the Glasgow School of Art

an Architectural Totality

Thesis Presented to
the University of Glasgow
for the Degree of
Doctor of Philosophy

George M Cairns RIBA ARIAS
February 1992

Synopsis

This Thesis presents a study of the Glasgow School of Art, based primarily upon study and analysis of the building's technology and spatial functionality, rather than of the visual attributes of the design. In so doing, the study analyses key factors relating to the School's origins, the means of its procurement and the likely contributions of parties other than Charles Rennie Mackintosh to the overall design process.

A 3-dimensional drawn study is presented which was prepared as an analytical tool in the study of the building's technology. The drawings also provide a record of the spatial assemblage of the School, the contrasts of openness and enclosure, the changes of scale and the interpenetration of spaces which cannot be presented either by photography or by 2-dimensional drawing. It presents views of the building which cannot be appreciated by observation, due to the nature of the surrounding developments.

In researching the origins of the building's functional requirements and of the means by which it was procured the writer has come upon documentation which has not, to his knowledge, been referred to in previous studies. This documentation records the requirements of British industry and the aims of the educational system which were to lead to the development of a substantial number of new Art Schools in Britain at the end of the nineteenth century. It also relates details of the means by which these developments were financed and presents information relating to the involvement of various members of the Glasgow architectural establishment with the Glasgow School of Art and with the competition for the design of the building.

The technical study is concentrated, primarily, upon the original system of warm air heating and mechanical ventilation, which was fully integrated into the design and construction of the building. This system was taken out of use in the 1920's and has, to a large extent, been ignored both in previous studies of the building and in the continuing existence of the major items of plant.

In relation to the design origins of the environmental system employed and to its technical performance, the writer has uncovered a substantial amount of documentation which has not previously been related to the architectural history of the design and which demonstrates the likely design input of John Keppie.

Study of the system shows it to be of major historical significance in relation to the development of environmental systems during the period 1890-1910. This significance has not been noted in the major work relating to the development of environmental design in relation to architecture.

It is hoped that this study, read in conjunction with earlier studies, will assist students of the building in reaching a greater understanding of the totality of the design.

Contents

Contents

Acknowledgements

I am indebted to my tutor, Professor Andrew MacMillan, to Tony Vogt of the Mackintosh School of Architecture and to Dr Bruno del Priore, for their guidance in the preparation of this study.

I would acknowledge the assistance of the following in tracing information and documentation: Mr Drew Perry, Neil McVicar, Peter Trowles, George Rawson and Colin Porteous of the Glasgow School of Art; John Hooson, formerly of Woods of Colchester; Dr S D Slater and Mrs A M Clackson of the Victoria Infirmary, Glasgow; Charles McKean of the Royal Incorporation of Architects in Scotland; R J Standley of Hoare Lea and Partners; John Tovey; Dr David Walker of Historic Buildings and Monuments Scotland; Dr J S Logan of the Royal Victoria Hospital, Belfast; Mr Jackson of Strathclyde Regional Council; Mr Richardson of the Fire Research Station; Fred Walker of the National Maritime Museum; William Ironside of the Scottish Maritime Museum; Mr Allan of the Hornel Gallery, Kirkcudbright; Mrs J C Hall of Birmingham General Hospital; Fran Shepherd, former librarian at DEGW Limited, London; Dr Frank Duffy; John Knowles of the Royal Institute of British Architects; I Flett and J B Ramage of the City of Dundee District Council; D Barrett, R M Burton, R A Garner and Mr Boniface of the British Library; R M Harvey of the Guildhall Library, London.

Campbell McIntyre provided assistance in measuring sections of the School, David Dumayne in assessing elements of the structure. Special thanks are due to Joe Kennedy for his invaluable help in tracing, measuring and appraising the original environmental systems installations and for assistance in formulating proposals for reinstatement of the system.

Finally, my thanks to my wife, Angela, for consistent encouragement and for assistance in word-processing this document.

Preface

This Thesis is intended to complement previous studies of the Glasgow School of Art, enlarging the body of knowledge relating to the building and contributing towards completion of a picture of the architectural totality of the School.

The writer is an architect who believes that excellence in architectural design can be achieved only through successful understanding of the full range of requirements of the client's brief and by the translation of these into a design which functions in terms of spatial provision and building technology, which is adaptable to change in these requirements over time and which provides a stimulating environment for the 'users' of the building, both internally and externally.

The Glasgow School of Art is such a building and much of the credit for its success must be attributed to the functional design of the spatial assemblage, to its adaptability throughout its lifespan and, also, to the application of building technology in the design. In earlier studies of the building these attributes have largely been over-shadowed by consideration of the visual attributes of the designs of Charles Rennie Mackintosh.

In recognising the importance of the architectural totality of the design, it becomes essential to consider the possible contribution of those other than Mackintosh to the design of the School. In previous studies of the School and of the works of Mackintosh, writers have promoted the diverse theories of Mackintosh as sole designer of the building[1], of John Honeyman as contributor to the plan development[2] and of the co-operation between Mackintosh and John Keppie in the design process.[3]

Similarly, scholars have supported both the theory of '....Mackintosh's willingness to absorb and utilise the new technologies of the time: central heating, electric light....'[4] and, conversely, the view that he had little or no interest in building technology.[5]

In researching the origins of the environmental systems design this Thesis investigates the likely design contributions of Mackintosh's associates.

This is not to denigrate Mackintosh as a designer, but to recognise the likely role of teamwork within the practice of Honeyman, Keppie and Mackintosh, whereby each contributed according to his experience in order to produce the most effective design solution.

It has been implied in previous studies that the Glasgow School of Art is not a building of its own time.[6] The quality of the building's design is not challenged by this Thesis, but the theory is investigated that it is a product of the society into which it was introduced, in terms of local architectural output, national education policy and the development of technology during the last decades of the nineteenth century.

The drawn study within this Thesis is intended to illustrate the spatial assemblage, the architectural detail and the building technology of the design in a manner and to a level of detail not previously demonstrated. This study will, hopefully, allow a fuller understanding of the building to those not privileged to have the unrestricted access afforded the writer.

The key sector of study of this Thesis is, however, the examination of the environmental systems of the building. The heating and ventilating systems of the School have been mentioned only briefly in previous studies of the building and, also, in the major historical study of the history of environmental design in architecture.[7]

This work sets out to examine the detail of the design and operation of the systems. More importantly, the Thesis aims to trace the origins of the technology employed in the design and to place the Glasgow School of Art in its rightful place within the context of the history of environmental engineering.

References

1 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p51.

2 Thomas Howarth, "Charles Rennie Mackintosh and the Modern Movement", Routledge and Kegan Paul, p79.

3 A Gomme and D Walker, "Architecture of Glasgow", Lund Humphries, p230.

4 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p51.

5 This view was expressed by Dr Frank Walker at the Charles Rennie Mackintosh Society's Conference, "Aspects of Genius", held in Glasgow in 1990, in response to the writer having questioned the Conference's concentration upon the visual designs of Mackintosh, to the exclusion of any consideration of technological innovation.

6 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p51.

7 Reyner Banham, "The Architecture of the Well-Tempered Environment", the Architectural Press.

Introduction

The Origins of the Thesis

This study was inspired by the writer's earlier Dissertation and Technical Study on the West Wing of the Glasgow School of Art[1], submitted to the Mackintosh School of Architecture in May 1988 and awarded the Haldane Fund Prize for Dissertation.

The Dissertation originated as a measured drawing study only, in the course of which the preparation of survey information required access to be gained to air ducts and plant rooms pertaining to the original plenum heating system. During these investigations it was noted that a considerable amount of the original heating and ventilating plant and installations remained, in near-perfect condition, despite the fact that the system had been unused since the 1920's.

