at the top of the chimney until the MIP has safely returned. Once the panorama lift has started the return journey, the MIP is held at the bottom level and doesn't accept any calls.

Reliable and safe day-to-day running is crucial for the success of the experience. A daily check of the vital systems allows for the reassurance that if anything were to malfunction or if a system may have a knock-on effect on one of the other lifts, passengers could be released.

Additionally, there was not only the normal running of the lift to consider but also modes including cleaning, chimney access, maintenance and rescue modes.

5.2 Cleaning Mode

Cleaning of the glass on a day-to-day basis allows operatives to access an additional deck located above the loading level of the panorama lift. Using the controls on that level, the lift can be driven to various heights where specialized cleaners then ensure that the top and sides of the upper deck are spotless for the passengers of the experience (see Figure 6).

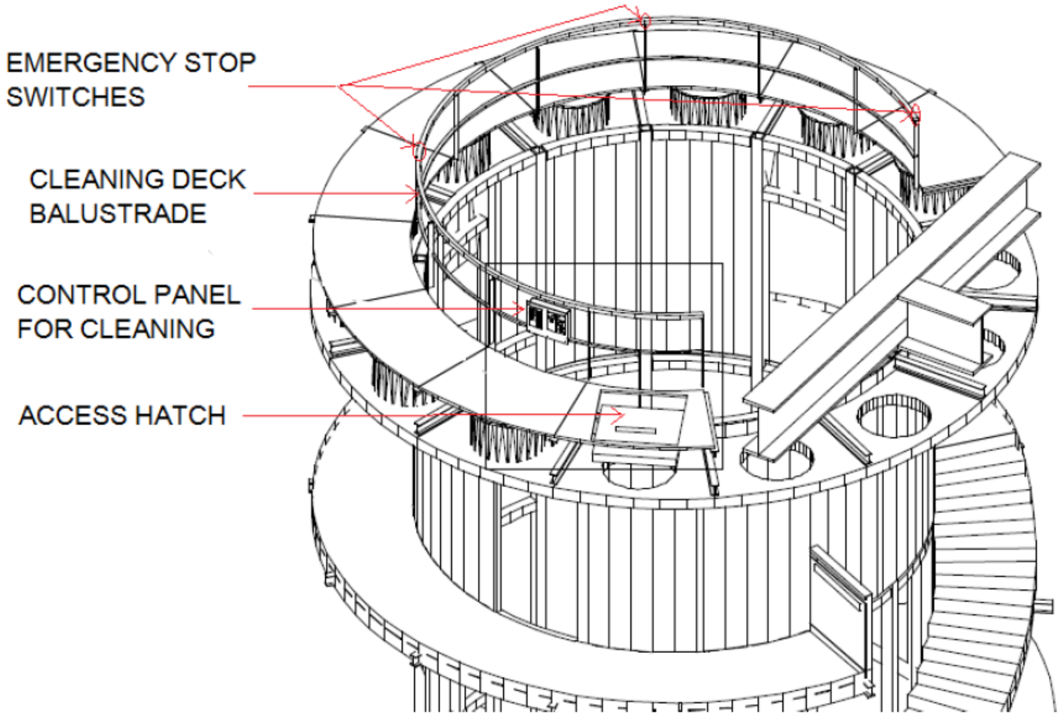

Figure 6 Cleaning schematic

5.3 Chimney Access Modes

Due to the structure of the chimney being made from cast concrete, the outer edge of the chimney needs to be inspected. Specialist engineers use the panorama lift to gain access by a mode which uses a secure Castell-type key exchange. The lift is driven to the upper level of the chimney where a second set of key exchanges allows for a set of car doors to be opened. The specialist engineers clip onto a rope access point and use the walkway to inspect the chimney and abseil down and around it.

5.4 Maintenance and Inspection Mode

Inspection of the components at the top of the chimney, including many pulleys and rope terminations, is vital as part of maintenance and for thorough examinations under the scope of the

Lifting Operations and Lifting Equipment Regulations (LOLER). The original intention was for maintenance and inspection to be carried out from inside the lower deck of the panorama lift. With the complexity of that work detail and the need for maintainers and engineer surveyors to physically access components, the solution was to revert to a more standard approach and work from the panorama lift car roof and use a temporary handrail system that provides suitable access (see Figure 7).

