Buro Happold
F E D R A

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GSA Mackintosh Building

Property Protection Feasibility Study

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Contents

1 Executive Summary

The need for an automatic property protection system for the Glasgow School of Arts' Mackintosh building, and its contents, has previously been identified and accepted. Previous studies and assessments have highlighted the high risk nature of the building, and its activities, and in the event of a fire, the outcome could be catastrophic. Total loss of the building and contents is currently a distinct possibility.

A hierarchical risk reduction exercise has been carried out, and the preferred methods of risk reduction were not possible as:-

- The overall nature of the usage of the building cannot be changed;
- The construction of the building cannot physically be changed; hence
- The possibility of fire occurring and involving the whole building cannot be eliminated.

As such the possibility of a fire threatening the building, and contents, as a whole must be considered and provision made for it.

A feasibility study of available fire protection solutions has been carried out. This exercise was enabled by survey of the building and analysis of information gathered from building users, support staff and potential installers. A literature review of technical papers on various of the options was also carried out. From these exercises the suitability, or otherwise, of each protection method was determined in the context of application to the Mackintosh building.

The outcome of this feasibility study is that only water mist suppression remains a viable option at this point in the assessment.

Further technical and qualitative evaluation of the technologies' suitability for application to the Mackintosh building requires to be carried out.

2 Introduction

2.1 Project Description

The Mackintosh building at The Glasgow School of Art is currently undergoing an extensive conservation and refurbishment project. The building in Renfrew Street, Glasgow is Grade A listed and contains teaching accommodation, art studios, a lecture theatre, a library and ancillary accommodation. Currently work is concluding on the provision of new research, retail and exhibition facilities. The building also houses various books and artefacts reflecting the work of Charles Rennie Mackintosh, other related Glasgow architects, and former staff and students of the school, in various locations.

In addition to staff and students, there are also regular visitor tours by members of the public to view the building, its extensive collection and archive. During the summer of each year, the building hosts a further influx of visitors for the annual degree show.

The building and its contents are world renowned and largely irreplaceable and as such the contents must be protected from risk of loss, or damage. One aspect of this risk protection is that from the threat of fire.

2.2 Current Situation

A previous study carried out by Buro Happold FEDRA, prior to the current conservation and refurbishment project commencing, highlighted various risks existing in the building and posing a threat to occupants, building and contents. The conclusions of this risk assessment were as follows:-

- Likelihood/ potential for fire occurring in building – Medium – High risk.
- Potential for fire to remain undetected – Medium – High risk.
- Potential for fire to grow/ spread beyond item first ignited – High risk
- Potential for fire to grow/ beyond room of origin – High risk
- Hazard posed by fire – High risk
- Consequences in the event of fire spreading – High

From this it was obvious that a fire posed a very real and present danger to the building and its contents. Various schemes were presented by FEDRA to mitigate the risk and whilst some of the options achievable in the shorter term have been applied, or form part of the planned works for the current project, more extensive and long term solutions required further consideration to ensure selection of the most effective solution.

Installation of a fire suppression system, or systems, throughout the building was identified as a possible feasible solution to successfully protect the building and its contents from fire. Such a solution was proposed as other means of risk reduction were not possible due to the nature of the building in terms of construction and use. Buro Happold FEDRA have been commissioned by GSA to further investigate this option and, if deemed feasible, facilitate the design, specification and installation of the protection system(s) into the building.

2.3 Fire Engineered Property Protection

Fire protection of people, buildings and contents generally follows the generic risk reduction hierarchy listed below, with 1. most effective and 5 least, in terms of risk reduction:-

1. Prevention/Elimination – complete removal of risk - (eg Hypoxic Atmosphere - no fire at lower O_2 levels.)
2. Substitution – find a different way of doing – (Change Materials/ Change Conflicting Use of Building)
3. Isolation/Limitation – dangerous areas segregated/valuable assets protected – (Compartmentation)
4. Engineered systems – Global/Zonal/Local/Item – (Sprinklers, Mist, Gas, Smoke Control)
5. Management systems (Fire Wardens, Auto Detection and Alarm plus trained staff)

Risk reduction cannot be considered in isolation however, and costs, building use, and regulatory restrictions will all have a bearing on risk reduction strategies which are most practicable when considering all other influencing factors. In this case hypoxic atmospheres are precluded by the ongoing occupancy of most spaces, and material changes/ intervention to form compartmentation are to a large extent precluded by the Grade A listing of the building.

2.4 Influencing Factors

In considering the feasibility of any fire protection measures for this building it is necessary to consider various issues and constraints which will affect system selection.

These issues and constraints include:-

- Existing listed status (Grade A) ;
- Construction methods used in the construction and subsequent alterations/refurbishment;
- Condition and configuration of each of the buildings enclosures;
- Occupant use and activities in the various areas;
- Plant/tank space availability;
- Co-ordination with services – existing/proposed;
- Aesthetics of any proposed equipment;
- Operability of the building with a particular system installed;

- Building occupancy with respect to installation works – Holidays/Out of Hours/Phased working; and
- Costs – capital & revenue – maintenance and life cycle.

A survey of the building and consideration of each of the above in turn allowed various protection measures to be assessed. Discussion with GSA staff and potential suppliers provided input on options for further consideration. Outline indicative estimates of what the most appropriate system might cost per unit area have been obtained from contractors experienced in the field.

It is proposed that, as a future step, the study be progressed by developing the proposals in consultation with the current projects' Design Team (Estates staff, Conservation Architects and M&E Services consulting engineers), and with end users and The Schools' administrators.

2.5 Feasibility Study

This document summarises the feasibility study which comprised an overview survey of the existing building, discussions with potential installers, and the subsequent option appraisal.

3 Building/Client Requirements

The Mackintosh Building at The Glasgow School of Art has a dual role as both a working teaching facility, and a national monument/ museum. The preservation of the safety and function of one should not compromise the safety and use of the other, and vice versa. This creates some potentially conflicting goals which must be accommodated.