Study of published documentation, readily available for public reference, revealed little information on these original environmental systems; being of only a general nature and not totally accurate. The writer's interest in the history of the system, in its likely performance in use and in the general technology of the School was such that the scope of the Dissertation was extended to include a technical study of the building.

Particular attention was paid to the environmental systems, describing, in detail, the construction and installation, analysing the likely performance by computer modelling and examining the possibility of reinstatement.

Comparative analysis showed the School's heating and ventilating systems to be of a similar type to those of the Royal Victoria Hospital, Belfast and of Frank Lloyd Wright's Larkin Building in Buffalo. These two buildings were cited by Reyner Banham, in his seminal work 'The Architecture of the Well-Tempered Environment', as being the key buildings in the history of environmental design at the turn of the century.[2]

In incorrectly dating the Glasgow School of Art[3] Banham had, however, failed to note that it pre-dated both the Royal Victoria Hospital and the Larkin Building. Detailed analysis of the systems of the other two buildings is presented in Banham's work, but there is only a general description of the School's installations, again not wholly accurate.

In contrast to the situation pertaining to the Glasgow School of Art, the environmental systems of both the Royal Victoria Hospital[4] and the Larkin Building[5] have been documented in sources other than Banham and the information relating to them can be verified accordingly.

The major conclusions of the Disseration were drawn from comparative study of the three buildings, based upon the survey and analysis of the School's installations and published information on the others.

Since it pre-dated both of the other buildings and had been constructed using similar technology, fully co-ordinated within a more complex spatial assemblage, the Glasgow School of Art was considered to rank as being of greater and, hitherto unrecognised, importance in the history of environmental technology than either the Larkin Building or the Royal Victoria Hospital.

Due to the lack of documentary information relating to the School's systems there was no presentation on the design origins of the School of Art's system made in the Dissertation.

Tracing the source of the design input to the Glasgow School of Art's environmental systems was to be the main research thrust of this Thesis and was to involve much fruitless investigation and a great deal of luck.

The Technology of the Building

Investigation undertaken in the preparation of this study was, for a long period, hampered by the lack of available references. Initial searches of major library databases and contact with central bodies responsible for the care and maintenance of public buildings failed to uncover any further information on the key buildings mentioned by Banham[6], or on the figure whom he mentions, with apparent significance but without bibliographic reference, as sharing home towns with the Glasgow School of Art; William Key.[7]

For many months the writer collated negative responses to requests for information from central bodies and institutions. Always the major question remained, which seemed likely to unlock the puzzle - Who was William Key?

Eventually the writer was to receive information, in indirect response to one enquiry[8], which was to illustrate clearly Key's contribution to the development of environmental systems design in the 1890's; a major patent approval granted to Key and a Robert Tindall for improvements to the design of heating and ventilating apparatus.[9]

There was to be a great deal more luck required, however, in leading the writer to the information which would demonstrate the practical application of Key and Tindall's designs.

Following the initial failure to trace information on key installations from the most likely sources the search for clues was widened. After enquiries of the Northern Ireland Health Board and Property Services Agency had led to the belief that there were no surviving records or installations relating to the Royal Victoria Hospital, Belfast worthy of investigation, the writer sent an enquiry about its environmental systems direct to the Hospital, addressing an archivist who may or may not exist.

After some time a response was received from a doctor at the Hospital.[10] This response was to lead the writer to a group of medical persons whose interest in the history of their establishments had inspired them to investigate and document rare archive material.

In studying the origins, sources of funding, design and operation of their respective institutions they had paid great attention to the development and application of environmental technology.

These amateur historians were to supply to the writer a substantial stock of contemporary papers; architectural and medical papers and newspapers; on the design of their respective establishments, relating the environmental systems design to the overall procurement and operational processes.[11]

This documentation provides a wide range of information on the development and implementation of environmental design during the second half of the nineteenth century and the first decade of the twentieth.

The initial batch of papers which were supplied, relating to the origins of the Belfast Victoria Infirmary's systems, as derived from the design of the Birmingham General Hospital, contained a misnomer relating to a Glasgow hospital which was considered relevant to the design evolution.[12] Identification of the correct hospital was to be one of the major steps in relating the Glasgow School of Art's environmental systems to other contemporary developments.[13]

Study of the total wealth of material supplied enables support to be established for the two theories which are central to the historical Thesis.

Firstly, it will be shown that the previous experience applied to the environmental system design of the Glasgow School of Art was likely to have been that of the architect John Keppie, partner in the practice of Honeyman and Keppie, in which C R Mackintosh was an employee at the time of the design competition for the School.

The second key theory relating to the environmental systems concerns the nature of the plant installed to the School within the original Phase 1 construction programme.

The major elements of the system design of the Glasgow School of Art are similar to those illustrated in Key and Tindall's previously unpublished patent[14]. This patent illustrates the first known description of the principles of true air-conditioning and pre-dates, by some 13 years, the American patents generally accepted as being fundamental to the introduction of air-conditioning.[15]

According to the Contract documentation for the heating and ventilating plant all of the key elements described in this patent were incorporated into the design of the School's systems, as installed in the first phase of construction in 1896-1897.[16]

The School in Context

The search for information relating to the Glasgow School of Art's building technology was to lead the writer, again by chance, to documentation relating to the origins of the building and to the education system into which it was to be implemented.[17] This documentation has not, to the writer's knowledge, been referred to in previous studies of the School.

The documents clarify the aims of the national art education curriculum in the 1890's, detail the means by which Art Schools were funded and, also, provide additional information on the relationship between the Glasgow School of Art and some of the notable members of the Glasgow architectural establishment.

Assessment of this documentation leads the writer to a view of the Glasgow School of Art as a building which is borne entirely of the nature of the society into which it was introduced.

The Drawn Study

In addition to the historical study, this Thesis develops the measured drawing study itself to cover the entire building, showing, as accurately as possible, the massing, spatial arrangements, technology and construction of the School as completed in 1909. These drawings show the building in a manner not possible with 2-dimensional drawing or photography.

The drawings were prepared in order to assist the technical study of the environmental systems and construction of the building and, along with these studies, are intended to complete the picture of a total architectural process, as outlined in the Preface to this study.

The starting point of the drawn study was the set of drawings, in Mackintosh's hand, numbered 1-10, completed in 1910, showing the School much as built. These drawings are not, however, fully accurate records of the building as completed. The main drawings from the set are reproduced, for reference, in Appendix 1.

These drawings, along with the handbook published by Glasgow School of Art[18], were of invaluable assistance in checking the originality of certain features and in showing the process of development of the design, from the initial drawings of 1896, through the redesign of 1907, to modification during construction.

Other than the set of 1/8":1'-0" plans, elevations and sections, which contain very few notes on construction and structure, there are few surviving records of the construction of the building. The author has been unable to trace any surviving record of large scale detail drawings used during the construction, other than the two 1/4":1'-0" part sections catalogued by Kimura[19] and the full size detail of the Library lights.[20]

Comparative study of the surviving drawings and of the building, as completed, indicates that the design was subject to many unrecorded detail alterations during construction.

The original Bills of Quantities for both phases of the development survive and are held by the Art School Library. These documents provide valuable records of the materials and construction of the School, including the environmental systems.[21]

The building has remained, throughout its life, first and foremost a working Art School, as a result of which it has been subjected to interior alterations to suit the needs of its users, the requirements of Building and Fire Regulations and the incorporation of updated systems technology. Only in recent years has a process been begun of reinstating some areas to their original character, whilst other changes continue to be implemented, not always sympathetically.