As this is a temporary handrail that is only in place during maintenance works, a number of safety switches for both normal and inspection modes had to be introduced. The design also had to provide sufficient strength of a suitable handrail without having any fixture points on a glass cabin. To achieve this as part of the complete temporary handrail system, four legs extend down to the lower cabin for support, with a cross-section and material that is light enough to be manually handled.

Some design considerations had to be met whilst developing the maintenance routine. Since there was no requirement for any of the lifts to be exposed out of the chimney, a maintenance limit was fitted, which meant that the engineers would be protected from the weather elements but also all components could be examined sufficiently. More importantly, if the lift malfunctions whilst it is located at the top of the chimney, the engineers can access the ladder which runs the length of the chimney.

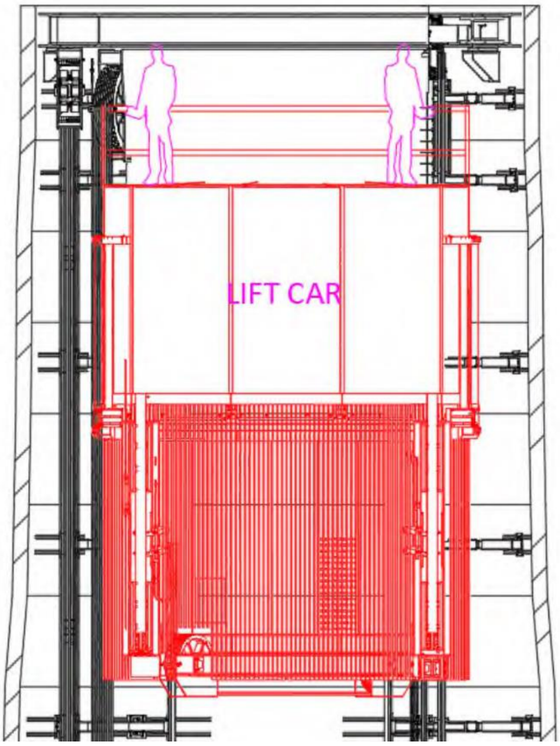

Figure 7 Maintenance and Inspection from the Panorama Lift

5.5 Rescue Mode

The evacuation of passengers in the event that the main lift is blocked or malfunctions was one of the most important challenges faced in the design. The original design intention was to install two separate cars with a car-to-car rescue from the upper deck of the main lift, but due to the client's requirements of a larger car dimension, the design was not progressed as this needed a single evacuation design (see Figure 8). This change required an assessment of how all those who visited the experience would be safely evacuated, especially where it concerned those with difficulties.

The solution was just as complex as the design of the lifts. Firstly, both the Panorama lift and MIP lift were supplied with primary and secondary power supplies. Secondly, an uninterrupted power supply (UPS) system was introduced, but it was acknowledged that air conditioning would be required at all times (normal or rescue modes) and the configuration of the electrical system meant that the incoming power supply would need to run in line with the UPS. Thirdly, the machines for both lifts were fitted with a pony motor, all giving optional methods to engage and drive the lifts in case of any power loss. This then left the challenge of the panorama lift being stuck; in this instance the MIP lift doubled up as a rescue lift.

Upon activation of the rescue mode, clamp devices on the panorama lift engage to all four guide rails to ensure it cannot move whilst the MIP lift travels beyond the normal levels it serves, docking with the lower cabin of the panorama lift (which can be at any point of the chimney) (see Figure 9). Constant pressure controls on the MIP lift are used to position the car, to couple with the lower deck entrance of the panorama lift, which allows passengers to be safely transferred to the MIP lift and returned to the bottom of the chimney. During the rescue, passengers can move from the upper deck to the lower deck, either by the internal staircase or by the platform lift.

