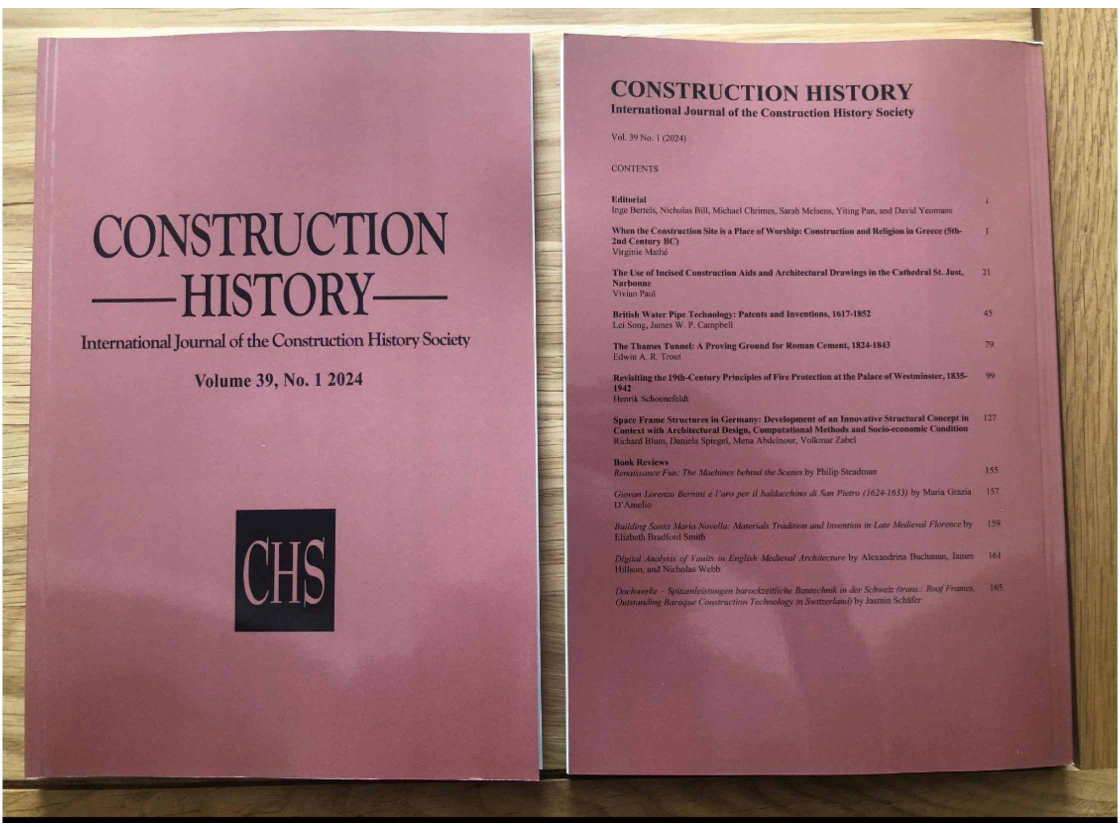
FULL REFERENCE:

Henrik Schoenefeldt, Revisiting the 19th-Century Principles of Fire Protection at the Palace of Westminster, 1835-1942, *Construction History*, Vol. 39, No. 1 (May 2024), pp. 99-126



Revisiting the 19th-Century Principles of Fire Protection at the Palace of Westminster, 1835-1942

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Abstract

Following a devastating fire in October 1834, fire safety became a central concern during the reconstruction of the Palace of Westminster. Although it was not considered at the stage of the architectural competition, between 1836 and 1860 the architect Charles Barry oversaw the development of a scheme for fire protection. This paper presents a detailed examination of the evolution of this scheme. The first part shows that Barry's office pursued a passive approach that combined the use of fire-resistant materials with structural compartmentation. This approach had implications for the cost and design of the structural fabric and also affected David Boswell Reid's design for the ventilation system. A study of the final scheme, which is the subject of the second part, illustrates that Barry, aware of the limitations of the structural measures, including the risk of ducts breaching compartmentation, also considered operational aspects. These became an integral part of facilities management procedures that had been implemented under Barry's supervision. The third part explores the history of the building in use from 1852 to 1942. Over this period the original principles underwent appraisals, involving the Metropolitan Police, Ministry of Works and London Fire Brigade. They remained largely unchallenged until 1941, when the destruction of the House of Commons by incendiary bombs, led to a fundamental loss of trust in these historic principles and the adoption of first modern interventions.

Keywords

Charles Barry, fire safety, structural engineering, parliament, ventilation, facilities management, compartmentation, police, 19th-20th centuries.

Introduction: Re-appraising Modern Assumptions

In October 2011, a study group appointed by the management boards of the House of Commons and the House of Lords published a report on the restoration of the Palace of Westminster. In one section, which emphasised the risk of the historic building being lost to fire, it was stated that the Palace:

> "…was designed with 'a comprehensive network of pathways' in the form of ventilation shafts and inter-floor voids, unintentionally creating ideal conditions for fire and smoke to spread through the building".[1]

This statement represents a twenty-first century re-assessment of a heritage building. Underlying this assessment is the assumption that those responsible for its original design in the nineteenth century were unaware of the fire risks. Archival evidence, however, challenges this assumption. The original nineteenth-century documents show that the danger of fires spreading through "shafts" and "voids" was understood by the architect, and also that his office devised strategies for mitigating the risks. These strategies were developed and implemented under the direction of the principal architect Charles Barry (1795-1860) between 1835 and 1860. The "comprehensive network of pathways" was part of the original ventilation system, developed by the Scottish physician David Boswell Reid (1805-63). The development of this system was underpinned by extensive inquiries into its impact on Barry's scheme for fire protection, which utilised vertical and horizontal compartmentation. Although the ventilation and fire protection require specialist technical knowledge, the responsibility for fire protection was not delegated to an external consultant. It remained the responsibility of the principal architect, collaborating with the staff employed within his office. The archival evidence does not clarify whether Barry was the conceiver of the original idea, but it has shown that the final technical arrangements were the outcome of a collaborative process. Hence, when naming them Barry's fire strategy, this article refers to Barry's office as a corporate entity. The study of the historic records has revealed that the chief superintendent of works, who acted as Barry's most senior assistant, held a central role in the implementation of the strategy. In addition of supervising the production of related construction and engineering details, their responsibility was to coordinate the integration of Reid's scheme for the ventilation system. During the early stages in the development, the role of chief superintendent of works was held by the architect Frederick Humphrey Groves (1803-95), who was succeeded by the architect Alfred Meeson (1808-85) in 1845.[2]

The influence of fire-safety considerations on the construction of the Palace has been acknowledged in various studies in the history of construction and architecture. Robert Cooke (1987) and Caroline Shenton (2016) have examined the fire safety as a factor affecting working relationship between Reid and Barry, but did not discuss the technical inquiries.[3] In Michael Port's edited book *The Houses of Parliament*, the civil engineer Denis Smith has shed some light on the role of fire safety concerns in driving the use of iron-framed construction, and provide some detail about its application inside the Victoria Tower and House of Lords.[4] Sara Wermeil, who is a historian of building technology, has undertaken extensive studies on the impact fire safety concerns on the development of nineteenth-century technology.[5] In a chapter, published in *Structural Iron and Steel, 1850-1900*, she also includes a short discussion of its application at the Palace.[6] In these studies, however, neither Barry's scheme nor its development has been examined in any great detail. This article provides the first in-depth study, combining archival research with the study of surviving features of the fire protection scheme inside the Palace. The archival evidence comprises drawings, letters, technical specification and parliamentary papers.

This article is divided into three parts. The first part retraces the development of the fire strategy over the period from 1835 to 1860, elucidating the challenges underlying its implementation, which included the difficulties with reconciling the requirements of ventilation and fire compartmentation. This shows that the scheme was developed in three stages. During the first stage (1835-39) Barry's office only considered the use of fire-resistant construction and compartmentation in selected areas. In the second stage (1840-46) its use was extended to all areas, but also had to be adapted to be compatible with Reid's scheme for a centralised ventilation system. In the third phase (1846-60) further adaptations were made following changes to the original design for the ventilation system.

The second part of the article examines the final arrangements. This shows that Barry's strategy focused on the use passive measures, exploiting the inherent safety provided through the use of fire-resistant materials, spatial separation, and structural compartmentation, but it also incorporated some active measures, such as fire dampers and firefighting equipment.

The third part, which covers the period from 1852 to 1942, explores the evolution of fire safety practices of the building in use. This operational history elucidates how firefighting became an integral part of the facilities management, following operational principles that were developed and implemented under the direct supervision of Barry's office. Over this period the original strategy also underwent various appraisals, involving the Metropolitan Police, Ministry of Works and London Fire Brigade. These show that original strategy remained largely unchanged for 90 years, yet in 1941 the experience with devasting fires caused by incendiary bombs, led to a first reappraisal of the historic principles through the lens of more modern principles of fire protection.

Historic Regulations, Precedents and the Role of the Architect's Initiatives

Since the seventeenth century practices of fire safety in buildings were partially shaped by legislation, and partially by principles that had been developed for specific building types in response to major incidents, most notably industrial buildings, such as factories, mills and warehouses, which acted as important settings for the development of passive fire protection measures.

In England, early regulations for the construction of building were confined to local laws for larger cities. In London, early laws were introduced through an Act of Parliament after the Great Fire of 1666. The 1667 Act focused on measures that helped to prevent the recurrence of conflagrations within urban areas. The objective was to reduce the risk of fires spreading to neighbouring properties. These laws mandated the use of tiled roofs, incombustible materials, such as brick and stone, for the construction of external walls, and also asked for the provision of party-walls between adjacent properties. These early regulations neither contained legislations regarding the internal construction nor requirements for interior compartmentation. The use of timber floors continued to be permitted. These early laws were rudimentary, but the scope of legislation was gradually expanded through amendments over the following 170 years. The 1667 Act was repealed and replaced by a new Act in 1772,[7] which consolidated several bodies of earlier legislation on fire protection into one single Act. It also included more detailed regulations relating to the construction of buildings, and introduced standards for fire services. The Palace was designed and constructed between 1835 and 1860, a period during which local laws underwent further changes.