The services installations, notably the heating and lighting systems, have been subject to major alteration. As stated earlier, the original warm air heating system went out of use in the 1920's, being replaced by a steam radiator circulation system with pipework run insensitively through corridors and into the studio window recesses, with the loss of much original panelling.

This system was again modified in the 1970's, but the opportunity to reinstate some of the original features at this time was not taken.

Although Mackintosh's decorative light fittings remain as an integral part of some of the major spaces, such as the Library, the studio lighting has been changed several times to meet the needs of the users, in accordance with advances in lighting technology. The original system of moveable lights on travelling pulleys remains only in photographic records.[22]

Most of the changes made during the building's life have not been recorded in the form of before and after drawings, as a result of which certain areas of the building are drawn in detail from evidence of what remains elsewhere, or are left in outline only.

The difficulties of producing a 3-dimensional record of so complex a building, of which there are such limited records of its original construction, are shown in the errors of scale and detail to be found not only in the model housed in the School Library and in earlier 2-dimensional drawings, prepared for the Wiggins Teape measured drawings competition[23], but, also, in the most recent, computer-generated studies, prepared within the School.[24]

Summary Aims

The text of this Thesis, in conjunction with the drawings, analyses the physical assemblage and the technology of the Glasgow School of Art building, examines the means of its procurement, placing it in its historical context, and assesses the fulfilment of its function.

The drawn study presents the building in a manner not previously attempted which, when read in conjunction with currently available drawn and photographic records, will allow a greater understanding of the building to those not able to gain the necessary access.

Based upon the research work involved in preparation of the Thesis proposals are included within a Postscript to the study for further amendment to the School, where features which have been subject to earlier alteration might be reconstructed to a state nearer to the original, without loss of performance or with improvement where possible.

References

1 George Cairns, "The West Wing of the Glasgow School of Art", Dissertation and Technical Study held by the Mackintosh Library, Glasgow School of Art.

2 Reyner Banham, "The Architecture of the Well-Tempered Environment", the Architectural Press, pp75-92.

3 idem. p84.

4 see bibliography references to documentation in the Journal of the Royal Institute of British Architects and, also, to the writings of John Tovey.

5 Jack Quinan, "Frank Lloyd Wright's Larkin Building - Myth and Fact", MIT Press.

6 Initial enquiries revealed no relevant information on the Birmingham General Hospital and Royal Victoria Hospital, Belfast, mentioned by Banham, through either the local Health Boards or Property Services Agencies responsible for their operation and upkeep.

7 Banham mentions the name of William Key twice in his book, firstly in relation to the application of his plenum ventilation system at Birmingham General Hospital (p76) and, secondly, as sharing home towns with Mackintosh (p85). There is no bibliographic reference for the source of this information.

8 The writer initially failed to find any reference to Key in the computer databases of the British Library, the RIBA Library and the Mitchell Library, Glasgow. At a later date a researcher at the British Library responded to the writer, stating that a search of British Patent records had revealed several approved applications by a William Key, who, from the content of the documents, was assumed to be the Key referred to by Banham.

9 William Key and Robert Tindall, "Improvement in the Heating...and Ventilating School Houses", British Patent No19 900.

10 Dr J S Logan of the Royal Victoria Hospital staff.

11 As will be seen in the Bibliography of this Thesis, there is a substantial amount of documentation on the subject within the pages of the Journal of the Royal Institute of British Architects. None of this information was revealed by initial enquiries of the Institute librarian.

12 John Tovey, RIBAJ, October 1981, p8.
In an article on the Royal Victoria Infirmary, Belfast's environmental systems, Tovey refers to William Key's involvement with the systems of the Royal Infirmary Glasgow in 1889. There is no record of major works to the Royal Infirmary at this time.

13 In discussion with Dr David Walker, the writer was to be made aware that the major hospital development in Glasgow around 1890 was the construction of the new Victoria Infirmary.

14 William Key and Robert Tindall, "Improvement in the Heating...and Ventilating School Houses", British Patent No19 900.

15 Stuart Cramer, "Improvements in and Relating to Humidifying and Air Conditioning Apparatus", British Patent No 17 247

16 I M Scott, "Bills of Quantities for the Glasgow School of Art", held by the Mackintosh Library, Glasgow School of Art.

17 Report by a Deputation from the Glasgow School of Art on visits to 3 English Schools in March 1893, held by the Mitchell Library, Glasgow.
This document is not catalogued under title and was found by chance, bound along with a variety of other documents relating to Glasgow in general. These included the Glasgow Building Regulation Act, 1892, which the writer was consulting, relating to the technical study.

18 Glasgow School of Art, "Charles Rennie Mackintosh and Glasgow School of Art", Glasgow School of Art.

19 Hiroaki Kimura, "Charles Rennie Mackintosh Architectural Drawings Catalogue and Design Analytical Catalogue", PhD Thesis held by the Mackintosh Library, Glasgow School of Art.

20 The existence of this drawing was relayed to the writer by Tony Vogt of the Mackintosh School of Architecture, Glasgow School of Art.

21 I M Scott, "Bills of Quantities for the Glasgow School of Art", held by the Mackintosh Library, Glasgow School of Art.

22 Glasgow School of Art, "Charles Rennie Mackintosh and Glasgow School of Art", Glasgow School of Art, p51.

23 drawings held by the Mackintosh School of Architecture, Glasgow School of Art.

24 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, pp179-184.

List of Illustrations

Drawings

Diagrams

Chapter 1
The Drawn Study

Introduction

"It is impossible, by such limited means (photography and commentary), however, to capture the true spirit of the building. One cannot portray two-dimensionally the sweeping vistas, the ecstatic soaring lines....or the vast, airy space...."[1]

The writer has been privileged, in the course of this study, to be granted almost unlimited access to the Glasgow School of Art and has, therefore, been able to build up a picture of the building which is available to few others, within the necessary restrictions of a working School of Art. It is a picture of spatial complexity which cannot be taken in and comprehended in a single, or even a few visits to the School.

"It is difficult to obtain a comprehensive view of the building because of the awkward site, narrow streets and surrounding property, and the visual effect is different from each approach."[2]

Even the setting of the building places access restrictions upon the visitor and admirer, due to the nature of the site and of the surrounding developments.

In the preparation of this Thesis, the set of drawings were an essential analytical tool; aiding the study, analysis and understanding of the building's technology

Concept of the Drawn Study

As stated in the Introduction, the purpose of this Thesis, in terms of the drawn study, was to produce a series of three-dimensional drawings of the Glasgow School of Art, regarded by many as the finest architectural work of Charles Rennie Mackintosh. These drawings were to illustrate the massing, spatial articulation and architectural detail of the building, along with detail of the structure, construction and environmental systems configuration. The drawings then served as a major analytical tool in the study of the building technology.

The drawings are intended, when read in conjunction with the text of the Thesis, to complete the picture of the architectural totality of the Glasgow School of Art.

It was in the persuance of this aim that the choice of view point for the main drawings was made, showing views to the interior from the internal angles of the south facade. These views show the interior spatial composition related to the building form and to the structure and, additionally, enlarge upon the available visual record of the School

The north elevation to Renfrew Street and those to Dalhousie Street to the east and Scott Street to the west remain largely as built, other than two windows at the lower levels at Dalhousie Street. They are easily viewed from the surrounding streets and are well documented in drawings and photographs.

The south elevation is, however, to a large extent hidden from view by the cinema developments to the south on Sauchiehall Street and is not well recorded in its completed form.

It is apparent that the architect paid no less attention to the form and detail of this elevation than to the main facades, going through the same procedure of drawing refinement and alteration during construction.