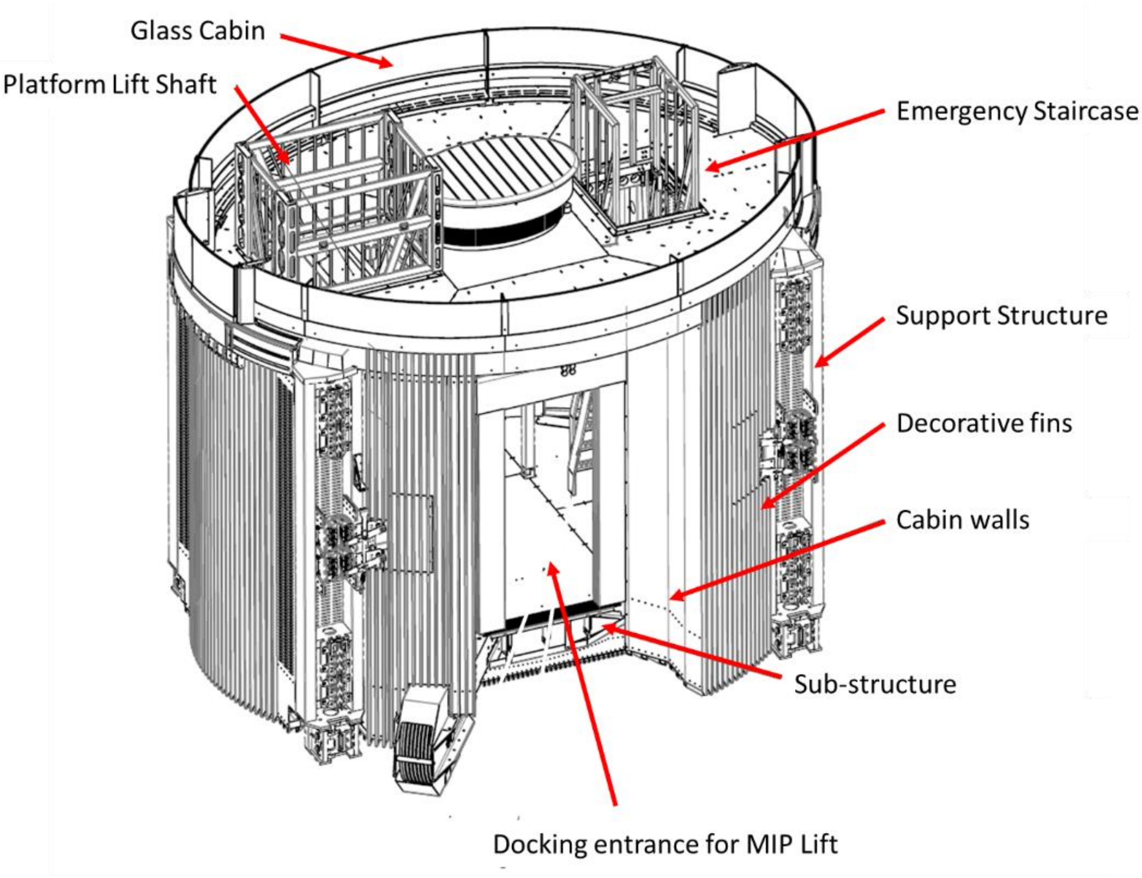

Figure 8 Panorama Lift and MIP Lift

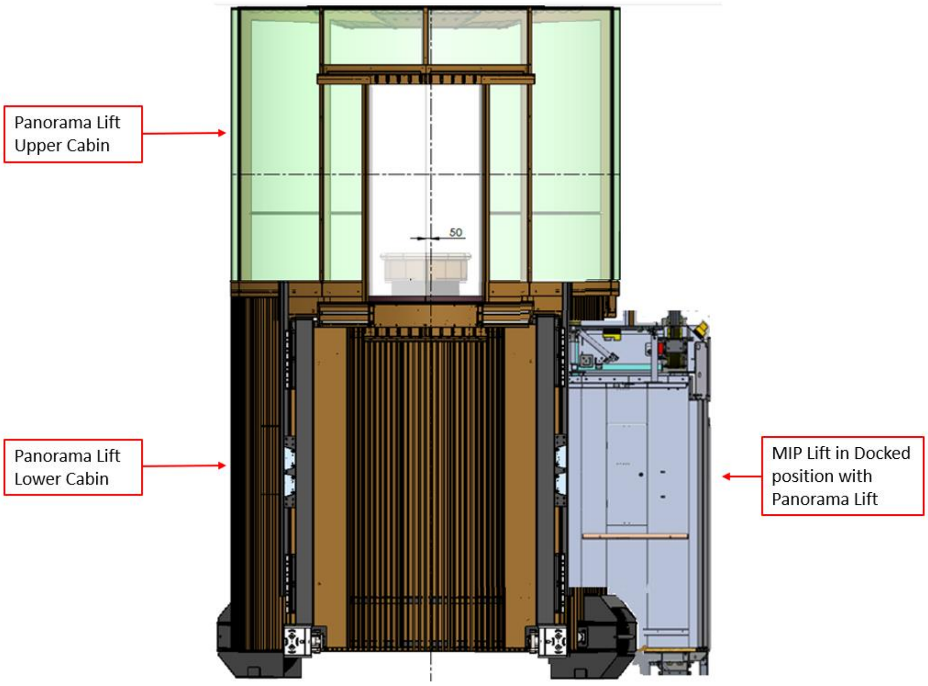

Figure 9 MIP Lift docked with Panorama Lift

The evacuation solution includes those who are able to walk un-aided using a set of stairs which link the upper deck of the panorama lift to the lower deck, and passengers who require step-free access using the platform lift to travel between the two decks.

In the upper panorama cabin, the platform and ladder hatches form part of the accessible floor. It is locked manually, with the locking electrically monitored and integrated into the safety circuit of the panorama lift (see Figure 10).

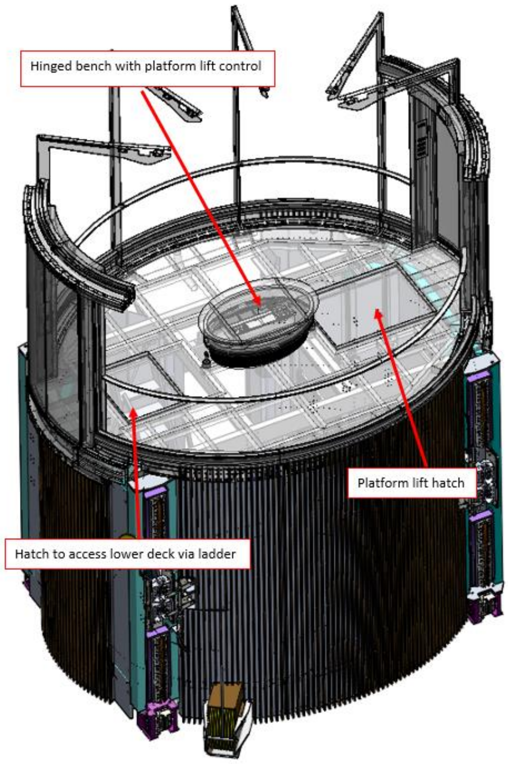

Figure 10 Panorama Lift hatches

In case of an emergency, the ladder hatch can be opened either with a triangular release lock in the upper cabin or from the lower cabin by an engineer. As part of the evacuation plan training, an experienced attendant must be kept up to date as they are critical when a malfunction takes place, not only to keep the passengers calm but also to keep in communication and assist with getting components in place for rescue purposes.

At the beginning of any evacuation, two engineers are required, one drives in the rescue operation of the MIP lift and the other assists with getting passengers from the upper to lower cabin.

To ensure the hatch and staircase are protected against people falling, a temporary handrail is extracted from the lower cabin manually.

Those passengers that can use the staircase travel down in small groups, enter into the MIP lift and are transported down to the lowest level.

Those that require an alternative method are guided to the platform lift.

Further handrails are placed around the passenger (see Figure 11). Only once all sections have been connected and in place, the electrical monitoring system unlocks the platform, and the use of a pendant control can transport the passenger down to the lower cabin ready for transporting in the MIP lift to the exit level.