As a working college and an irreplaceable historic building it must, as far as it's A - listed nature allows, have working environments that are safe, secure, healthy, comfortable, durable, aesthetically pleasing, and be accessible. The principles which provide a safe working environment for the occupants must be extended and broadened to protect the building contents and the building itself.

Important fire protection issues for this building are:-

- Life safety of staff, students and any visitors;
- Property protection is almost equally important given the nature of the building and its contents, and its continuing function;
- Any building property protection measures, whether passive, active, or management procedure should impinge and constrain the day to day working of the building as little as possible;
- Major intervention into building fabric, whether to create compartmentation, or to accommodate plant or services, is undesirable in the extreme and highly unlikely to be authorised;
- In line with the above, any system proposed should be 'buildable' and involve minimal intervention into existing historic fabric. This will be subject to increased levels of oversight before proposals are approved, and during installation works themselves;
- The building contains areas of varying levels of aesthetic sensitivity and fire protection measures proposed in all areas must be sympathetic to the rest of the space;
- The threat of accidental discharge, or system leakage must be taken into account and moderated as far as possible in any solution proposed. Such 'collateral damage' must be considered in selection of an appropriate system.
- Controlled access to many of the buildings' areas is not possible given its 'open' nature. All fire protection systems are vulnerable, to a greater, or lesser extent, to such deliberate acts of malice and it must therefore be recognised that arson is an omnipresent threat,

and must be dealt with by security measures. The installed system should however, be as robust as possible to accidental and deliberate damage.

- Capital, and long term 'running' costs should be considered as part of any final assessment, but should not form part of the determination of whether, or not a system is fit for purpose, or not.
- Consideration of a particular systems' environmental impact should also be considered, both in construction/manufacture, and upon discharge into the atmosphere.

All of these issues affect the property fire protection strategy for the building and as such these and any additional requirements should be taken into consideration when determining the most appropriate fire safety measures to be constructed / installed into the building.

(Note. It is understood that the building meets the requirements of the regulating bodies in terms of life safety. The fire protection measures assessed for suitability in this feasibility report relate to property & contents protection only, not the protection of life, though the assessment process followed does consider risk to occupant health, and safety. It is also noted however that any system which contributes to building protection will have some positive effect on the life safety of occupants of the building in the event of fire.)

4 Survey Findings

4.1 General

The building was surveyed on 6th, 17th and 26th June 2008 by Buro Happold FEDRA.

During all the visits invaluable assistance was supplied by GSA Estates Department Staff who provided guidance and access to most areas of the building. Some areas were not accessible due to security issues and other ongoing building activities, but it is believed that a reasonable representation of the building was obtained.

Given that the survey period encompassed the Annual Degree Show, and that visitor tours were also ongoing, a reasonable picture of the varying occupant profile was obtained. The buildings' activities and functional usage by staff, students and visitors were observed.

A wide range of fire load was observed in various areas during the survey and the changing nature of the loading profile within spaces was also observed across the three week period.

Access was gained to a range of offices, studios, workshops, service areas and galleries. All of the aesthetically sensitive areas were also accessed and surveyed.

Access was gained to the mechanical and electrical service spaces and an understanding of the buildings' M&E services historical development and strategy gained. No access was gained to the roof of the building, but it is understood that the roof area is not used for any major plant, housing/accommodating only some small water service tanks, and some small scale services routing.

4.2 Occupants/ Use

4.2.1 Students

The building is a working art college used for teaching and practical work by post and undergraduate students. Much of the students work is of a nature which involves amounts of combustible materials either in the substance of the work itself, or in its creative process. Historically these activities have also led to a build up of flammable materials on surfaces and impregnation of the buildings fabric and structure with similar substances contributing to flammability and fire load.

4.2.2 Staff

School teaching, administration and estates staff also have offices and tutorial facilities in the building.

A new suite of offices and study facilities will house a Mackintosh Research Centre and associated staff.

Areas housing the janitorial and security functions necessary for the security, safety and day to day upkeep are located on various levels of the building.

Estates material stores and a limited number of workshops are located on the two lowest levels of the building. Plant and services distribution generally originates from these levels.

The two lowest levels house newly created archival storage. The stores form separate fire compartments to protect the contents from fires originating externally to the archive rooms. The store located at Lower Basement Level is for furniture and other larger pieces of the Schools collection of Mackintosh artefacts. A similar, smaller store on the level above houses paper of various sizes in plan chests.

4.2.3 Visitors

As well as the art school function and its annual public show, the building itself, as one of Mackintosh's most famous works, and some of the items contained therein, attract a large number of visitors from around the world. These visitors are supervised by student guides, or staff in attendance, throughout the facility. This supervision is however not omnipresent, and there may be opportunity for these visitors to be unsupervised and, either accidentally, or deliberately, act in a way which may threaten the safety of themselves, other occupants, or the building and its contents.

New facilities to create new exhibition space and an interpretation space are almost complete which will also attract visitors to the building.

4.3 Configuration

The building is located on a steeply sloping site, and outside ground levels vary around the perimeter. For the purpose of this report the front of the building shall be identified as that elevation facing on to Renfrew Street.

For the purposes of this survey, the building has been divided into 10 levels, including the mezzanine/ gallery floors which are a feature of the building. The ten levels may be seen in plan form in Appendix A. The main entrance is on Level 4 and is accessed via steps up from Renfrew Street.

On each floor a central corridor runs from end to end, and most accommodation is accessed off that 'spine'. Vertical circulation is via three stairs, one at either end, and a grander main stair in the centre of the building which rises into the main gallery space.

Accommodation in the building ranges from small offices with low headroom to large studios and workshops with ceiling heights in excess of 8.5m. The largest of these studios have areas of 140m^2 approximately, and gross volumes in excess of 1000m^3.