Over the first nine years, the construction of buildings in London were subject to the Fires Prevention Act of 1774.[8] With 89 pages, compared to only 48 pages in 1772, the Act of 1774 was a considerably larger document that provided detailed technical specifications. These distinguished between seven different classes of buildings. Class 1 to 4 were domestic properties, divided according to their size and value, whilst Class 5 to 7 referred to non-domestic buildings, which included industrial buildings, such as warehouses and mill buildings. The Act of 1774 also introduced requirements for interior compartmentation of buildings with multiple occupants. These were referred to as "intermixed" properties, and the Act asked for such buildings to be sub-divided horizontally and vertically using a system of "party walls" and "party arches." The term "party-arches" was used to describe horizontal barriers, which were floors built from brick, stone or other fire-resistant materials. The Act set a minimum thickness for such party-arches, which ranged from 8½ inches (220 mm) to 13 inches (330 mm) according to the class of building.[9] These party-arches, which became a central feature in Barry's scheme, represented historic examples of compartmentation floors. They functioned as physical barriers that were intended to prevent the vertical spread of fire across several floors. The Act also introduced limits for the size for undivided spaces in warehouses, and technical specification for construction of fire resisting doors within party-walls. It stated that doors were not permitted, "unless the door-case and sill every" were stone and the doors panels made of "wrought-iron, of the thickness of a quarter of an inch at least." The requirements for party-walls and party-arches were retained within the Metropolitan Building Act of 1844. This Act, which was passed at the time when the Palace was already under construction, retained earlier laws, but also introduced new requirements, such as the provision for protected means of escape in public buildings. Under the category "fire-proof accesses and stairs" it asked for the floors of corridors, lobbies and staircases to be "supported, constructed, formed and made, and finished fire-proof".[10] This change was a significant as it introduces life safety as new criteria alongside property protection.

The impact of historic legislations is evident in Barry's scheme, but it was not solely a response to legislation or requirements of the client brief. It was also the outcome of initiatives taken by Barry's office to establish higher standards, in particular with regards to the protection of the interior fabric. The scheme combined the use of fire resisting materials with horizontal compartmentation, following principles that were first developed in the context of eighteenth-century mills. A notable example is the Ditherington Flax Mill in Shrewsbury from 1797.[11] The floors of these mills were composed of jack-arches and supported by an iron-framed structure internally. The jack-arches divided the interior into horizontal compartments in order to prevent fires from spreading to other levels or entering roof spaces. As Wermeil has highlighted, however, these principles were difficult to apply to public buildings as they were more spatially complex. She argued that the Palace was only "compartmentalised where necessary, but not generally."[12] Barry's office, however, was also faced with the additional challenge of adapting these principles for a building for centralised ventilation system. This exemplified a process of innovation that resulted from the adaptation of existing technologies, undertaken in order to meet a new, and more complex set of technical requirements in building construction.

The Early Brief and Specification, 1835-39

During the night of 16 October 1834, large sections of the Palace of Westminster were lost to a fire, and between 20 October and 7 November 1834 the Lords of the Privy Council undertook an inquiry into the causes.[13] Solely concerned with providing a diagnosis of the causes, however, it did not provide any recommendations for mitigating fire risks or technical guidance for the reconstruction. Inquiries into the reconstruction did not commence in earnest until the Spring of 1935, following a general election. Viscount Duncannon (1781-1847), who had sat on the Privy Council during the inquiry, was appointed First Commissioner of the Department of Woods and Forrest within William Lamb's (1779-1848) new government. He became responsible for coordinating the architectural competition and overseeing the development of the architectural scheme until 1841, a period during which critical decisions regards to fire protection were made.

During the first parliamentary session, which lasted from 19 February to 10 September 1835, the rebuilding became the subject of parliamentary debates as well as formal inquiries, which were led by Select Committees of the House of Lords and House of Commons.[14] Despite the severity of fire of 1834, fire safety was not primary concern during the architectural competition. Between March and June 1835 the Select committees had produced a brief and schedule of accommodation for the competition, but this did include fire protection as a criterion. In contrast, other technical aspects were given extensive consideration. The brief mentions the requirements for "due ventilation",[15] and on 29 July 1835, the House of Commons also appointed another Select Committee to undertake a specialist inquiry into questions of acoustics, lighting, ventilation and climate control. Aspects of construction or fire protection, however, were not given consideration.[16] An architectural scheme, produced by Barry in collaboration with the architect Augustus Welby Northmore Pugin (1812-52), was selected, but fire safety only began to be considered in earnest in conjunction with the production of first estimates of the construction cost. This included allowances for fire compartmentation. Barry referred to this scheme for first time in an oral statement to the Select Committee of the House of Commons. On 29 April 1836, he reported that his estimate included the cost for introducing "fire-proof" construction in parts of the building without providing further details.[17] He only mentioned plans for providing "fire proof depositories" for parliamentary records within the Victoria Tower.[18] The earliest technical details were given in the specifications within the builders' contracts, which Barry's office had prepared between September and October 1839. The contract for the superstructure of the River Front, specified "fire proof arches" within the ceilings of the committee rooms and libraries.[19]

Barry gave more comprehensive accounts of this early scheme in oral statements to two Select Committees in 1841 and 1842, and these show that the level of fire protection was rudimentary. In his statement from 24 September 1841 Barry explained that all of the public areas were "calculated to be rendered perfectly fire-proof", but also stressed that the "fire-proof principles" were not applied to the residential areas.[20] In another statement, given on 30 September 1841, Barry noted that only the ground floor, which was intended to function as a service with kitchens, boilers rooms and coal stores, were intended to have fire resistant floors.[21] Other floors were still intended to be constructed in timber.

This indicates that this early scheme was not intended to protect the interior fabric, but solely to contain fires within the boundary of each residence. To physically isolate residences from the public spaces Barry's office introduced internal party-walls. These party-walls transformed the residences into vertical compartments that extended the full height of the building.[22] In this early scheme Barry still intended to use a traditional timber roof construction. The first specifications for the construction of the River Front and House of Lords specified "Westmorland and Cumberland slates", which were to be nailed to timber battens and supported on wooden trusses.[23] In addition to introducing physical barriers, the early floor plans show that the building was divided into zones with different functions.[24] The public areas, which included the two debating chambers, libraries, committee rooms, and associated lobbies and corridors, were spatially separated from the residences. Officials of the House of Lords, such as the Black Rod and the Secretary to the Lord Great Chamberlain, had their residences around the Royal Court. Officials of the House of Commons, which included the Speaker, Serjeant-at-Arms and Clerks, resided in apartments around the Speaker's Court.

A New Budget for an Extended Brief, 1841-42

This first proposal formed the basis of the original budget of £724,984.[25] It was approved by parliament in 1837, but it was not the final scheme.[26] In 1841 Barry's office made further revisions. In the revised scheme the fabric of the building was to "consists entirely of incombustible materials, brick-work, stone and iron",[27] but Barry's office also extend the use of horizontal compartmentation to all floors. The objective was to prevent fires from spreading to other levels by containing them within the level of origin. Moreover, its design also became intimately intertwined with the development of Reid's ventilation and heating system. Barry's practice had not anticipated the impact of such system on the original scheme as it was only introduced after Reid's appointment in April 1840. Barry noted that it presented an entirely "new question".[28]

Reid's proposal was for a centralised ventilation and smoke extract system. In addition to flues for several hundred fireplaces, it had separate networks for the supply and extraction of air. Inside the roof space the smoke and air flues were connected to a large tower above Central Lobby through horizontal channels. Outside air was introduced through high-level inlets on top of the Victoria and Elizabeth Tower, and distributed across the site through horizontal passages at basement level. These passages were connected to rooms through vertical shafts. As Barry's scheme relied on the containment of fires through the physical separation, the introduction of flues had serious implications for the integrity of his strategy, and in 1841 Barry proposed a large programme of modifications. As the additional cost were not accounted for in the original budget, the ventilation system and modifications became subject of two parliamentary reviews. In September 1841 the House of Lords appointed a Select Committee to consider the plans "for the ventilation and warming" and "for rendering them fire-proof".[29] The House of Commons appointed another Committee. As these Committees were appointed close to the end of the parliamentary session, the inquiries were short. The Commons Committee had three sittings between 24 September and 1 October 1841, whilst the Lords held two sittings. These interviewed Barry and Reid, but due to the limited time, both Committees were unable to come to a final verdict. The Committees were re-appointed in 1842, and concluded their inquiries with statements endorsing the proposed changes. In its final report, dated 5 August 1842, the Select Committee of the House of Commons acknowledged that "protection from fire" was "afforded to a part only" and supported Barry's proposal for extending it to the entire building.[30] The Select Committee of the House of Lords came to the resolution that a budget of £86,000 should be granted to cover the cost of the proposed ventilation system as well as a scheme "for securing the buildings from fire, fire-proof floors under the roof, and brick floors on iron beams between the principle and upper stories".[31]

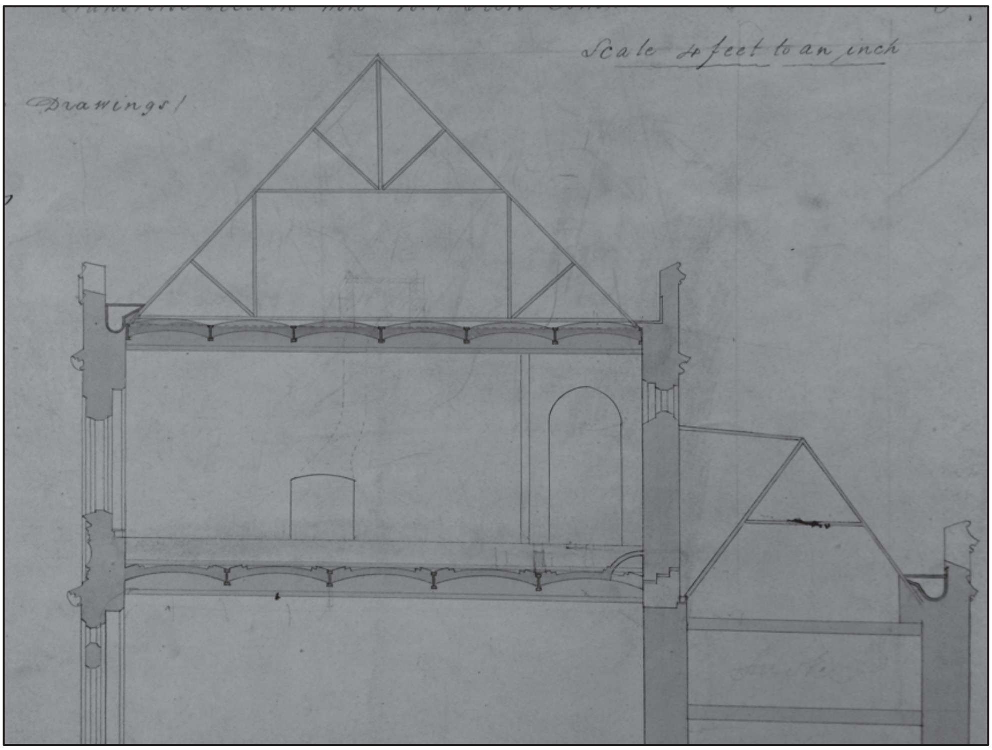


Figure 1: Cross-section, 1841, showing jack-arches in roof space and between floors (Source: National Archives: Work 29/2833).

