Devising a Fire Safety Strategy

The Sam Wanamaker Playhouse is the reconstruction of a Jacobean theatre next to Shakespeare’s Globe in Southwark. With authenticity at the core of the project, the principle aspiration from the Globe was to light all performances with candles. As a result the venue presented some key safety challenges and required a unique fire strategy.

Shakespeare’s company, the King’s Men, owned two theatres after 1608, a great amphitheatre on Bankside and an indoor playhouse in the Blackfriars precinct.

When Sam Wanamaker set out to reconstruct Shakespeare’s Globe theatre in 1970 he made it his mission to replicate this two-theatre model. Following the opening of the Globe in 1997, the indoor theatre space was created but was left as a shell, to be divided and partitioned into rooms for education workshops and rehearsals.

In 2011, a feasibility study was undertaken by Flip Tanner of Fischer Dachs Associates for the development of the indoor theatre. From this report a number of key objectives were established, with the Globe team’s driving principle being that authenticity should be at the very centre of the decision making process. The date to which the team set its target was Shakespeare’s Globe at 1616. So, along with 16th century timber architecture, authentic seating arrangements and sightlines, there was a strong desire to use candlelight to illuminate all performances.

Fire safety in theatres brings many challenges. It usually involves large numbers of people unfamiliar with the building geometry, introduces fire loads evident on stage and back of house, and often includes performances that require ignition sources and pyrotechnics. Theatre fires have been common throughout history; indeed the original Globe was destroyed by fire in June 1613, caused by a cannon during a production of Henry VIII.

Fire safety design in the UK is informed by a fire in the stage house of Edinburgh’s Empire Palace Theatre in 1911. Whilst there was loss of life from amongst the performers and stage staff, the safety curtain was lowered and 3,000 people safely left the auditorium in two-and-a-half minutes. Indeed, the commonly accepted maximum time of two-and-a-half minutes to evacuate from a fire compartment to a place of safety may have its origin here.

Photo: Pete Le May
It is these challenges, along with the innovative aspirations of architects and clients that require a more sophisticated approach to fire safety design using fire engineering principles.

Shakespeare’s Globe, a faithful reproduction of the 1599 original, opened near to its original location at Bankside in 1997. The building itself is constructed entirely of English oak with mortise and tenon joinery. It is in this sense an ‘authentic’ 16th century timber-framed building. The seats are simple benches and the Globe has the first and only thatched roof permitted in London since the Great Fire of 1666.

The process through Building Regulations and Fire Safety is well documented in the publication *Shakespeare’s Globe Rebuilt*. In chapter five, Jon Greenfield highlights the innovative approach to solving the need to satisfy Building Regulations of the 1980s; this could be recognised as early fire engineering, where timber joinery was sent to the Building Research Establishment for testing and when fire resistant periods of two hours were established.

The Sam Wanamaker Playhouse is relatively small, with an auditorium plan area of approximately 270m². Principal access is from the Globe foyer at ground floor level and leads directly to the Pit, which is the lowest audience level, seating approximately 60 people on timber benches. The Piazza is the next level, where access is provided by the foyer accommodation staircase and lift, and there is an upper balcony level at first floor. The attic space above the stage and auditorium is for theatre staff only during performances and maybe used for some rehearsals at other times. There is also a basement space that is currently used for plant and will be reused for ancillary accommodation to support the theatre.

The building’s outer structure is steel-framed with masonry walls. The inner structure is constructed of untreated green oak. There are two staircases which serve the Playhouse; one is designated for means of escape, and the other is primarily used by actors to transit between stage and dressing rooms. The Playhouse accommodates 120 on the piazza and 120 on the first floor.

Whilst all performances are illuminated by candles, discrete LEDs under the seats are used to assist with safe ingress and egress of occupants in the space. These fade once the audience is seated and are only be illuminated in an evacuation situation.