The largest single area is the 'Museum' area (180m^2) located at First Floor level which also links with the Ground Floor Entrance Hall and current shop area, then down to the Basement level below, via the open central staircase which links all three levels/areas.

4.4 Construction

The building is a masonry shell surrounding a predominately timber frame. Most floors are wooden and when viewed from below are either open joisted, or 'protected' by lathe and plaster ceilings. In some of the larger areas the wooden structure has been supplemented with steel beams, and there are some areas where concrete slabs appear to have been utilised.

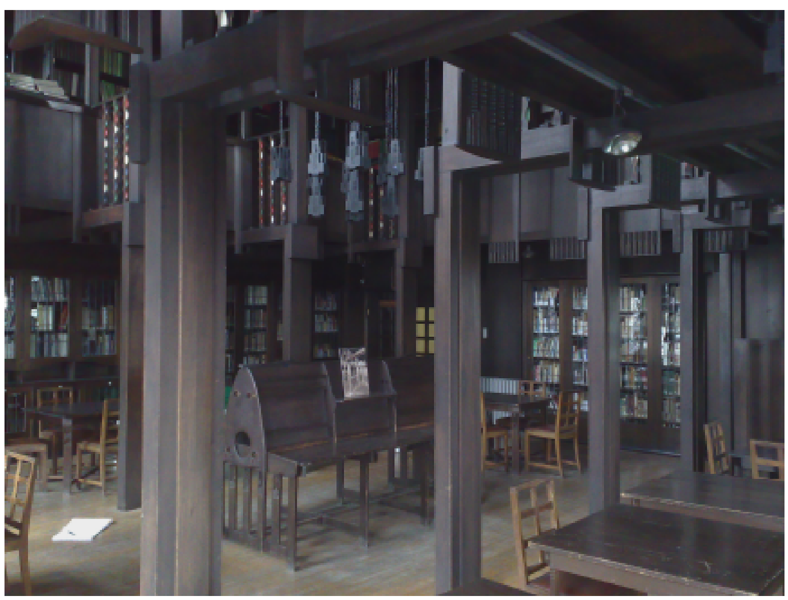
The solid areas of the roof consist of timber roof trusses with timber sarking and a slate finish. Other, studio and museum, areas have glazed roofs as may be seen in Fig. 1. Internal walls appear to be predominantly of masonry construction, as do the stair enclosures. The stairs themselves are concrete in the East and West enclosures and timber in the open central stair which connects the Basement to the First Floor 'Museum'.

Fig 1. - First Floor Museum

As noted above, timber is used extensively in the building as both structural element, and in the cladding of surfaces. Examples of the use of timber may be seen in the 'Museum' Fig.1 , the Lecture Theatre Fig.2 , and the Library Fig.3. Timber forms significant parts of the whole envelope in various areas. The Lecture Theatre, Library and Board room are three examples of this. Where this is the case, the construction of the room forms part of the fire load and its amount in location must be taken into account in protection method selected.

The building appears to be essentially uncompartmented in fire safety terms, with multiple voids (See 4.5) and penetrations of walls and floor/ceilings. Doors enclosing staircases, and separating sections of the building from one another, do not meet modern requirements for fire doors. Given the age and listed nature of the building, which makes it difficult to alter and upgrade, this is unsurprising.

Fig.2 (above) – Basement Lecture Theatre Fig.3 (below) – Mackintosh Library



The various enclosures within the building could not, with the possible exceptions of the new archive rooms, be considered to be airtight, or even low leakage envelopes. This will have implications with several of the protection methods under consideration.

4.5 Voids

Voids were noted throughout the building. The presence of voids creates both threats and opportunities in as much as the voids may promote rapid and potentially undetected spread of fire and smoke throughout the building, but also provide potential routes for the distribution of protection system equipment throughout the building. Differing types of voids were noted which will cause different challenges for different types of protection system. Major issues were 'stand off' voids noted in most, if not all, studios, and the horizontal and vertical building voids which form the historic services distribution route throughout the building.

4.5.1 Room 'Stand off' Voids

These may be found in various of the studios and working spaces where false walls have been created to provide sound, flat, working surfaces for students. These voids can be quite deep and provide a potentially shielded space in which fire may ignite and propagate. Most of these voids are, however, open at the top and thus offer a means by which suppressant may enter the void.

Fig.4 'Stand-off' void in studio.

4.5.2 Building Vertical & Horizontal Voids

Historically, the services distribution has been enabled using multiple horizontal and vertical voids throughout the building. Originating from the plant areas located at Lower Basement/ Basement levels and using the original horizontal heating duct which is located under the full length of the Basement Corridor, service ducts for piped and cabled services run along this void and thence up through the building in numerous vertical risers.

These risers were the original route for hot air, from the buildings hot pipe matrix room, which was driven through the Lower Basement horizontal duct and then up vertical risers for distribution on the various levels of the building. The vertical risers may be observed at each level on either side of the main corridor at regular intervals. No firestopping was observed in the extensive horizontal distribution duct at Lower Basement level which actually serves as a service corridor and acts as access to various plant spaces.

It was noted that these ducts have reasonable amounts of free space for the potential installation of any new fire protection services.

There is another large duct for horizontal distribution located in the floor void of the First Floor.

Evidence of the risers may also be seen in the numerous riser ducts located in the various studios. (See Section 4.8.2 Fig. 6)

The survey also noted the void underneath the sloping seating of the lecture theatre which will also require to be protected.

4.6 Services

Most mechanical and electrical services plant is located at Lower Basement and Basement Level, in the central section of the building, more or less underneath the Entrance Hall. Recent M&E upgrade works, including heating, have their central plant located in this vicinity.

Incoming electrical and water supplies are also located in this area.

This central location, at the centre of the distribution matrix of horizontal and vertical ducts and voids, and adjacent to incoming services, is the ideal place for such equipment.

Potential plant spaces for new protection plant have been identified in conjunction with Estates staff and Harley Haddow Consulting M&E Engineers. These are also all located in this central section of the building, again at Lower Basement, or Basement level.