Almost half of the total estimate was for additional fire proofing measures. Barry cited a figure of £41,680, but only parts of this sum were for fire safety measures directly connected with the ventilation. The proposal was to introduce jack-arches throughout the entire roof space in order to isolate horizontal smoke and air channels of the Central Tower from the main building. These floors alone were estimated to cost £20,680.[32] Reid noted that the horizontal flues inside the roof would "be constructed of incombustible materials, and would be laid upon a fire-proof floor".[33] An additional sum of £21,000 was allocated for the construction of jack-arches between the main floors. By replacing all of the structural timber floors, including those in the residences, with brick arches on iron beams, Barry extended the horizontal compartmentation to all areas of the building. He argued that this would result in a building that was "entirely fire-proof; that is, the rendering the floors of the residences, as well as very other part of the building, fire-proof".[34]

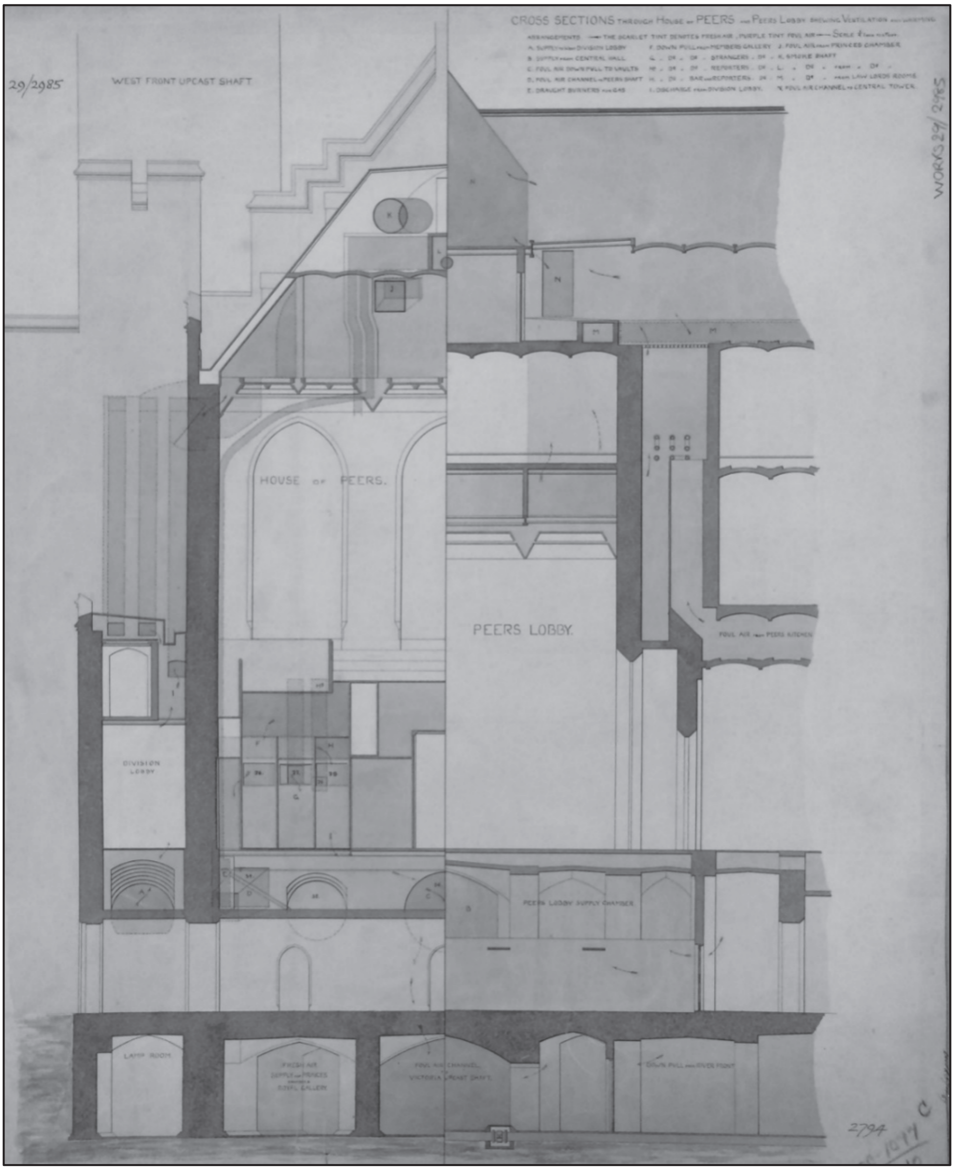


Figure 2: Cross-section through House of Lords, 1867, showing jack-arches above ceiling plenum (Source: National Archives: Work 29/ 2985).

Following the principles of eighteenth-century mills, the entire building was divided into a vertical stack of party-floors. In the basement and large parts of the ground floor, compartmentation was provided through traditional ceiling vaults. In the basement these vaults were constructed in brick, whilst some areas on the ground floor had more ornate stone vaults with carved ribs and keystones. These vaulted ceilings formed a horizontal plane of fire resistive materials that extended throughout the building. On the levels above the ground floor, the separation was provided through jack-arches. These were hidden within the depth of floors. On the principle floor of the River Front, for instance, jack-arches were place in the space between the panelled ceilings of the libraries and the timber floors of the committee rooms above. In order accommodate the air chambers required for Reid's ventilation system, some of the spaces above and below the jack-arches had to be very large. In the debating chambers and Royal Gallery, the jack-arches were separated from the timber ceiling by 3-metre high air chambers (Fig. 2).

These arrangements are an example of alterations that were made for the accommodation of the ventilation system. This system, which constituted an extensive network of horizonal and vertical voids, had much more far reaching impact on the construction of the floors and ceilings. To accommodate a network of horizontal voids for the air supply, Barry's office adopted a system of hollow groin vaults on the ground and principal floor level. In the Royal Gallery, Peers Lobby and Central Lobby, for instance, the floors were constructed from Yorkstone, and were separated from groin vaults below by the air chambers. The floor was supported on rows of piers and brick arches. On the River Front large part of the floors were covered with slate panels, which were supported on iron joists.

Two different types of jack-arches were deployed, reflecting a change in technology that occurred over the course of the long construction period. In the early phases the jack-arches were constructed with conventional bricks. These featured in the specification for contracts issued to the contractor Grissell & Peto at the earlier stages of the construction. In the specification for the River Front, dated September 1839, it was written that "the fire-proof arches in the floor over the library, committee rooms etc. on the principal floor […] to be turned in 9-inch work with sound hard stocks".[35] In later phases, the use of brick arches was superseded by lighter clay-tile arches, which also reduced the depth of the iron joists. Similar to timbrel arches, these clay-tile arches were constructed using three layers of plain roof tiles and joined with mortar made from Portland cement.[36] According to the historian Lawrence Hurst these arches were based on an established technique known as tile creasing, Tile creasing was used to create horizontal floor or roof slabs by joining layers of commons brick tiles through mortar made from Roman cement. In 1831, for instance, tile creasing was deployed by the architect Charles Fowler (1792-1867) for the roof of Hungerford Market in London. These spanned 4.6 feet (1.37 meters) between the iron beams. In this instance, however, the tiles were laid horizontally to form flat surface. Inside the Palace, in contrast, the technique was used to construct shallow vaults between iron joists. These vaults spanned distances of 1.1 to 1.7 meters. Hurst's paper only mentions its use within the roof space of the House of Lords,[37] but new research have shown that tile vaults were widely deployed across the Palace. They were first introduced in in the late 1840s within the roof spaces above the Royal Gallery, Princes Chamber, House of Lords and Peers Lobby, and subsequently inside the West Front, Victoria and Elizabeth Tower. In the specifications for the construction of the Victoria Tower from 1857, it says "turn fire-proof arches between the girders in two courses of plain tiles as those below, and pave floor with Hopton stone".[38] In some areas only one of the two typologies can be found. Inside the River Front, which was built in the first half of the 1840s,[39] all of the party-arches were brick-built. In the West Front, which was constructed in the second half of 1850s, all of the floors were separated by clay-tile arches. In sections that were built in two stages, such as the Elizabeth Tower, examples of both types can be found.[40] Clay-tiles arches, covered with a layer of stone paving slabs, can be found on the two floors below the belfry. These were completed in 1858. On the lower floors, which were already completed by 1847, traditional brick arches were deployed.