At all levels there are circulation corridors lit with modern lighting. The spill from this light is allowed to radiate into the theatre via the windows and doorways. It is intended that this simulates the daylight that would have strayed into the original indoor theatres.

In late 2011, The Fire Surgery was commissioned by Shakespeare’s Globe to develop a comprehensive fire strategy for the new indoor theatre with the following objectives, to:

- Meet the legislative requirements and also the aspirations of the Globe and the recent feasibility study;
- Develop a strategy in close consultation with all relevant stakeholders, inclusive of the approval authorities, Licensing and Insurers; and
- Propose a strategy that has optimum fire safety management provisions so that the buildings fire strategy is upheld through the life of the building.

It is not realistic that standard fire safety design codes can adequately cover all aspects of fire safety in this type of building. Designs are developed specifically for the building and are more appropriate than the generic code solutions. *BS7974:2001 Application of fire safety engineering principles to the design of buildings*, and *CIBSE Guide E Fire Engineering*, were used as the base from which to develop a unique strategy.
Forming a team of fire safety stakeholders is an important part of the fire engineering approach and key to early buy in on design aspirations. This includes those managing the building, the design team and the approving bodies.

The principal objective is to meet the functional requirements of the Building Regulations 2010. This is concerned with the life safety of people in and around the building, including the fire fighters. The design is subject to formal approval by Building Control, in this case, Approved Inspector Services (AIS), and a statutory consultation with London Fire and Emergency Planning Authority (LFEPA).

Entertainments licensing is necessary and the Regulatory Reform (Fire Safety Order) 2005 is applicable once occupied. Southwark Licensing and the Globe’s facilities managers were principle members of the fire safety team.

With the principal asset, the Globe, and its thatched roof, in such close proximity the insurers were keen to introduce a property
protection requirement, limiting the chance of fire spread from the Playhouse to the Globe.

Of course the question, ‘why use real candles’, is an obvious response by the safety conscience. Surely artificial lighting could be used to create the candle light, especially as technologies have advanced. The reason is simple: the candles – like the actors and audience – are live, and their light plays with the textures of costumes and paint finishes in a way quite distinct from artificial versions.

There has been considerable work undertaken by Professor Martin White at the University of Bristol to support the use of candles. This includes the number and location of candles, the type of wax used in 16th century candle making, and how the candles were operated by the stage assistants and the actors on stage.

A crucial fire safety team meeting was held with all key stakeholders, but mainly representatives of LFEPA, to present the case for live flame. Professor White lit some candles (a mix of wax and tallow), which burned throughout the debate. The first topic was safety – for both the audience and the actors. It was agreed that candles igniting the dense timber structure would be difficult, but protection against igniting secondary lightweight combustibles – drapes, clothes etc. – was a key factor. Rather like airplane safety, problems tend to occur during take-off and landing, therefore close management of the candelabras during ignition, hoisting, lowering and snuffing was required.

Note the ABTT’s Technical Standards for Places of Entertainment has proactively covered the use of real flame in all editions.

Any effects using real flame should be sited well clear of people and curtains, fabrics and soft-furnishings. Candle holders and candelabra should be robustly constructed and fixed in position.

Fire risk assessments have a fundamental part to play in the development of fire engineering designs. The fire strategy should identify the overall risk of fire within the building on the main objectives of life safety and property protection. A full Qualitative Risk Assessment was undertaken using the following steps:

- Identify the hazards;
- Identify the possible consequences and estimate their likelihood;
- Evaluate the risk;
- Take action to reduce risk to as low as reasonably practicable;
- Record the findings; and
- Monitor and review as appropriate.

For the purposes of the Playhouse the risk could be described as the following:

The likelihood of an accidental fire in the theatre from one of the candles igniting a secondary combustible material and causing a significant fire that compromises the escape of occupants and staff and/or spread of fire to the adjacent Globe Theatre.