Whereas the street frontages are constructed of ashlar masonry, the south facade is primarily finished with grey roughcast. The overall massing of the facade combines apparently casual changes of scale and form, carefully related to internal spaces and to requirements of the heating and ventilation systems, with precise symmetries of individual sections, such as the corridors, the Library tower and the imposing mass of the central section, housing the Museum.

These central sections to the south facade of the School, along with the internal angles containing the secondary stair towers, are no longer fully visible from the surrounding streets. The drawings accompanying this study record these views and enable the reader to establish the complete picture of the building's external form and composition.

The massing of disparate elements and the varied sizes and groupings of fenestration of the south facade are in contrast to the more formal, yet deliberately asymmetrical north elevation.

The material, forms and fenestration of the south facade relate more closely to Mackintosh's residential works, at Windyhill and Hill House, than to the other facades of the School or to his works for the Glasgow School Boards, showing more of the influences of Scottish baronial and vernacular architecture.

Some of these shared features, such as the misalignment of windows to suit interior function and the lapping of different planes, are put down to compulsiveness and a "conscious gaucheness" by Macleod in his commentary on Windyhill.[3] In this approach he draws comparisons with the work of English architects, such as Butterfield and Webb.

These features along with others, such as the towering roughcast gables perforated by small irregularly placed openings and the corbelled stonework of the stair towers are, however, characteristic of earlier Scottish architecture and would be known to Mackintosh, both from the works of McGibbon and Ross[4] and, also, from his own travels and sketching throughout Scotland.

As with the residential works, many of the details of the south facade can be related directly to those of the buildings of rural Scotland, in particular to those of the villages of Fife, such as Culross, on the Firth of Forth. Mackintosh knew this architecture well from his travels and it is likely that he would have visited Culross during his trip to Falkland in the 1890's, from which his sketches of the Palace survive.[5]

Even had he not visited Culross himself, Mackintosh would certainly have known it from the sketch books of his close friend Jessie King.[6]

The asymmetry of the total composition of the southern facade, although typical of the forms so much enjoyed by the English country house movement, is a reflection of the Scottish baronial precedent, giving external expression to functional planning of internal spaces, rather than of the Palladian symmetry of the English Renaissance.

In addition to illustrating the exterior form of the building, the measured drawings show the interior composition, the architectural detail and the structure and construction of the School.

The plan format of the building is apparently simple in its composition; the spaces disposed along the east-west axis of the site, with the primary distribution of north-lit studios to one side of a central corridor and support spaces to the other. The E-shaped plan permits daylight to penetrate the central spaces at the upper levels, whilst the use of roof lights to the lower levels, within the recesses, provides natural light where the building abutts a mutual boundary to the south.

Sections taken through the building at the main corridor locations also indicate an apparent simplicity of form, with the high studio spaces stacked up against the circulation and services zone. The main corridors have major air distribution ducts for the heating and ventilating system located above and below, along with some additional, small studio spaces, to make up the sectional height.

The original sectional drawings to the central area[7], through the Museum, and to the secondary stairs indicate more of the changes of scale between spaces, but they do not convey the extent of these changes and the manner in which they might be appreciated in the course of movement through the building.

It is only in 3-dimensional format that the true complexity of the spatial composition and the integration of the services can be demonstrated, along with the changes of scale and enclosure which contribute so much to the character of the building.

It must be noted, however, that these changes of scale and the appreciation of movement through the nature of the enclosure of the spaces are primarily demonstrated in the second phase of construction; in the West Wing and in the additions to the East Wing.

Other than in the spatial sequence of Entrance hall to Main Stair to the Museum, there is little continuity of space to be appreciated in the first phase of construction. The addition of the two secondary stairs, with their intermediate landings, along with the construction of the Loggia and the Pavilion, during the second phase of construction, has provided the majority of the changes of scale and enclosure which are, together with the magnificent Library interiors, the major contributors to the spatial experience to be appreciated within the Glasgow School of Art.

The Library, which must be considered the most significant individual space in terms of quality of space and light, bears little resemblance in its final format as constructed to that conceived by Mackintosh in his original design and illustrated in his competition-winning drawings[8], such is the degree of change in external form and fenestration.

The view must be expressed that, had the funds been available to enable the School to be completed in a single phase of construction, the end result might well have been a building of only minor, local interest, lacking the complexity of spatial composition and relationships which are central to its standing as an architectural masterpiece.

The architectural form of the School, as appreciated worldwide to this day, must be seen to derive from the application of experience gained and the confidence achieved by Mackintosh in the execution of his other major works during the 10 years which intervened between production of the initial design and commencement of the second phase of construction.

Layout Drawings

The drawings illustrate the manner in which the forms of the various spaces and the fenestration are related to one another, to the fall of the site and to the location of the south facade on a mutual boundary.

The drawings of the south facade illustrate the relationship of building to boundary, which was of considerable importance to the nature of the composition of the south facade. The facade contains a large number of windows, which would not be permissible to a mutual boundary under current legislation. This may be considered as implying that there was no similar limitation on development at that time.

Contemporary documentation shows, however, that the location of the fenestration was influenced by the views of the building's insurers and that it was, also, at their insistence that the large parapet walls to the lower levels were included in the final design. This was done to ensure separation of the rooflights to the basement studios from the roof of the adjacent Hippodrome building.[9]

Although the south facade is now devoid of openings below ground floor level it was noted that there was originally an opening to the basement level of the Janitor's house, facing onto the waste ground adjacent Dalhousie Street, as indicated on the measured drawings. This can be discerned from early photographs[10], but is not shown on any original drawings and no longer exists; the cinema development to the south now abutting the facade.

Mackintosh's drawings indicated that windows were to be included in the south wall of the Stone Carving room, situated within the basement of the Library tower. These were, however, removed from the design prior to execution, at the insistence of the building's insurers.[11]

The overall massing of the building, as viewed from the south, shows how the addition of the second floor studio space and the new stair to the East Wing was achieved during the second phase of construction. Particularly noteworthy is the ingenuity of the Pavilion construction, cantilevered from the wall head of the south facade in order to by-pass the existing major spaces of the Museum and Director's Studio. The link between East and West Wings is established without disruption to the existing spaces.

To the East Wing of the School, the drawings illustrate the manner in which the addition of the secondary stair was achieved relative to the existing spaces, in particular to the original Board Room (shown under its later designation, Design Room).

It is interesting to note the contrast in design between the two secondary stair towers, the east stair being quite literal in its interpretation of Scottish baronial architecture and having varied fenestration, whereas the west stair is stark and simple; a box construction with repetitive fenestration punched through it.

The fenestration of the east stair may be seen to derive from the relationship of this addition to the west windows of the original Board Room, across which it was constructed. It is interesting to note Mackintosh's repetition of the detail of the intersection of the stair with the existing windows in the new fenestration of the external stair wall opposite, with the stair flights running across the face of the windows.

It has been suggested to the writer, by one of the advisors for this study, that the east stair might be the work of someone other than Mackintosh, because of its totally alien character in relation to the remainder of the building. There are, however, no indications of any hand other than Mackintosh's in any known drawings of the building nor in any of his works as executed.

The stair was, however, a late addition to the construction of the East Wing. The surviving south elevation drawing dated 1907 shows the stair overdrawn onto the facade in a simplistic fashion. The final, constructed form is first shown in drawn format on the as-built elevation dated 1910.[12]

Final confirmation of the instruction to incorporate the stair into the design came after the committee meeting of 6 May 1908, when a unanimous decision was taken to proceed with its construction, despite reservations expressed at the previous week's meeting over the likely effect upon the level of daylighting to the Board Room.[13]

The late addition of such an important intervention into the composition of the plan and facade, at a time when Mackintosh must have been fully preoccupied with the completion of the major spaces of the West Wing, may have resulted in a lower level of effort being expended upon its design than might otherwise have been expected.