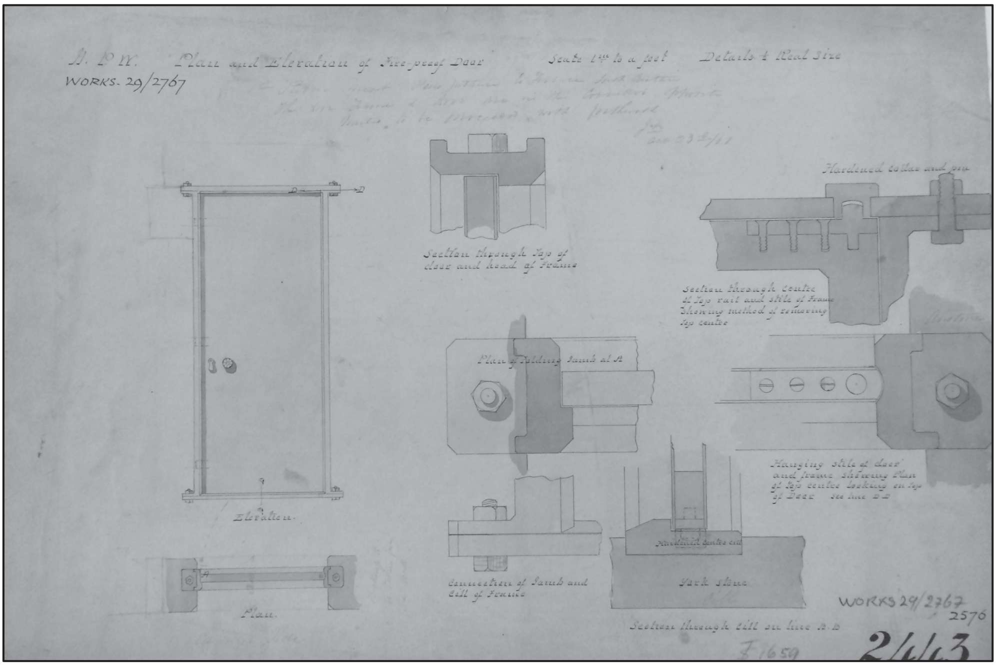


Figure 3: Construction details for 'fire proof door,' 23 October 1851 (Source: National Archives: Work 29/2767).

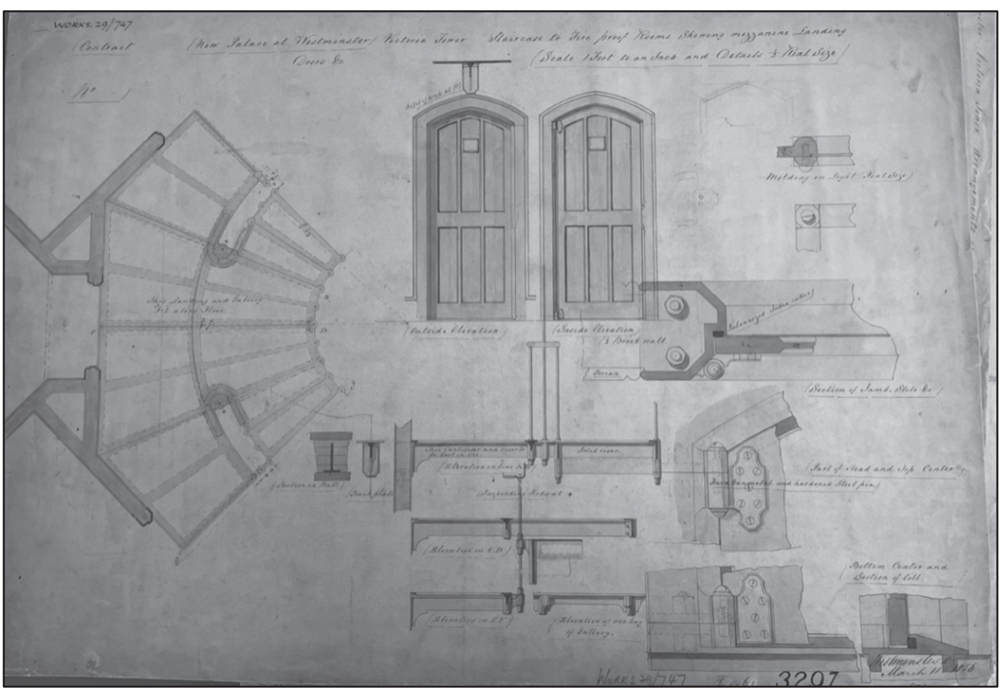
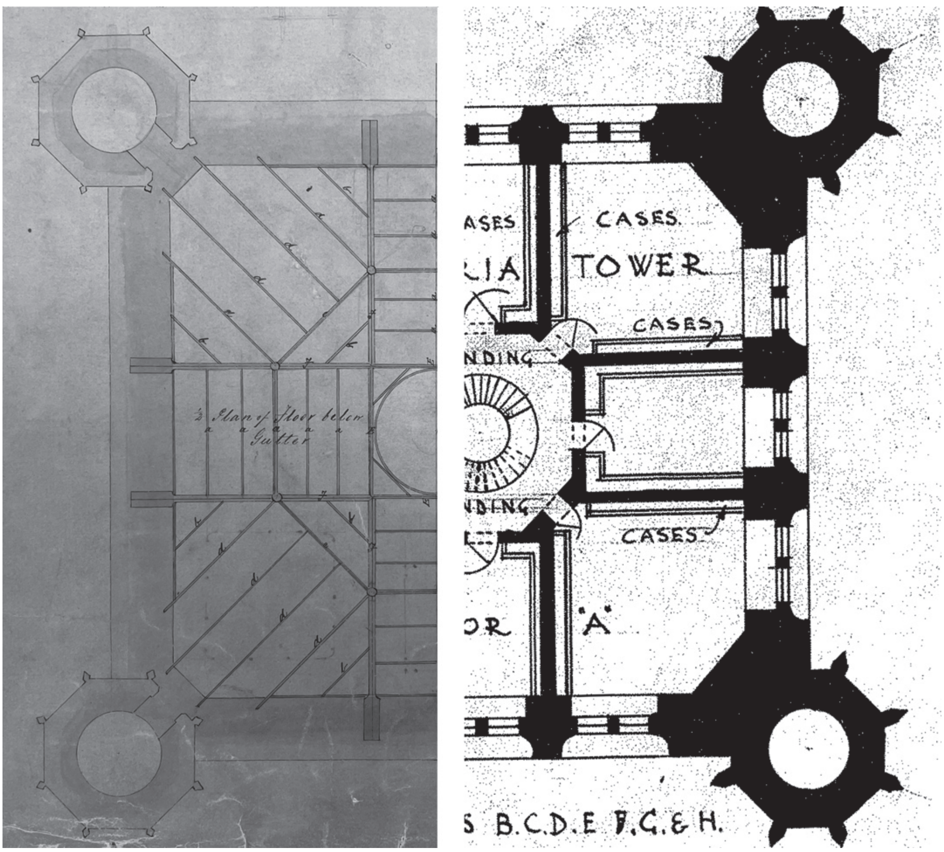


Figure 4: Detail of cast-iron fire door in enclosed staircase of the Victoria Tower (Source: National Archives, Work 29/747).

Although Barry's scheme focused on the use horizontal separation between floors, it incorporated party-walls, subdividing parts of the interior into volumes. These could be interpreted as historic examples of compartment zones, as they were designed to contain fires within one sector. Party-walls were used to separate each residence from other residences or adjacent public areas. Some of compartment walls contained cast-iron doors, which allowed to create connections without compromising the separation. In one of the original construction details, dated 23 October 1851, they were referred to as "fire proof doors" (Fig. 3).[41] A study of surviving fire-proof doors has shown that these were composed of cast-iron door panels with large hinges. These were tightly fitted within into wrought-iron doorframes, which surrounded the panels on all four sides.



A B

Figure 5: Half plans of Victoria Tower. (A) plan from July 1857, showing the layout of iron beams, and (B) the compartmentation of archive spaces on the second floor, 1938 (Source: (A) National Archives: Work 29/755, Plans and section of roof showing ironwork, July 1857; (B) IHSE Architectural Archive, Plan of the Second floor 1938, Office of Works, 1076/1).

The primary objective behind these structural measures was to protect the building fabric, but the archival research did not yield any evidence on how far they were also intended to contribute to life safety. The use of vertical barriers with iron doors, however, was not confined to party-walls. They were also used for the creation of enclosed stairwells, providing evidence that life safety had received some consideration. The staircases themselves were built from non-combustible materials, such as cast-iron and stone. Although many of the original staircases were enclosed, cast-iron doors were only deployed within back-of-house areas. They provided protected means of escape for the upper levels, such as the roof spaces and interior of the towers. Within the residences and public areas, the enclosuring walls had timber doors instead. Surviving examples of enclosed stairs with cast-iron doors can found inside the three larger towers: St Stephen, Elizabeth and Victoria Tower (Fig. 4). Other examples are the service staircases that gave access to the roof spaces above the House of Lords and Westfront.[42]

The interior of the Victoria Tower, which was designed to house archives for parliamentary papers or storerooms, had the most elaborate system of horizontal and vertical compartmentation. It had eight floors that were separated through clay-tile arches, and each floor was also divided into eight rooms through brick walls with cast-iron doors (Fig. 5B).[43] In a drawing from 11 March 1856 they are described as "fire proof rooms".[44] These clay-tile arches were supported by an iron frame. Each floor had four primary beams that were supported on eight columns.[45] The space between these beams was filled with clay-tile arches between rows of iron joists (Figs 5A & 6). Resting on top of these joists was a layer of Yorkstone slabs, forming a load-bearing floor that spanned across the fragile clay-tile arches below.