4.7 Room Specific Risk (Load, Location and Other Factors)

The previous Buro Happold Fire Risk Assessment(1) of the building identified various issues and practices which could lead to the outbreak of fire in the building. Given that we cannot completely prevent the possibility of fire, given the risk removal/reduction constraints noted previously, we must consider what circumstances should be catered for. The selection of an appropriate fire protection system is then, initially, driven by the specifics of fire load and other influencing variables in each area.

In general, with the exception of the store area above the shop, (fire) load was not noted to be particularly dense. Offices were observed to have fairly normal office type loads. In the studios, though large in volume, load was located sparingly at low level, and combustible construction of the room itself was generally also at low level within the space.

Specific issues require addressing where rooms have combustibles at high level eg. Board Room, Library, corridors where timber as, or on, ceilings must be dealt with by particular types of application technology for certain of the systems.

Large air movement in specific areas may influence the function of certain systems. No such currents were noted in the building during the survey period, even with the large throughput of visitors passing through the building and consequent open doors.

It is unknown if the performance of the building and its services is such that occupants may open windows or vents to ventilate spaces. This was not observed during survey, but such occurrences could influence the selection of certain systems.

4.8 Aesthetics

Though not a functional criterion for the selection of a viable protection system, the aesthetics of the finished installation (and the aftermath of any works required in the installation process) are of major significance in an installation such as this.

In consideration of suitable protection systems for the building the aesthetic impact of any fire protection installation needs to be carefully considered. Datum for this was the existing aesthetic of the various spaces, and the intent for any new system is that it meets, or exceeds the level of aesthetic of those services currently installed and deemed visually acceptable by the Client and the current refurbishment Design Team.

The building was surveyed with this intent in mind, and as such the following specific observations were made.

4.8.1 Aesthetics – Studios

As noted at the beginning of this report, the building is a working art school, and large areas of the building must continue to function as such, with services to suit. Within the general studio and office spaces much of the services and general fittings can be seen to represent the development of such equipment and design over the life of the building.

These are utilitarian spaces and are, as a result, heavily serviced with respect to the rest of the building. Examples of the services installations in several of the studios are shown in Figs. 5 & 6.

Fig.5 – Typical heating installation pipework in the studio spaces.

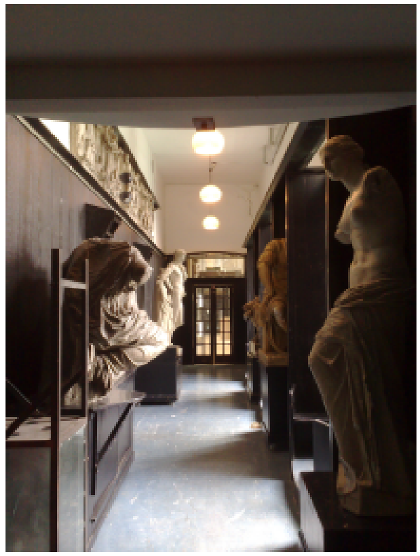
Fig.6 – Typical pipe riser in studios

Fig.7 – Typical services in Studio Areas

4.8.2 Aesthetics – Corridors/Stairs

As the major circulation routes through the building, the majority of the corridors currently have a level of visual impact which should be maintained. Figs.8 & 9 show the striking impact which these areas have visually.

Fig. 8 - First Floor Corridor East



Fig, 9 - First Floor Corridor West

As such, it is intended that any fire protection installations in the main circulation corridors on Ground, First and Second Floors be treated as areas of medium aesthetic impact and the new installation will be installed to suit, making use of the service risers and cornices/ledges in the corridors to hide the installation as much as is practicable. (Note the term – 'Medium' aesthetic impact is a relative one, and is only for comparison with the areas classified as 'high' aesthetic impact in Section 4.8.3

The same intent will be applied to the rest of the main circulation routes and, as such, all three staircases, the Entrance Hall and the Museum area would be classified in the same group and any installations in these areas applied in the same enhanced manner.

Also falling into this category are:-

- The Directors Room;
- Basement Lecture Theatre; &
- Directorate Secretaries Room.

The areas currently designated as being of medium aesthetic sensitivity are indicated on the plans in Appendix A.

All of the above classifications are obviously subject to Client and Conservation Architect approval, or input.

4.8.3 Aesthetically Sensitive Spaces

Certain of the rooms and areas stand out as being of especially high aesthetic importance, and works in these areas, for whatever fire protection system(s) were selected, should be subject to far greater levels of approval and oversight. The procedures for this should be written into the Tender Documentation.

Fig. 10 – The Mackintosh Library

The areas/rooms designated as being of high aesthetic sensitivity are:-

- The Mackintosh Room;
- The Board Room;
- The Library; &
- The Old Furniture Museum

The areas currently designated as being of high aesthetic sensitivity are also indicated on the plans in Appendix A.

All of the above classifications are subject to Client and Conservation Architect approval, or input.

Fig.11 - The Board Room

4.9 Potential Plant Locations

Potential plant space locations were identified at various locations in the building, but were generally limited in size, which has an influence on type of equipment which may be installed.

Many of the potential areas for plant installation have been utilised by the developing services requirement for the building.

After survey, discussions with Harley Haddow, and with GSA Estates staff, use of areas outwith the building envelope such as the roof, exterior and interior courtyards was discounted based on space limitations, loading restrictions and planning/historic approvals basis.

Use of existing accommodation has not been considered at this point. It is understood that the School is already operating with less usable accommodation than it would ideally like, and that all previous space which could be reasonably freed up for services installations has already been released.

Areas which may be suitable were identified in the Lower Basement/ Basement levels, in the vicinity of both incoming power and water supplies. The central location would also present an ideal position for distribution of services throughout the building.