Certainly the metalwork to the head of this stair, executed at the same time as that to the west stair, shows less attention to detail and is less satisfactory, both from a visual and from a structural point of view, having required a later addition of lateral bracing at its head.

The scale of the fenestration to the east stair, in comparison to that of the west stair, may be related directly to the concerns of the Board over lighting levels to the existing Board Room.[14] No similar situation required attention at the west stair.

Within the centre section of the School the most complex spatial composition of the phase 1 construction is demonstrated; the relationship of the main entrance from Renfrew Street to the enclosure of the Entrance Hall and the opening out of the stairway approach to the central public area, the Museum, and to the principal private space, the Director's Office.

The smallness of the main entrance doors, at the head of such a magnificent approach staircase, is cited by Leon Krier as being a major flaw in the design, 'demeaning the act of entry into the building'.[15]

It should be noted, however, that the external doors are located on the exposed, north-facing facade of a high occupancy building in a climate not noted for moderation of wind and rain. The size of the doors, themselves, is eminently practical and reading of the central north facade; the doors, the surrounding walls and the main approach stair; shows a visual composition in total balance with the remainder of the facade.

Below the Entrance Hall are situated the main plant rooms of the original heating system, which will be discussed later in this study.

The southern bay of the central section, below the Museum, accommodates a variety of support spaces, ranging from staff dining facilities to cleaners' rooms. These are centrally located for ease of access and yet are unobtrusive and not immediately noticeable to the visitor.

To the West Wing the drawings indicate the structure, construction and composition of the Library tower in particular detail. This section is widely regarded as Mackintosh's masterpiece and the drawings show the relationships of the internal spaces to the composition of the external facades.

The large vertical windows to the west and south Library tower elevations, which are major elements in the magnificent exterior composition, are shown in relation to the internal spaces, whereby their projection up through the School Store space, related to the form of the Library Gallery, produces the spectacular internal spatial effect. The deeply recessed windows, rising up through the Store, produce a high level of natural lighting to the Library whilst restricting the amount of direct sunlight from the south and the loss of usable wall space to fenestration.

The windows to the south facade of the Library demonstrate great ingenuity in the repetition of the bay form employed on the west facade, recessed in order to remain within the limits of the site boundary.

The internal views onto the north facade show how the rooflights to the projecting basement studios, below the level of Renfrew Street, are surmounted by the huge north-light windows and rooflights to the main studios, required by Francis Newbery's design brief.[16] These are shown in relation both to the studio spaces themselves and to the second floor, added in the second phase of construction. This floor is set back so as to remain invisible from Renfrew Street and, also, to remain clear of the rooflights to the studios below.

The relationship of circulation, ancillary spaces and main air ducts for the heating system to the major working spaces and to the stairs demonstrates how the architect integrated these spaces and the services within the height of the main studios. The changes of scale and enclosure between these spaces are fully exploited in the provision of interesting views onto the corridors from the intermediate levels of the stairs

These views have, unfortunately, been interrupted by the later addition of fire screens and doors, separating the stairs and corridors.

In order to show clearly the spatial relationships, main structure and architectural detail of the building on the layout drawings the vertical branch ducts for the warm air supply and air-extract are not shown. The location of these ducts, within the main walls and spaces, is indicated on the drawings in Chapter 5.

Detail Drawings

The large scale drawings show details of the circulation areas which could not be adequately represented on the main drawings and which are of significance both for their architectural detail and for their spatial quality.

The detail of the first floor corridor shows how Mackintosh made use of the width projected up from the main ground floor corridors to provide casual and intimate seating areas within a communal space, with niches between for display of items from the School's sculpture collection. The detailing of the canopy over provides a reduction in the apparent height, to suit the intimacy of the spaces, whilst allowing light to percolate through from the full-height windows to the corridor beyond.

An open view along the corridor is provided from the intermediate landing to the stair, which originally gave access to the Library Gallery.

The metal work to the head of the west stair, shown in detail, provided the necessary balustrading for safety, where the window pattern alteration required by the projection of the Conservatory would not permit daylighting to the lower flight had the central wall continued up. The omission of the central wall itself, which is not required for load-bearing purposes above the top flight, also reduces the weight of the structure and the loading to the lower levels. The detailing of this metalwork, apparently highly decorative, provides great rigidity by the nature of its form, particularly in the use of the hoop around the lower main posts to provide a three-point fixing.

The metalwork of the east stair is drawn in similar detail, indicating not only the repetition of major detail but, also, the weaker visual and structural composition of the design.

The detail drawing of the intermediate level of the east stair, adjacent the original Board Room windows, shows again the repetition of details employed in the west stair to the landing balustrades and to the spine wall.

Although the exterior composition of the east stair shows less originality than the remainder of the building, the internal detail and, in particular, the attention to detail and the quality of workmanship in the casting of the stair flights across the face of the windows is worthy of note.

Further architectural details are shown in photographic and sketch format in Appendix 11.

Drawings Numbers 1A and 1B

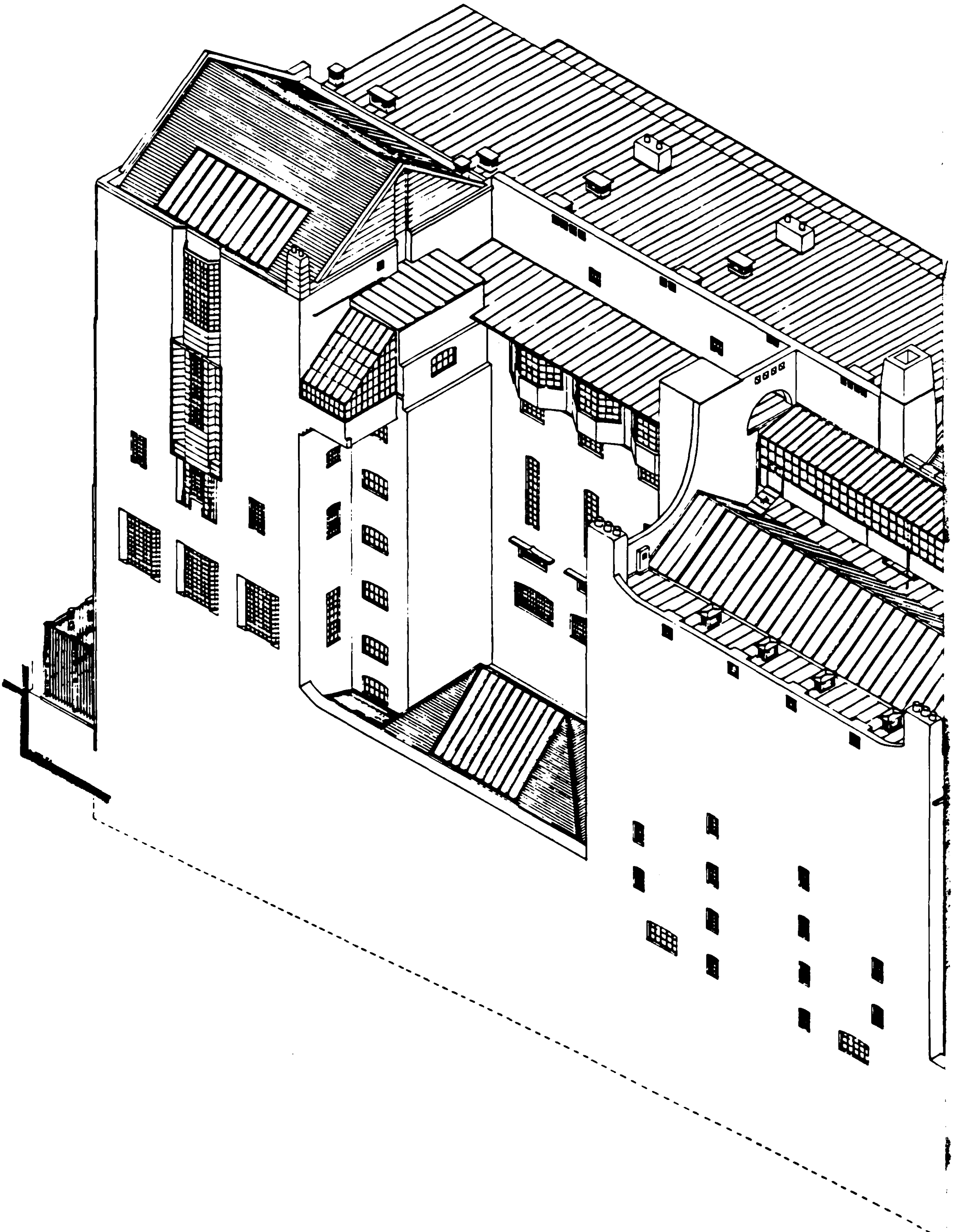
These drawings show the entire building, viewed from the south-east, enabling the overall form and massing to be appreciated.