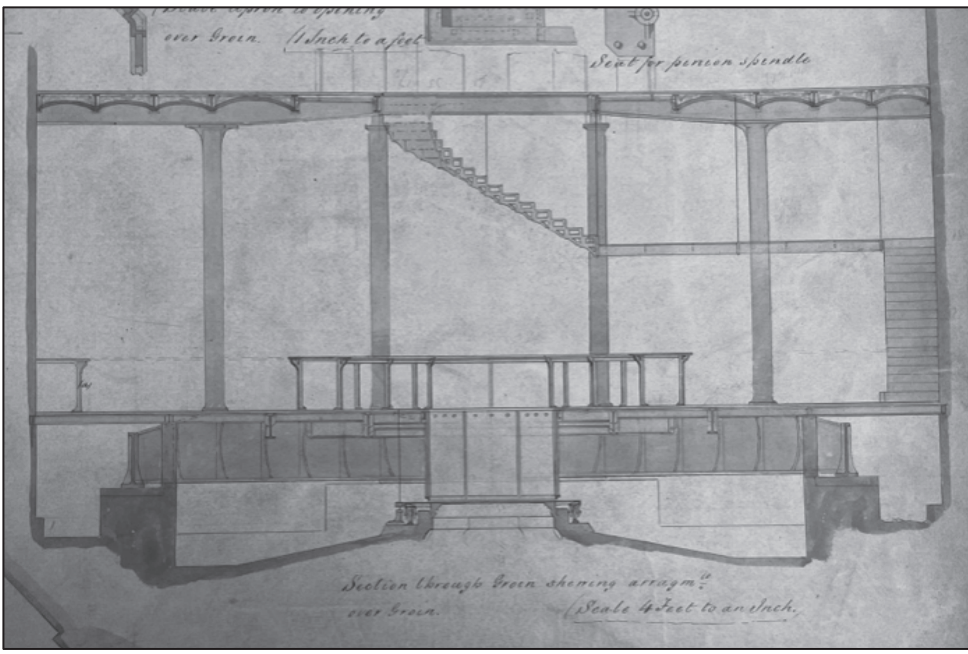


Figure 6: Drawing, 11 March 1856, showing jack-arches and iron frame inside Victoria Tower (Source: National Archives: Work 29/748).

The Role of Fire-resistant Materials

Vertical and horizontal compartmentation was an important feature of Barry's strategy, but it also incorporated other passive measures. After 1842, Barry also substituted timber with fire resistant materials in order to reduce the quantity of combustible substance in the construction of roofs and floors. The new materials were described as incombustible. In the debating chamber and voting lobbies of the House of Lords perforated cast-iron floors, supported on iron columns and beams, were introduced from December 1844.[46] These replaced an earlier scheme for timber floors.[47] The most common fire-resistant floors were constructed from slate or Yorkstone. Slate floors, supported on iron beams or sleeper walls, were deployed in most corridors and throughout rooms on the ground and second floor of the River Front.[48] The Yorkstone floors, covered with encaustic tiles, were utilised inside the public lobbies, including Central Lobby, as well as inside the Royal Gallery and St Stephen's Hall.[49] Fire resistant materials were not applied to all internal finishes. In many rooms ceilings and walls were finished with wooden panelling, whilst some floors were constructed using timber joists and floor boards. Barry was not unaware of the risk, but considered the loss of wood finishes acceptable if the fire could be contained within the room of origin through the jack-arches. In 21 March 1844, Barry noted that the ceilings were designed to have "a complete fire-proof floor above it, so that if fire reached the ceiling it would not extend further".[50]

Figure 7: Photograph of original cast-iron roofs on the east and north side of Royal Court, taken c.1920s (Source: Historic England Archive, Swindon, AL 1016).

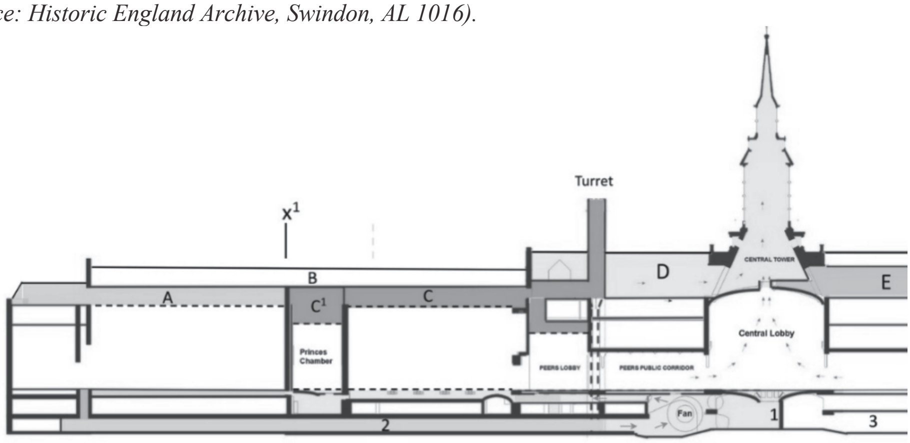


Figure 8: Diagrammatic cross-section showing compartmentation zones at roof level (Source: Author's own drawing).

Another significant change, undertaken in the mid-1840s, was the adoption of fire-resistant materials for the roof construction, which was originally planned to be timber-framed. This idea was first discussed on 27 September 1841 during a sitting of the Select Committee of the House of Lords. Barry reported that the roofs could be made fire resistant if "the battens for the slates, and the entire roof, were of iron",[51] but initially did not consider it necessary as the roof spaces were already isolated through jack-arches.[52] In the final design two different types of fire-resistant roof construction were adopted. In 1857, 16 years after his original statement, Barry wrote that the introduction of large smoke flues necessitated the roofs to be "constructed entirely of fireproof materials".[53] The main roofs were covered with thick plates of cast-iron (Fig. 7), supported on wrought-iron trusses (Fig. 8).[54] The lower roofs, which were located inside the courtyards, were covered with large panels of natural slate, supported on iron beams.[55]

Difficulties of Implementation, 1842-46

The approval of the budget in 1842 had provided Barry's office with the funds and political mandate to realise the extended scheme of fire protection. Subsequently the focus of Barry's office shifted towards the development of the technical details. To produce these details the number staff involved in the design was significantly increased, and Barry's office also had to collaborate closely with Reid's office. From March 1842 Reid began to employ three assistants in his office for the productions of ventilation drawings,[56] but the production of the final construction details, which incorporated features of the fire protection and ventilation schemes, was undertaken by clerks within Barry's office under the supervision of the chief superintendent of works. Frederick Groves (1803-95), who acted as chief superintendent until May 1845, had supervised the production over the first three years. He oversaw the development of details for the fireproof construction, and liaised with Reid about the configuration and construction for the ventilation network. The integration of the ventilation and fire protection schemes was challenging, and after three years also caused serious tensions between Barry and Reid. The written correspondence does not yield any evidence that Grove had voiced concerns about the integration over the first three years. It is unlike that these difficulties had not already become apparent over this period, but it only began to feature in the written correspondence in 1845, following the involvement of Alfred Meeson. Meeson had joined Barry's office in July 1844, and succeeded Grove as chief superintendent of works on 11 May 1845.[57] Fears that the system might compromise the compartmentation was voiced for the first time during a meeting between Meeson and Reid on 11 April 1845. This was four weeks before Meeson took over from Grove. Meeson reported issues with vertical flues breaching the line of jack-arches between the principal and first floor on the River Front. He also warned that fire could spread horizontally through a 200-meter long channel below the principal floor.

After this meeting Meeson alerted Barry to the issue, and this was followed by a lengthy dispute between Barry and Reid, which was documented in their written correspondence between April and May 1845. Barry took Meeson's warnings seriously. In a letter, dated 15 April 1845, he asked Reid for a statement on the issue.[58] In his reply, dated 17 April 1845, Reid denied that his system was inherently incompatible with the principles of compartmentation, but acknowledged that buildings with ducts require different solutions to traditional buildings ventilated through openable windows.[59] Not satisfied with his reply, Barry had a meeting with Reid to discuss proposals for mitigating the impact of the flues.[60] Reid did not deny the problem, but suggested that the integrity of Barry's compartmentation could be maintained through the use of dampers. According to John Imray (1820-1902), who was one of Reid's technical assistants, the proposal was to introduce "valves for entirely shutting off this communication". This was to include the "shutting valves in both the fresh and vitiated air channels in case of fire".[61] Barry, however, was still dissatisfied with the outcome. In another letter, dated 21 April 1845, he reiterated that his objective was to follow principles of physical separation Barry wrote that any "communication between the rooms of one story and those of the story either above or below it" had to be stopped "by means of fire proof floors so as to arrest the progress of fire vertically, and that party walls with iron doors in them wherever communications are required should divide the several occupations of the building so as to check to a considerable extent the spreading of fire horizontally".[62] He asked Reid for a definitive statement whether he considered his system incompatible with this principle.

Reid's reaction became increasingly defensive, and the written correspondence show that their dispute was largely the outcome of a disagreement about the boundaries between Reid and Barry's respective responsibilities for resolving these conflicting technical requirements. This represented a new layer of complexity that had not been anticipated by Alexander Milne (1818-61), Third Commissioners of Woods and Forest, when setting out the original divisions of responsibilities.[63] In a letter from 24 January 1840 Milne had stated that Reid "must defer" to Barry "upon all points affecting either the solidity or the architectural character of his building." Fire protection did not receive any mention, yet as the fire safety scheme was largely based on structural measures, it fell within an area of responsibility held by Barry's office. This led Reid to argue that the resolving the conflict between the fire and ventilation requirements was primarily Barry's responsibility. In a letter, dated 23 April 1845, Reid told Barry that he should have been fully aware of his plans and take part "in all those structural arrangements by which they have been applied so far as the works have proceeded during the last 5 years".[64] Barry was not impressed with his accusations, and subsequently refused to approve Reid's proposals. On 24 April 1845, he wrote that it was his duty to reject the plans that were "interfering with the fire proof principle",[65] and stressed that he had promised the government to deliver a fire proof building. In another letter, dated 26 April 1845, Reid reiterated his position. He wrote that difficulties were "founded not on defects of warming and ventilating arrangements, but on the defective fire proofing of certain portion of the air channels".[66] In this Reid was clearly attempting to direct the blame at Barry by portraying the issue of construction rather than configuration, but Barry interpreted this as an admission of responsibility on his part. In another letter from 26 April 1845, Barry claimed that Reid had admitted that his scheme "would be fraught with danger to the building".[67]