The areas identified as being potentially suitable for plant are:-

- The Ex - Timber Store (Fig. 12) at Basement level underneath the entrance stairs on Renfrew Street;

- The front (Renfrew Street section) of the now redundant heating matrix room, also at Basement level; and
- A solum area at Lower Basement level to the rear of the building, located to the East of the new heating plant room.

All of the potential areas have limited space. Of the potential spaces, the largest footprint is that of the (Ex) Timber Store, at 22m^2, but access may be problematic, and equipment may have to be dismantled and reassembled in situ to make use of this space. Headroom is however quite good.

The heating matrix area has better access via the previous air intake/ filter area, but would have less area, and may involve more disruption of plant and equipment which is intended for retention. Headroom is believed to be reasonable.

Fig. 12 – Potential plant space location – Ex-Timber Store at Basement Level

The area to the rear of the building is very much third choice, being smaller again, with poor access and a requirement to dig out to achieve a potentially reasonable headroom.

The locations of the potential plant spaces are also indicated on the plans in Appendix A.

4.10 Fire Service/ Manual Fire Fighting

The local fire station is in quite close proximity, and attendance times anecdotally have been noted as good.

The building has a 24 hour staff presence that both monitors the recently upgraded automatic fire detection and alarm (AFD&A) system, and is trained in first aid fire fighting.

Anecdotal evidence exists of poor pressure and reliability of the water mains in the proximity of the Mackintosh Building.

5 Available Fire Protection Methods

As noted previously at 2.3, a risk reduction hierarchy has been applied to property protection in the Mackintosh building, and each level in the hierarchy has been considered in descending order.

5.1 Prevention/Elimination

– complete removal of risk - (eg Hypoxic Atmosphere)

The first step of this concept could not be applied as neither ignition sources nor combustible load can be wholly removed from the building. Such a situation can still be dealt with by, for example, oxygen depletion systems which use nitrogen to lower oxygen content of the air to a point where combustion cannot be sustained, or is very limited.

In this case the application of such technology is not possible due to several reasons, the main of which are the integrity of the enclosures, the plant area which would be required for equipment, and the nature of the activities in the building.

5.2 Substitution

– find a different way of doing – (Change Materials/ Change Conflicting Use of Building)

This option was precluded by the dual function nature of the building and the planning/listed status which would preclude many of the changes required to moderate existing problems inherent in the current building.

5.3 Isolation/Limitation

– dangerous areas segregated/valuable assets protected – (Compartmentation)

Compartmentation has been applied on a small scale in the construction of the archive rooms at Lower Basement/ Basement Level. This strategy option is ideally suited to small compartments where the client is prepared to accept total loss of that compartment, and fire damage can be confined to that area.

(Note. Considering the above the client should consider that suppression /protection systems should be extended into these areas, or at least have a risk assessment of the risk and potential consequences of fire both inside and outside the archive rooms unless total loss of the contents of that room is acceptable.)

Wholesale application of such a policy would however be virtually impossible given the current structure and the amount of compartmentation and firestopping which would be required. If funds were available to carry out these works, it is highly unlikely that permission could be obtained to carry them out given the buildings listed status.

Even if compartmentation were applied, the Client would have to consider total loss of some of the larger spaces as the accepted outcome of this type of strategy.

5.4 Protection/Suppression Methods

Having eliminated the more preferable strategies of risk reduction due to Mackintosh building/use limitations, it becomes necessary to accept that a fire could occur with potential to spread throughout the building. Various systems and strategies are available which, if appropriately applied will extinguish, control or suppress growing fires and moderate damage to the building and its contents.

Consideration of the various available systems in the context of the circumstances applying at the Mackintosh Building is shown in Table 1. The Table shows each potential solution and any limitations on its application which may be applied due to the building requirements noted in Section 3, or to constraints driven by survey of the building.

Agent	Chemical info.	Method of suppression	By-products produced in fire conditions	Comments
<u>Inert gases</u> **Inergen** Total flooding system. **Argonite**	 52% nitrogen 40% argon 8% carbon dioxide 50% nitrogen 50% argon	Inert gases – reduces available oxygen levels to inhibit combustion.	Inert.	Gases are components of air – no environmental impact. CO_2 is a combustion product from fire – adding it into the suppression gas makes nothing worse. High pressure system – consider need for over-pressure relief venting to the space. (Note – Tyco now claiming that room integrity not as important as previously thought – some leakage acceptable – claim to be substantiated.) Significant space needed for gas cylinder storage. Requires 2 distinct smoke detection systems – aspirating and another less sensitive option - for 'double knock'

				activation. Question ability to penetrate deep-seated burning. Maintenance – periodic room integrity testing by short term pressurisation with air may be advised. Would this affect the collection? By assessment, could integrity testing be dispensed with? Additional bank of cylinders will allow prompt re-instatement of cover following activation. Avoids extended down-time while cylinders are replaced. Cost. Pipeline distances may be limiting factors – additional cylinder banks may be necessary. REJECT DUE TO ENCLOSURE INTEGRITY, AMOUNT OF PLANT SPACE
Inert Gas **Carbon dioxide**	100% carbon dioxide	Reduces oxygen levels to inhibit combustion.	Inert	Generally as Inergen. Toxic to humans at concentrations involved. Not advised for occupied areas. REJECT DUE TO ENCLOSURE INTEGRITY, AMOUNT OF PLANT SPACE, TOXICITY
Chemical Gas	Heptafluoropropane CH_3CHFCF_3 Pressurised with	Chemical action and cooling.	Hydrogen fluoride (HF) CO_2, CO, H_2O	No ozone depletion potential. Atmospheric lifetime 30 – 40 years. Exposure in excess of design limits

FM 200 **FE 227** Total flooding system	nitrogen.			may cause cardiac sensitivisation in humans. Low pressure system – over-pressure of rooms less of an issue. Room integrity testing as for high pressure systems. Less gas storage space than high pressure systems, but still significant given volumes involved. Same 'double knock' detection systems as Inergen. Penetration of deep seated fires as Inergen. Expect FM200/FE 227 to be phased out in UK due to high atmospheric life and availability of alternatives such as NOVEC. REJECT DUE TO ENCLOSURE INTEGRITY, AMOUNT OF PLANT SPACE, HIGH ATMOSPHERIC LIFE
Chemical Gas **NOVEC 1230** **Sapphire** Total flooding system.	Dodecafluoro-2-methylpentan-3-one $CF_3CF_2C(O)CF(CF_3)_2$ Pressurised with nitrogen	Chemical action and cooling	Hydrogen fluoride (HF) CO_2, CO, H_2O	No ozone depletion potential. Atmospheric lifetime 3 – 5 days. Exposure in excess of design limits may cause cardiac sensitivisation in humans. Generally as FM 200. REJECT DUE TO ENCLOSURE INTEGRITY, AMOUNT OF PLANT SPACE.