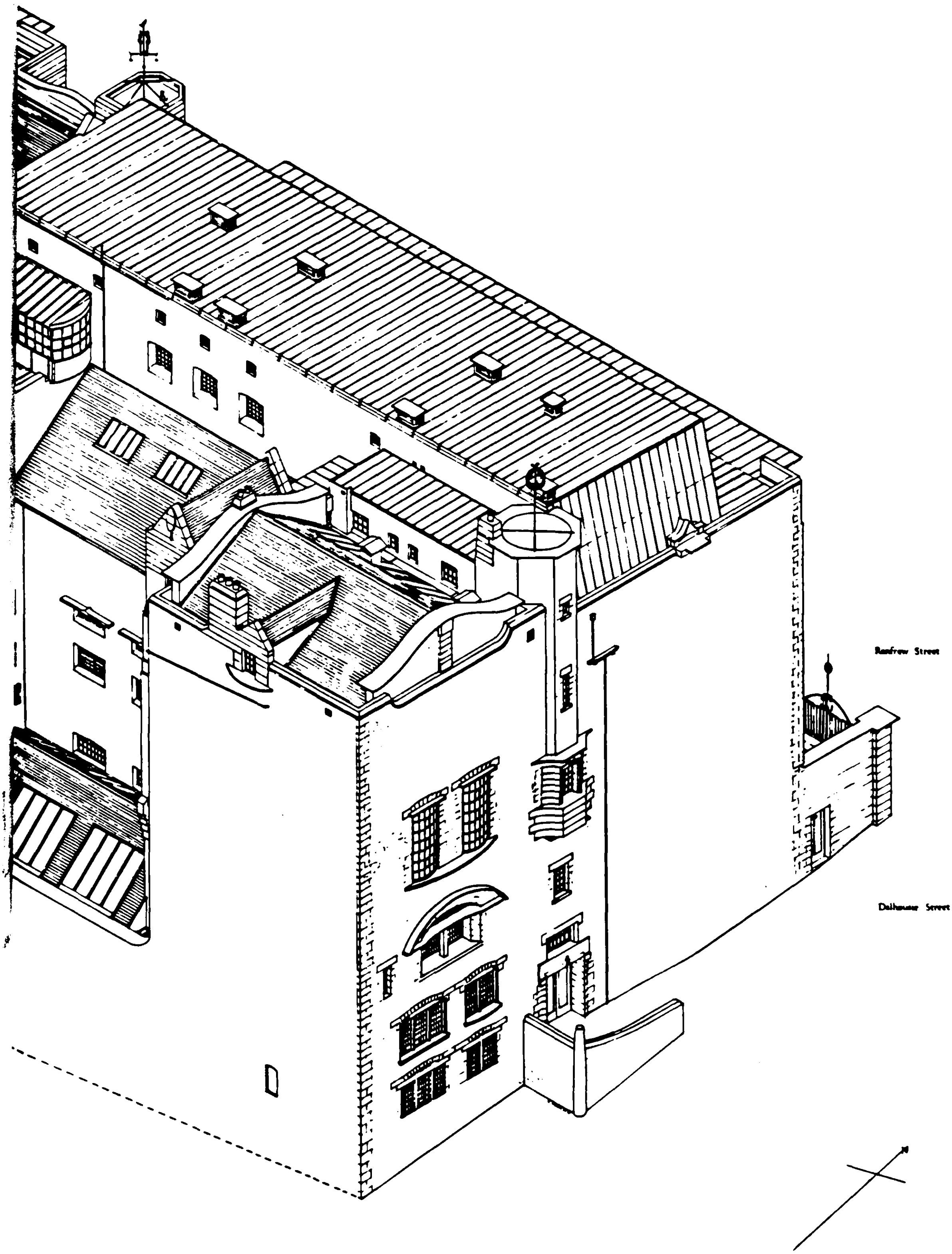
These drawings form the key external reference for location of the sectional drawings which follow.

The E-plan format of the School is clearly illustrated, along with the overall form of the south facades. The relationship of the Loggia and Pavilion to each other and to the remainder of the building is clearly shown, indicating the circulation link from East to West Wing, established during the second phase of construction without affecting the existing roofs to the Museum and Director's Studio.

The form of the main facade at the lower levels should be compared with that indicated on the computer drawings included in the book 'Mackintosh's Masterwork - The Glasgow School of Art'.[17] The reality of the strength and coherence of the form, along with the subtlety of the curves to the lower sections, is truly remarkable.

It is a sad truth that, with the continuing rise in inner city land values, this magnificent composition is unlikely ever to be made visible in reality.