The situation had become intense, and on 5 May Barry threatened Reid with requesting a review through an independent tribunal.[68] Between 7 May and 9 May 1845 had further correspondence about proposals,[69] but their relationship remained fraught. On 14 May 1845 Reid wrote to the Commissioners that Barry had effectively terminated conservations about fire safety issues by refusing to meet him.[70] Having led to delays in the construction these tensions became the subject of several inquiries. The first inquiry, commissioned by Earl of Lincoln (1811-64) First Commissioner of Woods, was led by the architect Joseph Gwilt (1784-1863). Starting on 28 July 1845 Gwilt cross-examined Reid, Barry and his staff over 14 days.[71] In his final report, completed on 29 September 1845, Gwilt concluded that the system did "interfere with the accomplishment of the desired object of rendering them fire-proof".[72] His verdict was serious, and in 1846 the House of Lords and Commons appointed Select Committees in order to review the situation. In addition the First Commissioner appointed a panel of technical experts, which comprised the architect Philip Hardwicke (1792-1870), civil and mechanical engineer George Stephenson (1781-1848), and the chemist Thomas Graham (1805-1869). These came to the same verdict as Gwilt. In a report from 25 June 1846 they concluded that the ventilation could not "be made compatible with rendering many portions of the building fire-proof".[73]

Final Changes, 1846-52

Boundaries of Local Stack System

The Committee of the House of Lords also completed its inquiry in June 1846, and it came to the verdict that further delays in the project could only be avoided if Reid's involvement was terminated, and the full responsibilities for completing the ventilation was transferred to the architect.[74] Reid's contract was not terminated, but his responsibility was confined to the debating chamber of the House of Commons. Barry, who became responsible for all other areas, including the House of Lords, made serious adaptations to Reid's original scheme, and this also affected the design of the compartmentation. He abandoned the original concept for a central stack system, which was replaced with a series of local systems with separate towers. Seven towers for the extraction of air and smoke, and two large smoke stacks, were added. Inside the roof space the original network of air and smoke channels also became subdivided into compartments through "party-walls" and "jack-arches". These changes, which marked the final stage in the development of Barry's scheme, added another layer to the evolving design. The final fire arrangement was an assemblage of multiple layers established at different stages.

The impact of these changes are well-illustrated by the arrangements inside the roof space of the House of Lords. As shown in figure 8 the roof space was divided into sectors, which were defined by the boundaries of the local stack systems. The roof space was divided into two levels through a floor of clay-tile arches. The upper level (B) contained the smoke flues, whilst the lower level accommodated a large plenum (air chamber) for the extraction of used air. This plenum was split into three sections through brick walls. Section C is the main plenum of the House of Lords, which was connected to a turret at north end of the Peers Lobby. x^1 marks the position of a load-bearing wall with a cast-iron door, which provided the physical boundary between the zone C and A. Not all zones, however, were bound by structural walls. At the north end of zone C the boundary was defined by light brick partitions. In a similar way, the central tower (D) was separated from the system of House of Commons (E). The plenum of the House of Lords also contained internal partitions. One these partitions, which had four cast-iron access doors, enclosed the plenum above the Princes Chamber (C1). Few of these walls extended the full height of the building. Some of the walls were confined to the roof level, others extended to the ground floor. None of the party walls, however, continued into the basement as these contained the horizontal passages for the central air supply. These passages had only one internal division, which was located below the Central Lobby (1). This separated the passages for the House of Lords and River Front (2), which received air from shaft inside the Victoria Tower, from those of the Commons (3). The latter was connected to the shaft inside the Elizabeth Tower.

Network of Flues

These arrangements show that Barry's practice introduced an additional layer of compartmentation in order to adapt the fire protection scheme for the altered ventilation system, but the Palace had two distinct types of ventilation systems. The House of Lords was an example of the plenum-stack typology. Air was extracted through air chambers above ceilings, which was connected to a local ventilation tower. The supply was provided through air chambers below perforated iron floors, which were fed with air through the basement passages. This typology was deployed in areas with large, inter-connected spaces, and a different typology was deployed in areas with large numbers of cellular spaces. Cellular spaces are dominant throughout the residential areas and River Front. In these areas, each room was connected to the ventilation turrets through a network of horizontal channels and vertical flues. Another set of vertical flues connected them to the horizontal passages of the central supply within the basement. Figure 9 and

10 shows the arrangement of flues inside the River Front. This typology was at the centre of disagreements in 1845 as the flues were found to breach the vertical and horizontal compartmentation. By the time Reid's involvement in these areas had ended, this issue was still not resolved, but surveys and the study of archival evidence have yielded insights into measures adopted to mitigate the impact.

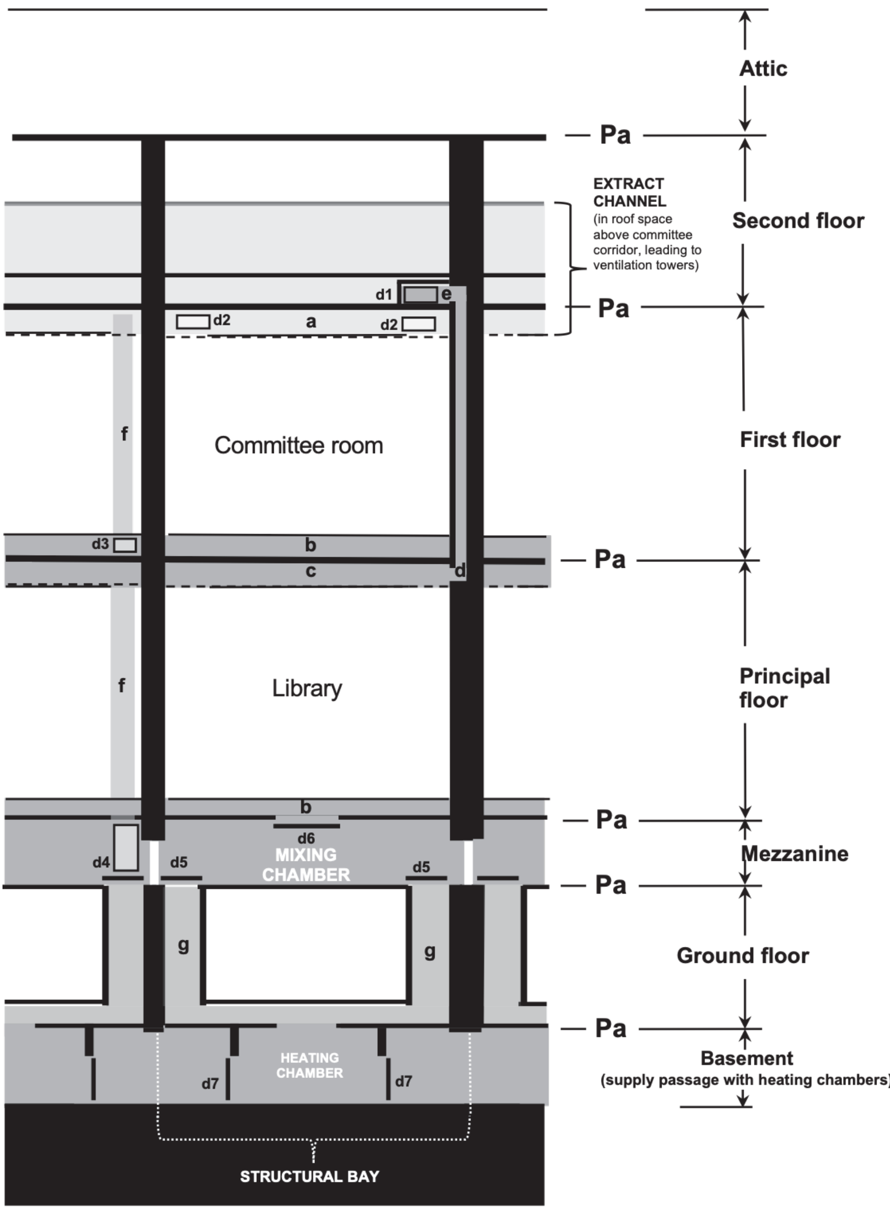


Figure 9: Longitudinal-section of River Front, showing typical bay with compartmentation and network of flues with dampers (Source: Author's own drawing).