Chemical Gas **FE 13** Total flooding system	Trifluoromethane CHF_3 (Pressurisation with nitrogen not necessary)	Chemical action and cooling	Hydrogen fluoride (HF) COF_2, CO	No ozone depletion potential. Atmospheric life 264 years. Generally as FM 200. REJECT DUE TO ENCLOSURE INTEGRITY, AMOUNT OF PLANT SPACE, HIGH ATMOSPHERIC LIFE
Chemical Gas **FE 25** Total flooding system	Pentafluoroethane CHF_2CH_3 Pressurised with nitrogen	Chemical action and cooling	Hydrogen fluoride (HF) COF_2	No ozone depletion potential. Atmospheric life 33 years. Generally as FM 200 REJECT DUE TO ENCLOSURE INTEGRITY, AMOUNT OF PLANT SPACE, HIGH ATMOSPHERIC LIFE
Sprinklers	Water	Cooling		Low cost of agent. Known technology. Drainage considerations to prevent excess water damage real or accidental/ malicious activation? Large storage tank and pumps required. Plant space? Likelihood of water supply directly from street main low given both doubts over its suitability and permissions required from utility supplier for direct connection. (PPP pump an option?) Large bore pipework required for distribution.

				Aesthetically more obtrusive than mist In fill options limited by potential poor pressure problems at site. If heat activated –significant fire development before operation compared to smoke detector activated systems. For smoke detector activated, see note on accidental activation. (Note potential for double knock pre- action system to prevent spurious activation.) High specification for pipework if reduction of risk of coloured water discharge to be avoided ('black water'). – Potential collateral damage. Potentially less effective than a gas system in penetrating deep seated fires. Penetration into stand off voids? REJECT DUE TO PLANT/PIPEWORK SPACE REQUIREMENT, POTENTIAL FOR SIGNIFICANT LOSS OF/DAMAGE TO CONTENTS , NEED FOR DRAINAGE AND PENETRATION DIFFICULTY
Water mist Total flooding or local directed	Water	Cooling, Radiant Heat Blocking,		Significantly less water used than for sprinklers. 10- 20% for HPWM typical Wetting of all room contents, not just

spray		Oxygen Depletion by Generation of Steam.		below discharge head. No established benchmark standards for performance of the design. Penetration as for a gas Plant space requirement lower than other options. Distribution pipework space requirements much smaller than sprinklers CONSIDER SUBJECT TO SATISFACTION WITH INSTALLER PROPOSAL ,REFERENCES AND TEST
No fixed systems Reliance on staff with extinguishers and fire service intervention	Water; CO_2 gas.	Cooling;		High risk of total loss if fire gets a good hold and response is delayed. Measures will be necessary to ensure brigade access 24/7. Property protection - Brigade may decline to enter and leave to burn (defensive fire fighting). Given issues with voids and lack of compartmentation, potential for considerable smoke contamination of whole building. Safety issue for manual fire fighting. Potential for much higher levels of water damage compared to a suppression system. Water damage and smoke staining

				probable in all areas adjacent to fire seat. May affect school operation for an extended period. REJECT DUE TO HIGH POTENTIAL PROPERTY LOSS, COLLATERAL DAMAGE AND FIRE-FIGHTER SAFETY ISSUES

Table 1 – Suppression/Protection Options

6 Water Mist

From the foregoing assessment exercise, only water mist seems potentially applicable given building/user/site constraints and conditions.

6.1.1 Water Mist Fire Suppression

Water mist (or water fog) suppression of fires is a relatively new technology, particularly if taken in the context of more traditional suppression measures such as fire sprinklers, and offers a seemingly attractive alternative to older methods of fire suppression such as automatic sprinklers, or manual hose suppression.

The method makes use of various physical mechanisms to control and suppress fires and, appropriately applied, offers an effective means of fire protection with much less consequent water damage than the other methods noted above.

A water mist system may, and can, extinguish fire extremely rapidly and efficiently. The technologies' main difference from traditional sprinkler systems is much smaller droplet sizes and a potentially significant reduction in amount of water used to extinguish a fire.

The extinguishing effect is mainly a function of a two part process:-

i) Heat absorption due to the high thermal transfer capacity of the fine water droplets; then

ii) Oxygen depletion.

In this way the system mimics two accepted means of fire suppression ie. i) sprinklers and ii) total flooding gaseous suppression systems. Other mechanisms may also beneficially affect the fire by surface cooling and/or by creating a barrier to radiant heat spread.

Depending on system design the following mechanisms may (inter)act to control, extinguish, or suppress the fire and prevent its spread:

- gas phase cooling, (heat extraction from the fire);
- reduced oxygen levels as water vapour displaces oxygen near the seat of the fire;
- radiant heat attenuation; &
- surface wetting of adjacent combustibles

There are various types of systems being marketed at present:- varying in pressure(high, medium and low); continuous / cycling application of mist; wet, dry, or pre action pipework; gas, or pump driven; thermal element nozzle, or discrete detection activated. At the low pressure end of the scale, the systems are much like traditional systems - real differentiation in the system characteristics may be seen most significantly with high pressure systems.