the
Glasgow School
of
Art

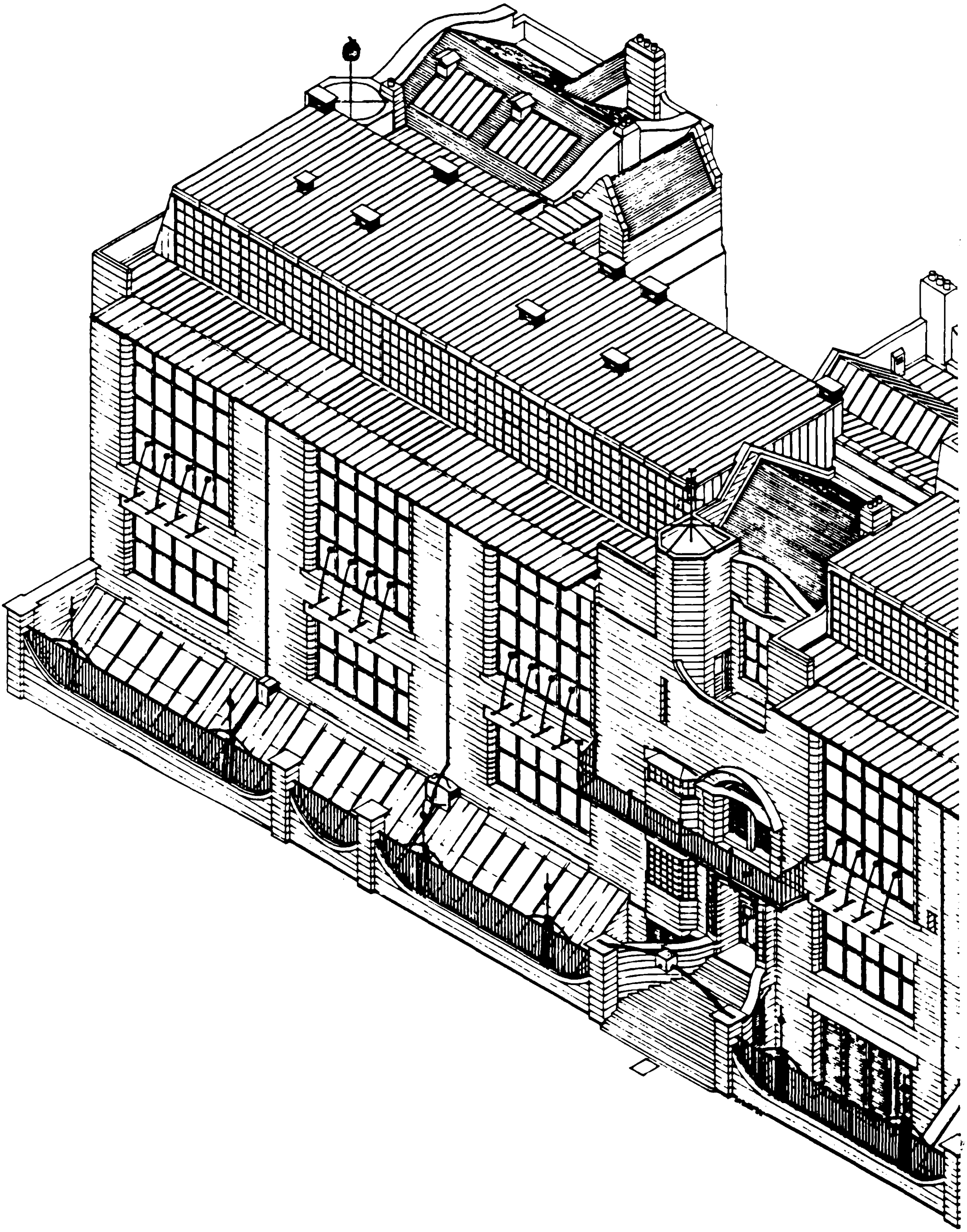
Drawings Numbers 2A and 2B

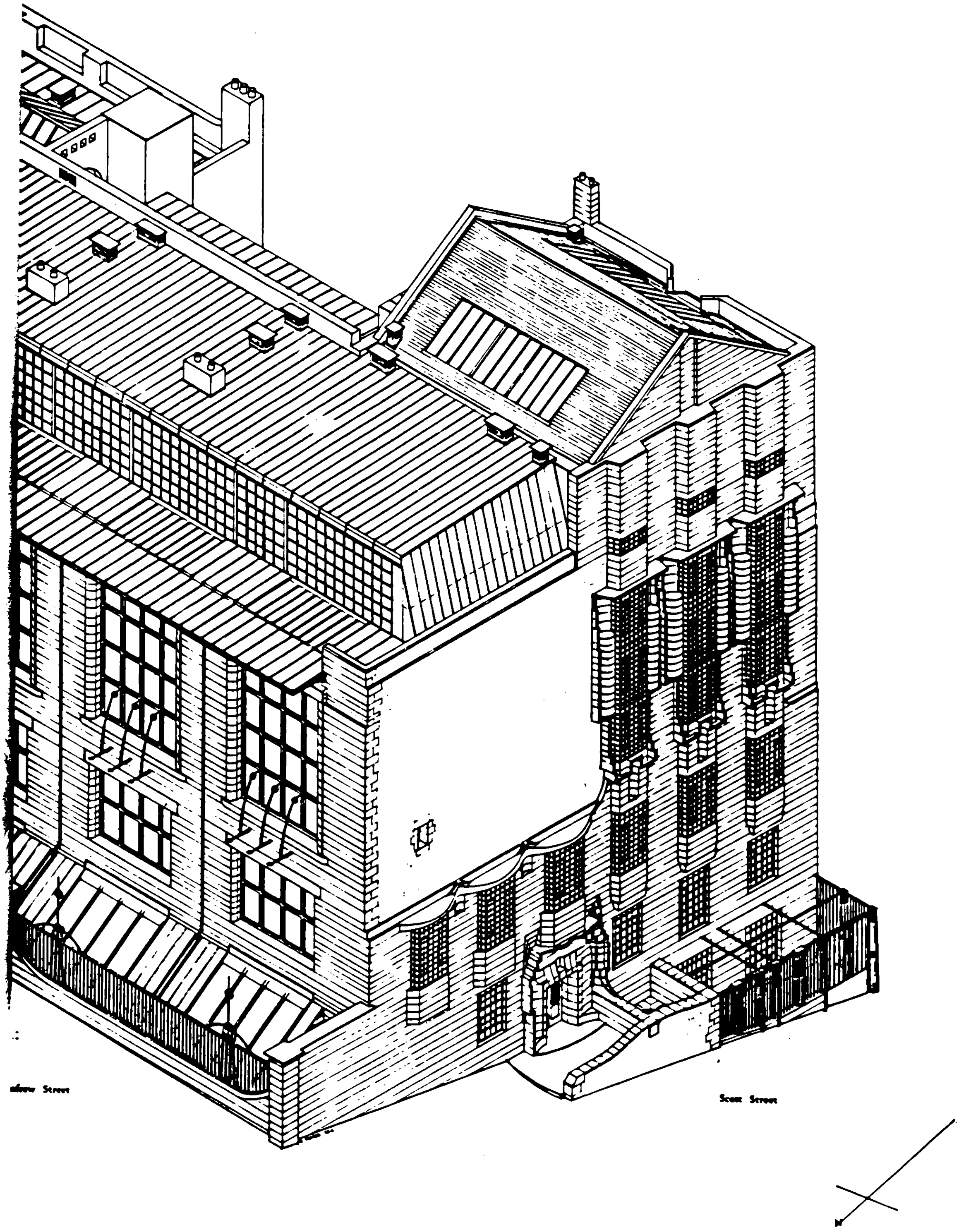
The viewpoint for these drawings is taken from the opposite direction to that of the previous set, from the north-west, completing the exterior view of the building.

The views shown are the most readily accessible from the surrounding streets and are the most frequently illustrated, including as they do the west facade to the Library.

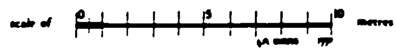
Of particular note is the relationship of the set-back second floors to the East and West Wings. Added during the second phase of construction, these floors rise above the centre section of the building, completed during the first phase.

The overhang of the eaves to the original roof line of the Wings does, however, conceal the top floors from view from most angles at street level. This construction maintains an illusion that the centre section, including the main entrance and the Director's rooms, is, in fact, the highest section of the composition.