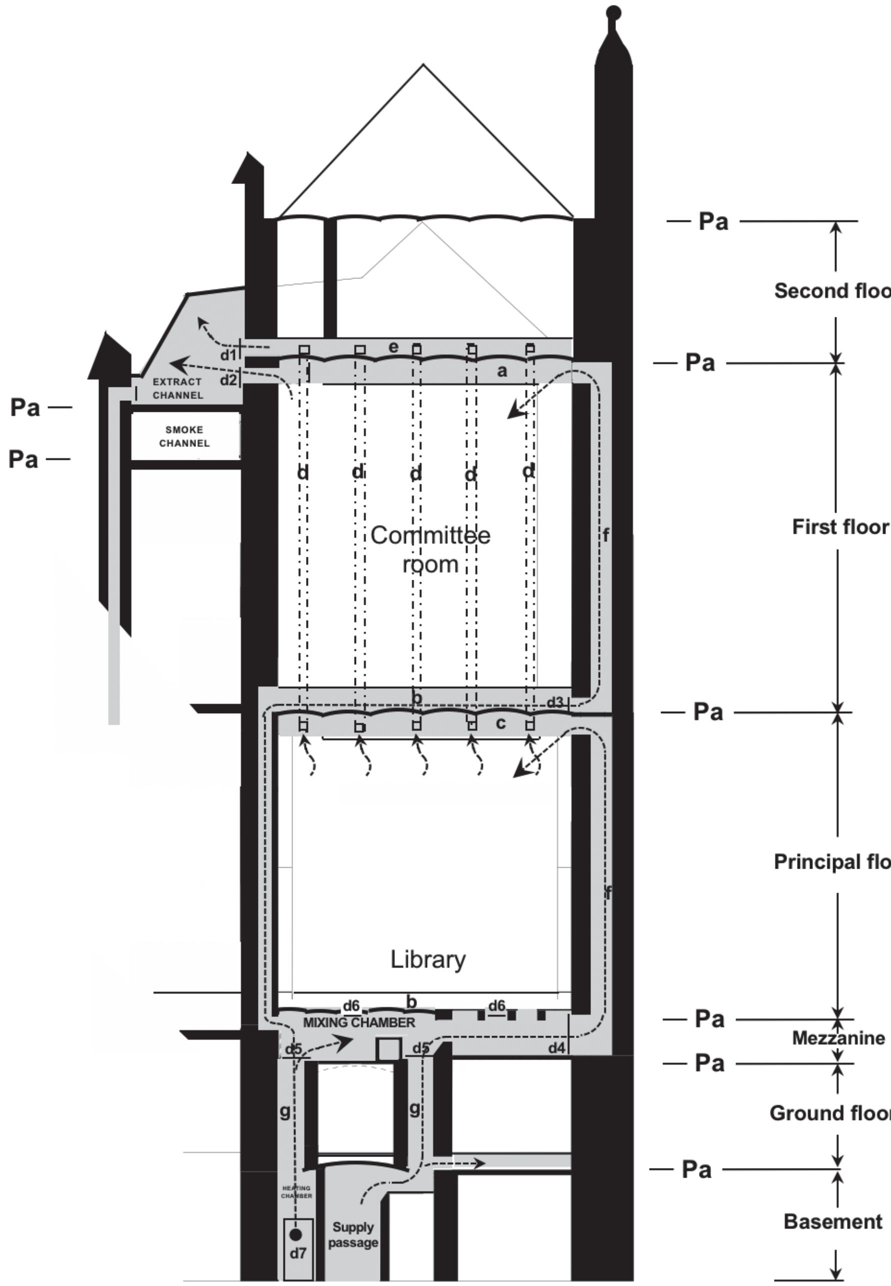


Figure 10: Diagrammatic cross-section of River Front (Source: Author's own drawing).

The first measure was to provide physical separation between flues, which resulted in an arrangement where each room was provided with separate vertical flues. In the River Front the flues were organised into vertical clusters, one within each structural bay. (Fig. 10) These were separated by the brickwork of the loadbearing walls. The second measure was the use of fire-resistant materials, such as iron, natural stone, brick and clay tiles, for the construction of flues and channels. Most of the vertical flues were voids buried within the depth of buttresses or structural walls, which were connected to horizontal air channels.

Most of the channels in the roof space and floor voids were enclosed with brick and stone. An example is the extract flue network for the libraries on the principal floor. These flues, buried within the depth of the walls (See 'd' in Fig. 9 and 10), bypassed two layers of jack-arches (See 'Pa'), and terminated inside fire-resistant horizontal channels (e). These channels were hidden inside the floor void (a) above the jack-arches, which, as they were constructed from brick and slate, allowed to preserve the separation between the floors. The use of fire-resistant materials, however, did not eliminate the risk of fire spreading through flues, but dampers were provided for regulating the ventilation as well as to close flues in case of a fire. Historic drawings and the surveys undertaken by the author have shown that every flue of the River Front was equipped with an individual damper. The position of these dampers is shown in Fig. 9 and Fig. 10, marked d1 to d7.[75] The extract flues (see 'd' and 'e'), which connected the ceilings (c and a) to the main extract channel inside the roof, were fitted with iron panels (d1 and d2). These could be raised or lowed with aid of pulleys. The network for the supply of air was equipped with several sets of dampers. One of these sets was located within the heating chamber at basement level (d7) and another set, which is marked 'd5', was provided on top of the large flues (g) that linked the basement to a mezzanine above the ground floor. This mezzanine, which was referred as a mixing chamber as it was used for the blending of cool and warm air, contained several sets of dampers. These allowed to close the supply to individual rooms. One set of these dampers (d6) was provided to close openings within the jack-arches of the library floor (b). Another damper (d3 and d4) was placed at the base of large buttress flues (f), which were used to supply air to the high-level inlets in the ceiling of the library.

Key for figure 9 & 10: a. Air chamber between jack-arches and panelled ceiling, b. air chamber between floor and party-arches, d. extract flues for rooms on principal floor (libraries), e.'fire'proof' air channel above party-arches, f. flues inside external buttresses for ceiling-level supplies on principal and first floor, g. main supply flues from basement to mixing chamber, Pa: line of jack-arches between floors. Set of dampers: d1. damper for extract flues of libraries, d2. damper for air extract above ceiling of committee rooms, d3. damper for supply flue to ceiling of committee rooms, d4. damper for supply flue to ceiling of libraries, d5. damper for supply flues from basement to mixing chamber, d6. damper for supply to floor low-level supply in libraries, d7. dampers in walls of heating chambers

Operational History, 1852-1942

Situating Barry's Compartmentation within a Wider Framework of Fire Protection Measures

Barry's strategy has followed a largely passive approach to fire protection, exploiting the inherent safety provided through structural compartmentation, spatial separation, and the use fire-resistant materials. From 1845, however, Barry's office became increasingly aware of the limitations of these passive measures, and his final scheme incorporated firefighting services and considered the role of facilities management, exposing its reliance on human interventions. Manual operations, such as the closing of hand-operated valves, represent historic examples of active measures, and they were part of a larger set of operational procedures that were concerned with the detection, containment and fighting of fires. The administrative files of the Office of Works, which cover the period from 1852 to 1942, reveal that the passive measures need to be understood as part of a socio-technical system, in which the structure, services and management procedures fulfilled complementary functions (Fig. 11).

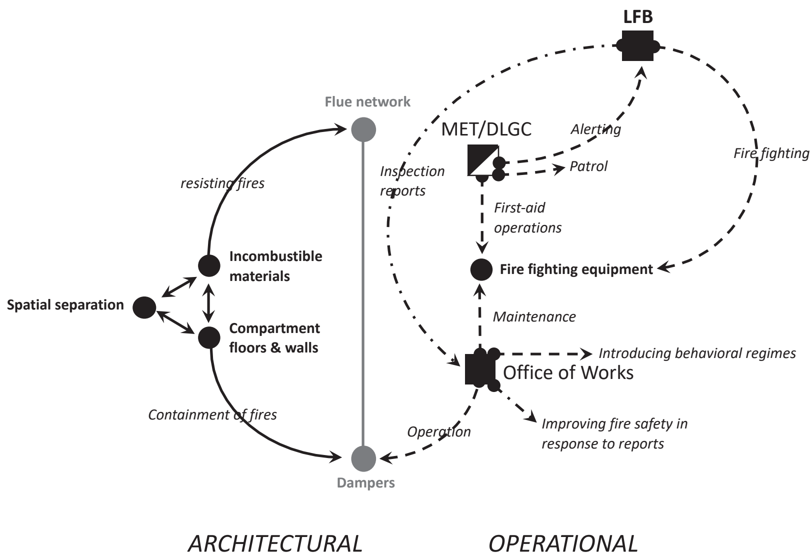


Figure 11: Architectural and operational functions within the socio-technical system (Source: Author's own diagram).

Plans for firefighting mains were first mentioned during the inquiries of 1845, when the limitations of the structural compartmentation began to be discussed. In this context it was stipulated that fire safety could not be achieved through compartmentation alone but also required human intervention. On 2 August 1845, Meeson stipulated that the building has become reliant

> "on a watchman being continually in the air flues to perceive if any fire took place in a room; that then he could give the alarm, and where a fire was discovered in the that manner the room should be flooded with water" [76]

The original firefighting services were integrated into a gravity driven network, which was fed by cisterns within the roofs of two towers on the River Front. The cisterns supplied water to lavatories and kitchens, but also served firefighting mains with an array of internal hydrants to which hoses could be attached.

It is unclear when this system was fully operational, but by 1850 the correspondence of mentioned technical issues with the mains. Between August 1850 and July 1851, Reid, Barry and the First Commissioner raised concerns about the system's ability to provide sufficient water for firefighting.[77] In a Memorandum, Reid proposed to complement the cisterns with a steam-driven water supply.[78] Barry rejected the proposal, but the capacity of the gravity driven supply continued to be a concern, and was revisited in January 1881. John Taylor, who in his role as the Clerk of Works at the Ministry of Works had been overseeing the testing and maintenance of firefighting equipment, reported to the First Commissioner that the supply was "seriously deficient". He advised to increase the capacity of the supply by introducing two additional cisterns and enlarging the existing cistern.[79] In a letter addressed to H.M. Treasury the First Commissioner wrote that the "internal fire arrangement of the building are entirely dependent on the supply of water contained in these tanks".[80] A grant of £2000 was authorised on 24 December 1881 to cover the cost of the improvements.[81] The records did not yield much detail about these changes, but later records describe the extent of firefighting mains at the turn of the century. These show that the Palace had access to three types of firefighting mains. The first comprised an interior network of hydrants. This was served by the gravity-driven system with the 'high service water tanks' at roof level.[82] In 1911 it was reported that 58 fire cocks where located within the interior.[83] In addition, the Palace had access to two sets of external hydrants that were connected to public mains. One of these sets were located within the boundaries of the Palace. In 1905 it was reported that four hydrants were located inside the courtyards and two on the terrace.[84] The second set was composed of public hydrants, located in the street outside New Palace Yard and Old Palace Yard.[85]

After the completion of the House of Commons in 1852, the Office of Works employed in-house officers for the monitoring and fighting of fires. According to the annual budget reports, these officers worked under the direct supervision of Barry's office from 1852 until 1857, after which it was transferred to the Metropolitan Police. Under the heading "services under the Direction of Charles Barry" these reports listed wages for "firemen and watchmen".[86] The responsibility for the supervision was held by Meeson.[87] Alongside overseeing the day-to-day operation of the ventilation, heating and gas lighting, he held the responsibility for the "protection of the building from injury and depredation, particularly from accident by fire".[88] The involvement of Barry's staff is not insignificant as it enabled the architect to oversee the implementation of his scheme from an operational perspective. After Charles' death in 1860, his son Edward Middleton Barry (1830-80) continued to show concerns about fire. Edward Barry conducted the earliest recorded building inspection in 1865, which focused on the roof spaces of House of Commons. In a letter, dated 29 April 1865, Edward Barry noted that the roof space was originally constructed from "incombustible materials," but found that it had become unsafe as a result of later changes undertaken without "architectural supervision". This included the introduction of combustible materials, but the risk of fire had also increased due to the installation of gas lights above the glazed ceiling of the House.[89] Amongst the changes he recommended was the replacement of the lath and plaster linings with rivetted iron sheets. To reduce the risk of fire spreading through air ducts, he also advised to substitute timber dampers with "valves be of sheet iron stiffened by suitable ribs".[90] These changes were completed in December 1866.[91]