Each type and configuration of system will be dependent on the specific enclosures, and the defined protection objectives. In non standard buildings, water mist applications require to be fully engineered. If applied to the Mackintosh, the same high pressure water pumps may serve several different configurations of mist application, each tailored to the specifics of fire load and enclosure geometry for that area. Variations of nozzle positioning and actuation principle would for instance be based on location and amount of fire load, mounting positions for pipework and nozzles, detection time based on nozzle/detector location and ventilation conditions in room. Detail such as this would be defined as the next stage of the property protection exercise.

6.1.2 Advantages

Water mist technology has many apparent advantages over more traditional water based protection methods, the main being reduction in water damage after system activation. On the face of it this holds true as, in the same way as a sprinkler relies on far less water than a fire fighting hose, high pressure mist systems are claimed to use as much as 90% less water than traditional sprinklers, taken on the basis of water used per head for a similar spacing layout.

Due to the delivery process, and consequent fire extinction/suppression mechanism, the water distribution is different and has been analogised as acting partially like a gas, partially like sprinkler discharge. Even when large quantities are discharged, the wetting mechanism is different, with less penetration into surfaces, and more 'coating of surfaces'. This phenomena allows the pre-wetting of objects in proximity to, but currently, uninvolved in the fire, and introduces fine particles of water into the air where they may be evaporated to create steam and lower air oxygen content like a gas, whilst also creating a barrier to radiant heat spread.

Other apparent main advantages of mist systems are:-

- less plant and equipment space required (due to lower storage/flow requirements);
- smaller pipe bores (a benefit in retrofit and historic applications),
- though equipment is generally more expensive, reductions in size of equipment, particularly storage, may yield overall savings,
- nozzles and equipment can be more attractive than sprinkler alternatives,
- cleaner water than traditional sprinkler systems (stainless steel pipes).

6.1.3 Disadvantages

Water mist also has disadvantages. Some are related to the way in which the system works and the physical mechanisms relating to that; others to the fact that the technology, in widespread use, is quite new and there is a lack of:-

i) standards and guidance;

ii) research and testing; &

iii) experience in installation and use.

Aesthetically a mist system may be smaller, but may rely on more hangers and other supports which will impact more on historic structure.

In terms of the way the system works, mist systems were designed initially for smaller confined spaces such as ships cabins and machinery enclosures. As such the method transfers readily to small standardised rooms like prison cells and hotel rooms. It has also been successfully applied as a means of object protection where the nozzles protect and shield specific objects within rooms.

Use of mist in larger volumes with high ceilings such as the Museum and the larger studios was initially found to be problematic due to filling times and the loss of momentum from the nozzle spray. We note however that installers contacted during the course of the feasibility study have referred to applications and test approvals for similar large spaces. Independent reports from US users and experts in the field also support the validity of the application of the technology to such spaces as fully engineered solutions.

Automatic activation of systems in such a scenario can also be problematic due to response times. Where discrete zonal smoke detection is utilised as a means of activating the system, water may be discharged into wrong areas if the zone is not large enough to take account of smoke spread. This is particularly a problem where there is significant air movement within the space, but may be overcome by appropriate configuration and use of smoke/heat sensing elements. Conversely, larger zones may also mean that more water than is necessary is discharged into the space being protected.

Air movement which affects smoke spread, particularly in large volumes, may affect the mist droplets which do not have the same momentum or density as a sprinkler system droplet. Some mist protection systems have been installed in aircraft hangers but these are in effect object protection systems -nozzles are located at low level or in the floor, protecting the fuel load (planes) at that level, and not covering the upper levels where, rationally, it is considered there is little, or no, load and hence little, or no, risk. Water mist is not generally effective against small fires in proportionately larger volumes, or shielded fires until they grow larger and entrain the mist into the plume.

It is noted that high pressure mist protection of large volumes may be achieved. Buro Happold FEDRA have previously been involved in the satisfactory installation and acceptance of high pressure water mist suppression at Syddansk University in Denmark. In this case however type approval was not available and the acceptance process involved extensive full scale testing in the absence of accepted design codes, or standard tests for the technology in this application.

Water mist will be less effective for slow, smoky fires which do not have enough heat to create steam nor enough movement to entrain the mist into the plume. (It should be noted however that sprinkler systems are similarly ineffective against such fires due to delays in thermal activation). In this case the building detection system should detect the fire and, if appropriately trained, the 24hr staff presence should be able to deal with such a non flaming fire. If this is not the case, fire service attendance should be able to deal with this.

In terms of guidance, there is little available which allows an independent assessment of the technical merits of individual manufacturers systems in the same way that sprinkler and fire/smoke detection systems are laid out in BS EN 12845[(2)] and BS 5839 Part 1[(3)] respectively. Whilst NFPA 750[(4)] (US) and Draft EN 14972[(5)] (Europe) cover the principles of design, both refer back to manufacturers test results, and as such designs must be assessed through disclosure and understanding of the manufacturers tests for each nozzle. Some of the national testing agencies have approved water mist systems for use in certain types of occupancies, but again the listings are generally qualified, and must be considered in the context of manufacturers testing. As such the use of mist systems in large, or irregular spaces requires to be linked to and supported by suitable testing, or approvals. Specialist engineering knowledge of suppression systems will be required to properly assess a system.

Given the relative newness of the technology, and the limited number of installations in specialised and irregular spaces such as historic properties, finding suitably experienced contractors can also be a problem. The specialised nature of the equipment, and the above noted proprietary nature of systems, means that finding a choice of maintenance contractor may also be difficult.

6.2 Water Mist Precedent

High Pressure water mist systems have been installed at the following locations to protect historic buildings and contents.