A considerable amount of discussion went into a Qualitative Risk Assessment matrix with the fire safety team. This comparative table is where the likelihood and the consequence(s) are related to each other according to a qualitative ranking. With naked flame, a fire could be considered likely. The consequence on the people and the Globe was considered ‘moderate’ and ‘major’ respectively. Reducing these risk to ‘as low as reasonably practical...
by introducing active and passive fire safety system and proactive management regimes, was necessary.

The Playhouse is designed on simultaneous evacuation. A confirmed fire within the theatre initiates full evacuation of the building, including the auditorium and back of house areas. An automatic fire alarm and detection system is necessary in public buildings to notify the management of a fire and to allow them to make on stage announcement to commence escape. In addition, auditorium smoke detection is needed to activate the smoke control system.

To allow for the monitoring of the ambient condition of smoke from the candles, an aspirating detection system was proposed. This uses a series of small pipes placed around the protected space, which continuously sample the air looking for particulates related to combustion. The system is particularly effective in high volume spaces, and for authenticity the pipes are hidden behind surface linings with small bore holes for air to be drawn through.

With the use of candles in the auditorium the system acclimatises to the environment so that false alarms are minimised. The system is intelligent and can recognise candle smoke from real fires. The VESDA system by Xtralis was used, which also has a general i/p contact that, by using a switch, can set the sensitivity from one setting to another, and can be used for candle lit performances or performances lit traditionally.

A series of tests were carried out using the VESDA system at the Siemens test laboratory at the Fire Service College in Gloucestershire. These tests showed that the candles burnt relatively cleanly and did not trigger an alarm whilst the system was set at enhanced. Other cellulosic materials (dry cedar wood) were ignited using a hot plate whilst the candles were burning and did activate an alarm on the system.

Exhaust ventilation, preferably mechanical, should be provided over any open stage. The extract system over an open stage should be sized to keep the auditorium relatively clear of smoke during the period of evacuation in the event of a fire on stage.

The Playhouse system was designed to extract the smoke produced from a fire such that the concentration on escape routes open...
to the auditorium is low and will not be problematic for those escaping through it based on visibility, temperature and toxicity.

If a tenability limit for visibility for escape purposes is set at 8m (for light-reflecting surfaces), then for most fire types smoke at this concentration will cause some eye irritation, but it is unlikely to contain irritants at concentrations high enough to seriously inhibit escape. Temperature should not exceed 60°C, as beyond this occupants could potentially experience lung burns from hot gases. To calculate suitable extract rates to maintain tenable conditions, a design fire size is necessary, taken from the possible fire size likely on the stage.

Smoke calculations can be used to consider the extract rates necessary to keep the agreed tenable conditions. With an axisymmetric fire plume on the open stage and a 2MW heat release rate as agreed fire size, the extract rate in the roof would need to be in the order of 10-15m$^3$/s to keep visibility greater than 8m. With the tight space constraints in the attic, two fans operating at 6m$^3$/s could be installed in this location.

Hand calculations are simplistic at steady state conditions so Computational Fluid Dynamic (CFD) modelling can be used to gain a greater understanding of smoke properties to get confidence in design solutions.

CFD allows a space to be split into a computational grid containing millions of small volumes or cells. Well-validated transport equations and sub-models are applied to these cells, which produce linear equations describing the transfer of quantities such as heat, velocity, pressure, chemical species, density etc. between each other. The solution of these equations builds up a transient three dimensional model of the specific system. The modelling software used is the Fire Dynamics Simulator (FDS) version, which is available from and supported by the National Institute of Science and Technology (NIST) (www.nist.gov). FDS is widely regarded as the industry benchmark for fire modelling.

The results are taken over a time period from fire initiation to untenable conditions. Visibility and temperature iso-surfaces are considered at 1.5m above the first floor gallery (head height). Using an agreed design fire size of 2MW and 12m$^3$/s of mechanical smoke extract, the auditorium remains tenable for 180 seconds. This is before visibility drops below eight metres on the first floor level.