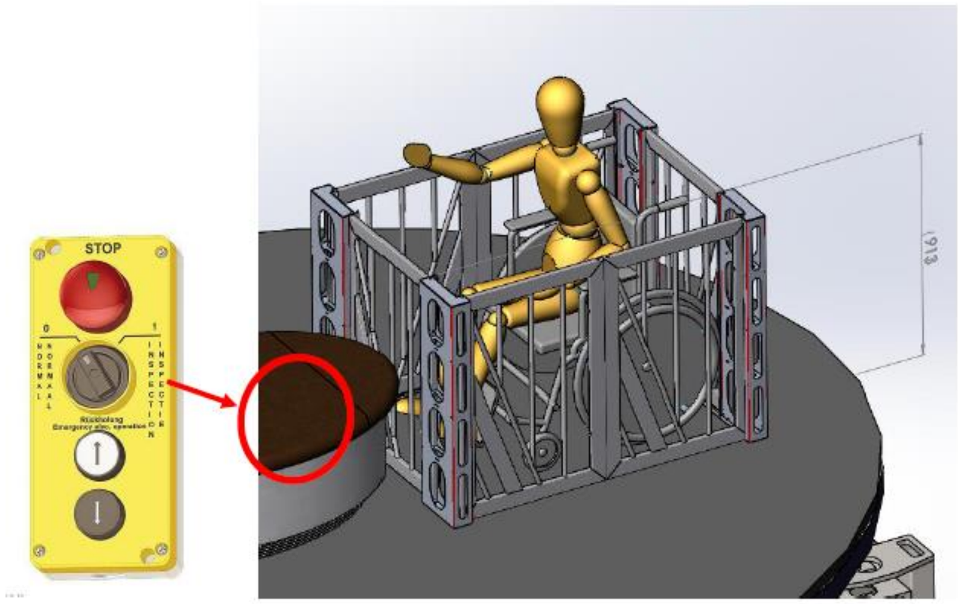

Figure 11 Platform **Lift** Handrails and Controls

After the Wheelchair user has descended to the lower deck, the manually operated swing door can be opened and transported down to the lowest level via the MIP lift (see Figure 12).

The sequence can be repeated where more than one wheelchair user is in the upper cabin.