- National Portrait Gallery, London , UK.
- Duchess Anna Amalia Library, Weimar, Germany
- La Scala Opera House, Milan, Italy
- National Gallery of Art, Washington, US
- Contemporary Art Museum MARCO, Vigo, Spain

7 Contractors, Costs & Tendering Issues

7.1 Potential Contractors

The relatively short history of water mist as a suppression technology, and the limited percentage of those mist installations in historic and heritage properties, means that there are not a great deal of suitably experienced contractors in the marketplace.

Two of the major names in water mist technology, Marioff and Tyco, were contacted for their views on application and feasibility of water mist within the Mackintosh Building. Both had meetings with FEDRA and discussed the potential project in outline. Both noted that final determination of viability and cost would be dependent on full survey of the building, but that they were not put off by the drawings and photos viewed at that stage.

Marioff attended site to get a feel for the scope of the potential project. They commented that, based on their short (3 hour) visit, the project was within realms of their successful experience in terms of aesthetics and installation difficulty.

Should it be decided to progress the project further, other suitable tenderers would be sought.

7.2 Budget Costs

Given the nature of the building and its unique construction and configuration, definitive costs may only be obtained after extensive surveying of the building during the tender period. The system required by the challenges presented will require to be fully engineered after survey. As such budget estimating based on drawings, or brief survey is likely to be inaccurate in terms of final cost.

Two potential tenderers with considerable experience in the fitting of mist systems in sensitive and difficult occupancies were contacted and floor plans of the building were discussed. One subsequently offered to visit site. Prompted on costs they noted an indicative cost of around £60/m^2 including pumps and tank. The tenderers also noted however that the exact layout and height of rooms would cause variations both up and down of this area rate, and that an exact price could only be confirmed based upon full building survey and knowledge of tender requirements.

Given previous experience with sprinklers in similar applications, this would offer a similar order of cost per unit area to that expected for a traditional sprinkler system, including tanks and pumps. Based on this, and assuming a building area of 7,000m^2, the indicative cost for the water mist installation itself (see below) would be around £420, 000.

It is stressed that this cost is indicative only, and will require to be confirmed after full building survey when the extent of the engineered system and the equipment required can be more completely quantified.

The above costs only cover the mist system itself. To this should be added builderswork, access equipment, protection works, mechanical and electrical services provision, supervision and fees.

7.3 Tender Issues

Given the fully engineered nature of the final design for the Mackintosh Building, tenderers should be made aware of the need to visit site, and fully survey to appreciate the requirements of the building and the specification. This should provide a greater level of cost certainty in the returns.

A separate bill, possibly including a provisional sum for ad-hoc builders attendance should be included for the necessary builderswork and making good which will be an integral part of this contract.

In order that the necessary aesthetic outcome is achieved in the previously noted sensitive areas, it may be prudent to allow for additional third party site supervision or ‘clerk of works’ services when these areas are having suppression installed.

Access equipment for work at height will be essential and, from previous experience, will constitute a major element of the works package. A provisional sum for protective works should also be included where works are taking place around historic and/or (in)valuable building elements, furniture and fittings.

Works will be required to connect to mechanical and electrical services. There may be some costs associated with upgrade of existing electrical supply as the pumps required for high pressure water mist systems have large electrical requirements.

Given the aesthetic requirements of the project in certain areas, the tenderers should be asked to offer up mock ups showing their proposed installation and standard of workmanship for at least two of the aesthetically highly sensitive areas.

Tenderers should also be made aware of level of oversight and approvals that will be required for works and final installation in the aesthetically sensitive areas.

Programme of installation would also need to be determined, and it is suggested that some indicative programmes are included within the tender documentation. It is noted however that the tenderers are unlikely to be able to advise more concrete timescales until after tender survey and determination of the extent of the works.

8 Conclusions

8.1 Conclusions

The configuration, use and condition of the existing Mackintosh Building means that all but one of the potential property fire protection options have been ruled out in terms of buildability, usability and fitness for purpose.

The remaining option is that of water mist. This is a relatively new technology, but offers advantages in terms of plant space (primarily), buildability and aesthetics. It also offers advantages in the way it suppresses fires over both sprinklers and suppressant gas.

A system for the Mackintosh building will have to be fully engineered and will require that the building is extensively surveyed prior to final costing. Up to that point viability cannot be guaranteed. Given the newness of the technology, and the building specific system required, there will require to be considerable technical evaluation of the proposals.

Due to the variation of conditions and challenges throughout the building, the system(s) installed may be a mixture of protection principles eg. object protection, local protection, zonal protection, total flooding. Total coverage, as would be the expected norm with sprinkler standards may not be achievable. This need not be viewed as a major deficiency however, as the way the water mist suppression/extinction mechanism operates, it will contain and envelope small fires, and works better as fires increase in size. As such small fires will be contained, and large fires should be put out. Also, in probability terms, it should be noted that this perceived 'partial coverage' is much preferable to no coverage, and will result in a positive change in the risk to the building and contents.

8.2 Next Steps

It is proposed that the following parties need to be involved in the clarification/confirmation of the proposals as follows. Initially:-

- Current technical Design Team + FEDRA, to confirm the content of the report in technical terms;

Then, either singly or together;

- Meeting or Correspondence on acceptability with Building Insurers;
- Present to GSA administrators and end users; &
- Meeting or Correspondence with Historic Scotland, planners and any other interested parties.

9 References

1. 024289 3809, GSA Mackintosh Building, Stage 1 – Fire Safety Assessment, May 2006, Buro Happold FEDRA, Glasgow,

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3. British Standards Institution, BS 5839-1: 2002, Fire detection and fire alarm system for buildings Part 1: Code of practice for system design, installation, commissioning and maintenance, British Standards Institution, London.

4. National Fire Protection Agency, NFPA 750: Standard on Water Mist Fire Protection Systems, 2006 Edition, National Fire Protection Agency, Quincy, Massachusetts, US.

5. CEN, Draft EN 14972. 2004. Fixed Firefighting Systems. Watermist systems. Design and installation. European Committee for Standardisation, Brussels.

10 Appendix A - Building Plans

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