The notional evacuation period is 55 seconds. There will be some pre-movement time prior to escape, but this is unlikely to significantly impact on the 135 second (two minute 15 second) margin of safety.

Fire safety in buildings is a balance between the technical systems within the building and how the building is used and managed. It is not possible to rely solely on the technical provisions in the building and an active role on the part of the management is essential. It is therefore necessary that the building is used as intended and that the systems are managed appropriately.

As with all buildings, there will be standard fire safety management requirements for the day to day operation of the theatre. With fire engineered buildings, it is likely that the level of management will need to be higher. Effective management of fire safety can contribute to the protection of the building occupants in many ways. By:

- Working to prevent fires occurring in the first place;
- Monitoring the fire risk on an on-going basis and taking appropriate action to eliminate or reduce risk;
- Being aware of the types of people in the building (such as disabled people, elderly people, children, pregnant women, etc.) and any special needs;
- Ensuring that all of the fire safety measures in the building are kept in working order and in particular that the means of escape are always available;
- Training staff and organising the evacuation plan, to ensure that occupants leave quickly if a fire occurs;
- Taking command in the event of a fire until the fire and rescue service arrives; and
- Updating the Fire Strategy for changes, such as the introduction of split tenancies should these be introduced.
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With fire engineered buildings it is important that fire safety management take on an active role in the operation of the building. They will be required to provide evidence of the above procedures under the Regulatory Reform (Fire Safety) Order 2005, but should also be capable of specific measures and contingency planning such that they prevent the chance of a candle igniting secondary materials that results in a fire compromising the escape of people from the auditorium. Level 1 fire safety management as prescribed in BS 9999:2008 was agreed as appropriate.

The key to the success of the fire strategy is managing the safe use of the candles. A candle management strategy was developed for this purpose. This includes how the candles are stored, moved, installed, ignited, trimmed, extinguished, removed and discarded.

There are four competent trained Globe stage staff whose task it is to monitor, maintain and operate the candles during a performance. A member of the stage management team will remain in the theatre for 15 minutes after the last candle is extinguished to make sure no candles are left burning or smouldering. The candle management strategy was approved by the fire safety team.

There are generally two ways of demonstrating compliance with statutory Building Codes and Regulations. One is to follow the prescriptive guidance given in codes of practice and statutory guidance, and the other is to use a fire engineering approach. The concept of fire safety engineering provides a framework that enables designers to demonstrate that the functional requirements of legislation are met, or bettered, and offers a flexible alternative to prescriptive approaches, especially when designing for unusual or difficult buildings. 21st century fire engineering principles have supported the Globe’s aspirations for a 16th century theatre.

There are no guarantees that there will never be an accidental fire. In risk terms it is possible, but should one occur, we have developed a suitable strategy with all key stakeholders and introduced active and passive measures along with management regimes to reduce the risk to, ‘as low as reasonably practical’, with the use of real flame.

To quote the Guardian’s Rowan Moore, “To have candles in a timber structure is not out of the best-practice rulebook for health and safety in modern theatres. The fire engineers’ contribution is vital: without the combination of wood and flame, which makes the interior feel like a kind of boat, floating in shadow, more than half the point of the project would be lost.”

Summary of fire safety systems
Aspirating smoke detection system in the auditorium
PA/VA system throughout indoor theatre
Discreet level LEDS used for Emergency lighting within the auditorium
No emergency signage in auditorium seating areas based on intuitive escape supported by stewarding
High level mechanical smoke extract system with low level supply air through powered open pit doors and windows
Automatic sprinkler system to back of house areas including basement and attic
One hour fire separation and sprinklers in the attic to limit fire spread to the Globe
Mechanical smoke extract system to basement areas
Untreated green oak based on previous Globe fire test data

The Fire Surgery are specialist theatre fire engineers, sit on the ABTT Safety Committee and are ISG Members.

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