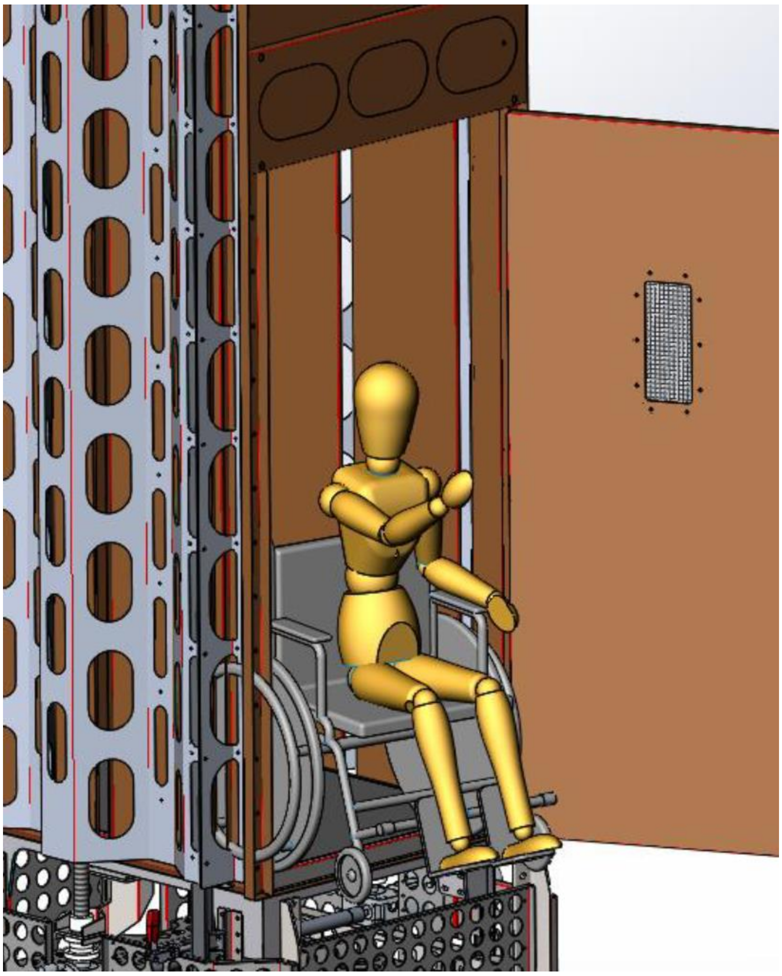

Figure 12 Platform Lift to Lower Deck Rescue Level

6 ENVIRONMENTAL FACTORS TO BE MONITORED AND CONSIDERED

6.1 Wind

The maximum safe operating average windspeed for the chimney was tested with an anemometer positioned at the top of an adjacent chimney which constantly monitors the average wind speed and automatically prevents the operation of the lift should the windspeed be more than the safe operating maximum. If the monitored average wind speed is 16 m/s or above, the indicator in the panorama lift cabin alerts the attendant of the potential high winds. If the wind speed is 21 m/s or above, the system follows the sequencing to return the lifts to the base of the chimney.

6.2 Humidity and temperature

With the effect of the glass of the panorama lift car, the temperature inside can get hot quickly. The panorama lift is provided with air conditioning to ensure passengers remain in a comfortable condition following the embarkation of the passengers at the entrance level. With the added temperature range from the base of the chimney and the top, the air conditioning also assists with keeping the car from fogging up where temperatures do not meet. Atmospheric pollutants, including salts due to proximity to the Thames, were all considered when the materials and equipment for the lift were selected.

6.3 Lightning

Having such large metallic components situated high in the air exposed, battling the effects of a lightning strike, meant that the earthing of the structure was suitably completed. This was taken from the Ringbeam down the chimney and onto the structural earth point.

6.4 Precipitation and ice formation

The precipitation events that occur influence the entire equipment. Due to the design of the chimney, the rainfall is pushed to the side walls and collects on a deck above where passengers enter the panorama lift. The drainage system then slopes around the chimney and diverts down and out of the chimney. Any ice formed on top of the car is carefully cleared during the daily cleaning schedules.

6.5 Bird fouling

It was always likely that bird fouling would occur. Having a protected area made it a perfect place to roost. Thankfully, the situation is managed by a Kestrel which is brought into the chimney and surrounding areas to move any birds away and minimise the risk of nesting and roosting within the chimney.

7 CONCLUSION

Battersea Power Station’s silhouette has long been a prominent fixture on the London skyline. Built in the 1930s and operational as a power station until the early 1980s, at its peak, it generated one-fifth of London’s power. Since then, the building has provided us with a whole lot more than electricity, becoming a cultural icon. With the building’s rich heritage, architectural significance and enduring presence in popular culture, ‘Lift 109’ is now a magnet to the Battersea re-development and has rapidly become the ‘must-see’ landmark attraction for visitors to London. This project has been a journey with many trials, obstacles and lessons learnt. Now complete and reliably in daily use, we’re proud to have taken this icon of the past into an icon of the future.

8 REFERENCES

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[2] The Supply of Machinery (Safety) Regulations 2008

[3] The Lifts Regulations 1997

[4] BS 6440:2011: *Powered vertical lifting platforms having non-enclosed or partially enclosed liftways intended for use by persons with impaired mobility – Specification*

[5] BS EN 81-50:2020: *Safety rules for the construction and installation of lifts — Examinations and tests – Part 50: Design rules, calculations, examinations and tests of lift components*

[6] BS 8486-3:2017: *Examination and test of new lifts before putting into service – Specification for means of determining compliance with BS EN 81-20*

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Images in presentation courtesy of P&N Lift Installations and Battersea Power Station Development Corporation.

10 BIOGRAPHICAL DETAILS

Kevin Vinson, a Mechanical Engineer by discipline, previously worked globally in marine, oil & gas, and the special effects sectors before settling into Vertical Transportation in 2005. He is currently the Business Development Director for Otis UK.

Michael Grover-White has NVQs in Testing and Commissioning and Electrical Installations. He was the Technical Manager overseeing the technical requirements at Otis until moving to the Lift and Escalator Industry Association as Technical Manager. He is a Technician Member of the Institution of Engineering and Technology (IET).