Handover of Responsibilities

The operations were under the stewardship of Barry's office only until 1857, after which these responsibilities were transferred to the Metropolitan Police and Office of Works. The Office of Works was responsible for the maintenance of the equipment, whilst the Met police was charged with conducting fire patrols, building inspections and coordinating firefighting drills. In an emergency, the policy was also in charge of summoning the Metropolitan Fire Brigade (MFB) and perform first aid firefighting procedures prior to its arrival. A series of small fires were documented between 1863 and 1872, and newspapers reported cases where the policy took part in active firefighting.[92] On 13 June 1863, for instance, it was reported that the police "immediately set to work, applied the hose, and turning on the water with which the mains are constantly charged […] were soon subdued".[93]

This arrangement remained largely unchanged for 70 years. The Civil Service Estimates for the years 1856 to 1923 refer to wages for "police engaged in watching and protecting the building from fire".[94] In a letter, dated 22 September 1873,[95] it was reported that the night-watch police, which was headed by an Inspector of Police, were expected to undertake regular tests and inspections of their equipment. One of the earliest reports of a hose drill dates from 16 February 1874, and this had been conducted on request from the First Commissioner of Works in order assess the efficiency of the police in the handling of fire emergencies.[96] Evidence of annual inspections of equipment go back to 1891.[97] These involved tests looking at water pressure as well as physical condition and functionality of hoses and hydrants, and any defects were reported to the Clerk of the Works, who was in charge of coordinating repairs.

By 1902 the Palace had become subject of external inspections by the Chief Officer of the MFB. In annual reports submitted to the Office of Works, the Chief Officer presented the results of inspections and made recommendations. The earliest report from the MFB dated from 19 February 1902, and was signed by Captain Lionel de Latour Wells (1859-1929), who had acted as Chief Officer since 1896.[98] These reports, alongside correspondence with the Office of Works about the implementation of their recommendations, are evidence of the MFB's growing influence on the development of the fire precautions. Over the first twenty years the reports provided reviews of the firefighting equipment and its water supply, but also highlighted risks associated with electrical services, gas lights and the storage of inflammable materials. In the report of 1902 it raised concern about the use of cotton wool filters in the air supply of the House of Commons,[99] which was subsequently removed and replaced.[100] A particular concern to the MFB was volume of flammable materials, in particular within the store rooms of the Victoria Tower.[101] In addition to reducing the quantities of these materials, the MFB and Office of Works also considered proposals for installation of new firefighting equipment. Between 1902 and 1910 they explored the technical challenges of introducing a system of vertical risers with hydrants at the upper floor of the Victoria Tower,[102] and a sprinkler system was proposed in 1910.[103]

Reappraisal of Structural Measures, 1903-42

These and earlier discussions elucidate the scope of historic inspections, and it is noticeable that the correspondence rarely questioned Barry's original compartmentation or raised concerns about the risk of the ventilation systems. The earliest evidence of MFB questioning the soundness of the compartmentation was from 1903, but it was limited to the Victoria Tower, and the Office of Works was also not in agreement. In a note from 16 March 1903 the Office of Works argued that the installation of fire hydrants, which had been recommended by the MFB, was not necessary as the cellular spaces of the archives would be capable of containing any fire. "Each room", it noted, was "fitted with an iron door and the content of any room could be burnt out without risk of fire spreading".[104] In 1904, it was reported that a fire extinguisher and six buckets of water were placed on each floor as an intermediate solution.[105] The MFB, however, raised the issue again in their report for 1905, but John Wescott, surveyor at the Palace, reiterated the view that the Victoria Tower was safe. He wrote that "each chamber in the tower is fireproof in itself and any fire be confined to the chamber in which it occurred".[106] James de Courcy Hamilton (1860-1936), Chief Officer from 1903 to 1909, challenged this claim in his annual report for 1908, and asked for the volume of combustible materials to be reduced to a level at which sufficient heat to "seriously affect the cast iron column and stone flooring".[107]

These reports are significant as they introduced the Office of Works to the idea that the iron structure and compartment floors had a limited fire resistance. This critique, however, was confined to the Victoria Tower. As the tower was one of only a few areas that was not equipped with a ventilation system, the appraisal also did not raise concerns about the impact of the ducts. The latter, however, became the subject of a major re-appraisal after an intense fire, caused by incendiary bombs, had destroyed the House of Commons. The fire, which occurred in May 1941, had resulted in the full loss of the interior. Only the external shell had withstood the fire. In a report, dated 5 August 1941, the Ministry of Works noted that the chamber was "entirely gutted and has no roof. Within the walls of the chamber everything combustible has been burnt".[108] Having revealed the vulnerability of the historic fabric to the impact of incendiary bombs, the Ministry asked the Brigade to conduct an appraisal of the existing fabric, and propose interventions.[109] On 6 September 1941, Frank Jackson (1885-1955), Deputy Chief Fire Officer, submitted a report, outlining an extensive programme of physical alterations.[110] Many of these measures were implemented between October 1941 and July 1942.[111] In his report Jackson identified the ventilation system as a serious fire risk. In a letter accompanying his report, he noted that the fire in the House of

Commons had "become intense owing to the draught created by the ventilation system' and warned that a "similar situation may arise in the House of Lords and in other sections of the building".[112] Jackson argued that the risk could be addressed by replacing the hand-operated wooden valves with automated dampers. He specified fire resistant "metal flaps" with fusible links. The latter were thermally sensitive mechanical actuators that allowed the damper to close automatically. Furthermore, his advice was to close the connections between vertical and horizontal ducts.

Eric de Norman (1893-1982), Deputy Secretary of the Ministry of Works, considered the extent of the proposed programme unreasonable,[113] and on 6 October 1941 the Ministry of Works held a meeting with Jackson to agree on a reduced programme by identifying areas of priority. Addressing the risk of posed by the ducts remained a priority, but instead of introducing automated dampers, it was agreed to permanently seal the shafts. In the minutes of the meeting it was noted that "whenever there was any doubt about ducts discharging into the roof being alive they would be stopped as opportunity offered".[114] In a report from 6 November, it was noted that that "work of sealing off all possible ducts" was progressing,[115] and in another letter, dated 19 November 1941, Jackson reiterated his view "that the stopping up of ducts that discharge into the roof should be treated as a matter of urgency as this would from an important step towards minimising the risk of a spread of fire".[116] In December 1941, it was reported that 250 shafts had already been stopped inside the roof space.[117] A new system of vertical compartmentation, referred to as "sectionalisation" was also adopted.[118] In a letter to the Office of Works, dated 19 November 1941, Jackson wrote that "if the building could be structurally separated by means of brickwork and double iron doors or shutters into several sections, the risk of spread of fire would be considerably reduced".[119] The correspondence from December 1941 to May 1941 provided details for "vertical fire breaks" in different areas.[120] A letter, dated 17 December, described a scheme for sub-dividing the roof space,[121] and another letter outlined a proposal for introducing "fire resisting doors and screens" inside corridors, including the 200 meter long committee corridor inside the River Front.[122]

The physical alterations of the early 1940s embodied a fundamental shift in the approach to fire safety. They represented a first attempt to superimpose a new system of compartmentation onto the historic fabric, and also showed that fire safety started to become an important factor in driving the gradual decommissioning of the historic ventilation arrangements. The fire-stopping of historic flues within the roof and ceiling voids, has resulted in parts of the ventilation network to become defunct. These alterations were only temporary measures, introduced to mitigate against the risks of air raids rather than to make a historic building comply with modern standards or regulations. Underlying these interventions, however, was a fundamental loss of trust in the historic principles. This distrust persisted, and continued to influence alterations undertaken after the war, which were not covered in this article. Instead of improving the existing arrangements, the objective of these postwar alterations, including the most recent programmes delivered between 1995 and 2021, was to align a historic building with modern principles.

Conclusions: Questions of Responsibility

Although this study did not determine whether the Palace in its current or historic stage can be considered safe, it has illustrated the level of consideration that Barry in his role as the principal architect had given to questions of fire safety. The original correspondence provided detailed evidence of a historic engagements with fire risks throughout the design evolution, including the development of measures for the mitigation of these risks. These measures were the outcome of personal initiatives and advocacy on part of the architects. They were only partially driven by nineteenth-century regulations or requirements within the client's specification. The scheme developed over a period of nine years, during which the original specifications, which only accounted for a rudimentary scheme, were substantially revised. This required the architectural office to take responsibility for an aspect that in contemporary architecture would be considered the domain of specialist fire engineers, and it added another layer of technical complexity. Although it drew on established principles of compartmentation, they had to be adapted for the use in a public building that was both large and spatially complex.

Following the appointment of Reid in 1840, the requirements of fire protection also added another layer complexity to the design of the ventilation system, affecting its configuration, construction and operations. Reid and Barry's office were faced with complex design problems, but their collaboration was also compromised by insufficient clarity about the division of responsibilities between those involved in different aspects of the design. The failure to agree on the divisions, and to some degree the refusal to accept personal responsibility, resulted in the mutual blaming for the failure to find an integrated solution. For Barry's office the question of responsibility for fire safety also did not end there. Under Barry's supervision the question was also extended to those in charge of building maintenance, security and the day-to-day operation of the ventilation. Although the focus of Barry's strategy was on the use of passive measures, it also incorporated firefighting services and operational procedures. Alongside the monitoring, reporting and fighting of fires, these procedures also encompassed the management of the ventilation. Located the intersection between the history of construction and facilities management, the final outcome needs to be understood as a socio-technical system, in which the construction, services and operational procedures were acting as complementary measures. The final outcome was a sophisticated design with known limitations of passive measures.

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