the
Glasgow School
of
Art



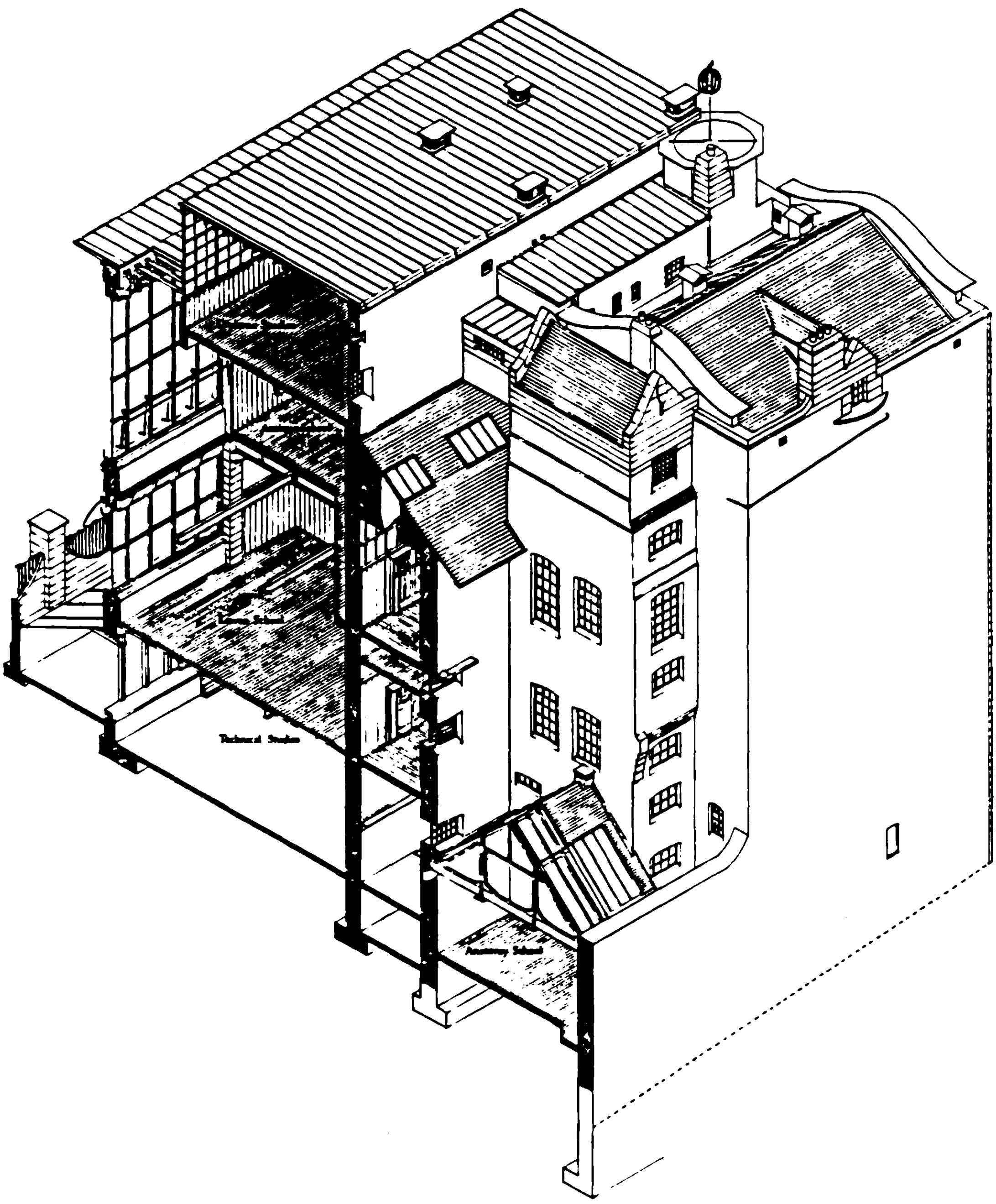
Drawings Nos 3, 4 and 5

This group of drawings shows the internal form of the East Wing of the School.

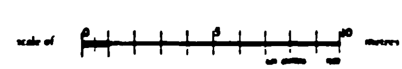
The original construction of this Wing, in 1897-1899, excluded both the second floor studio space and the stair tower. A pitched roof, similar to that shown on the previous drawings of the central section, continued along the full length of the Wing.

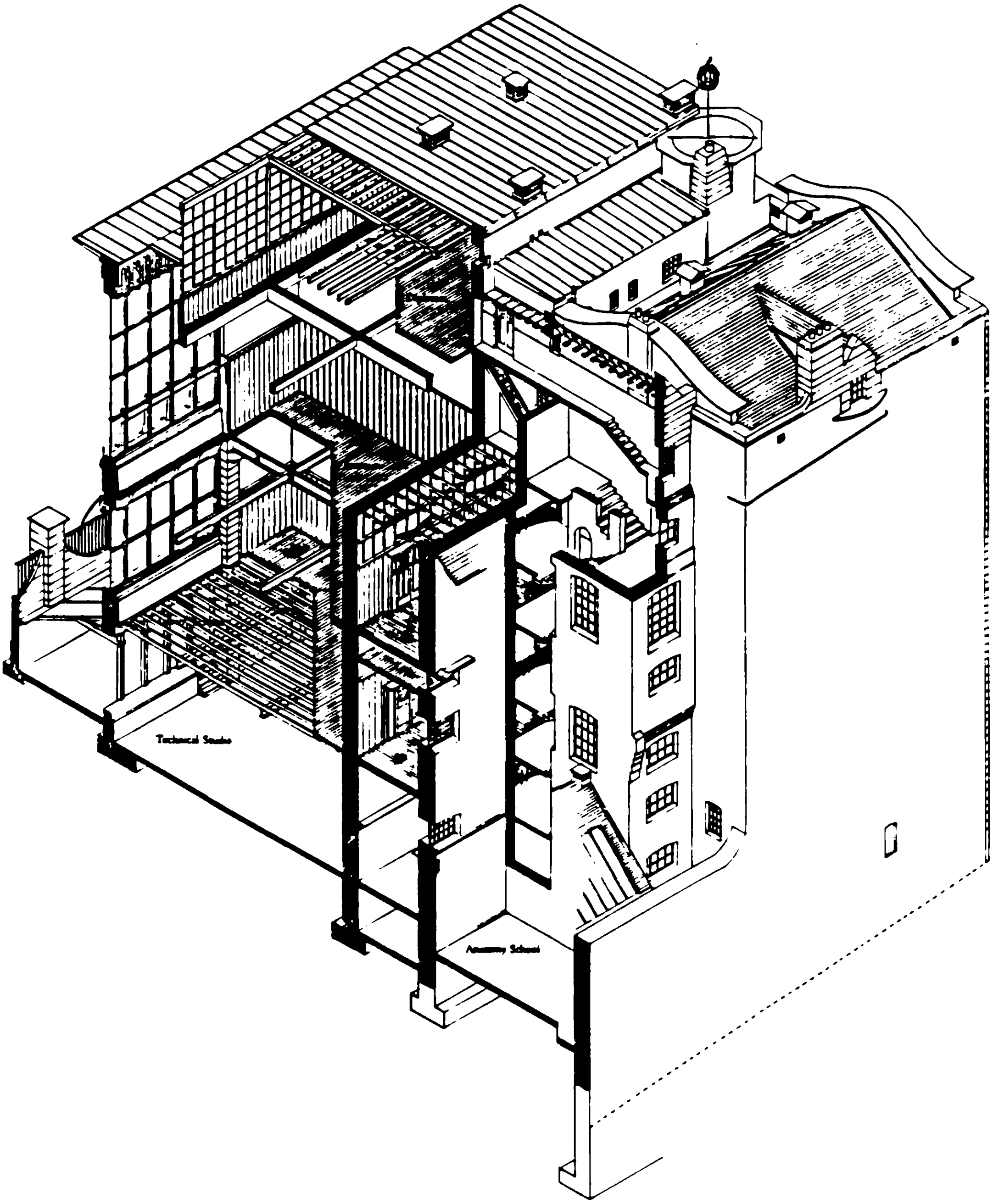
The space designated Design Room on these drawings, in accordance with the convention adopted from the plan drawings of the completed building, dated 1910, is the original Board Room.

The detail of the East Wing today remains much as it was at completion of the construction, including the exposed, fabricated girders to the main floor structure. These may be compared with the beams to the West Wing, encased in lathe and render during the original construction.

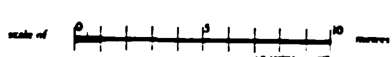


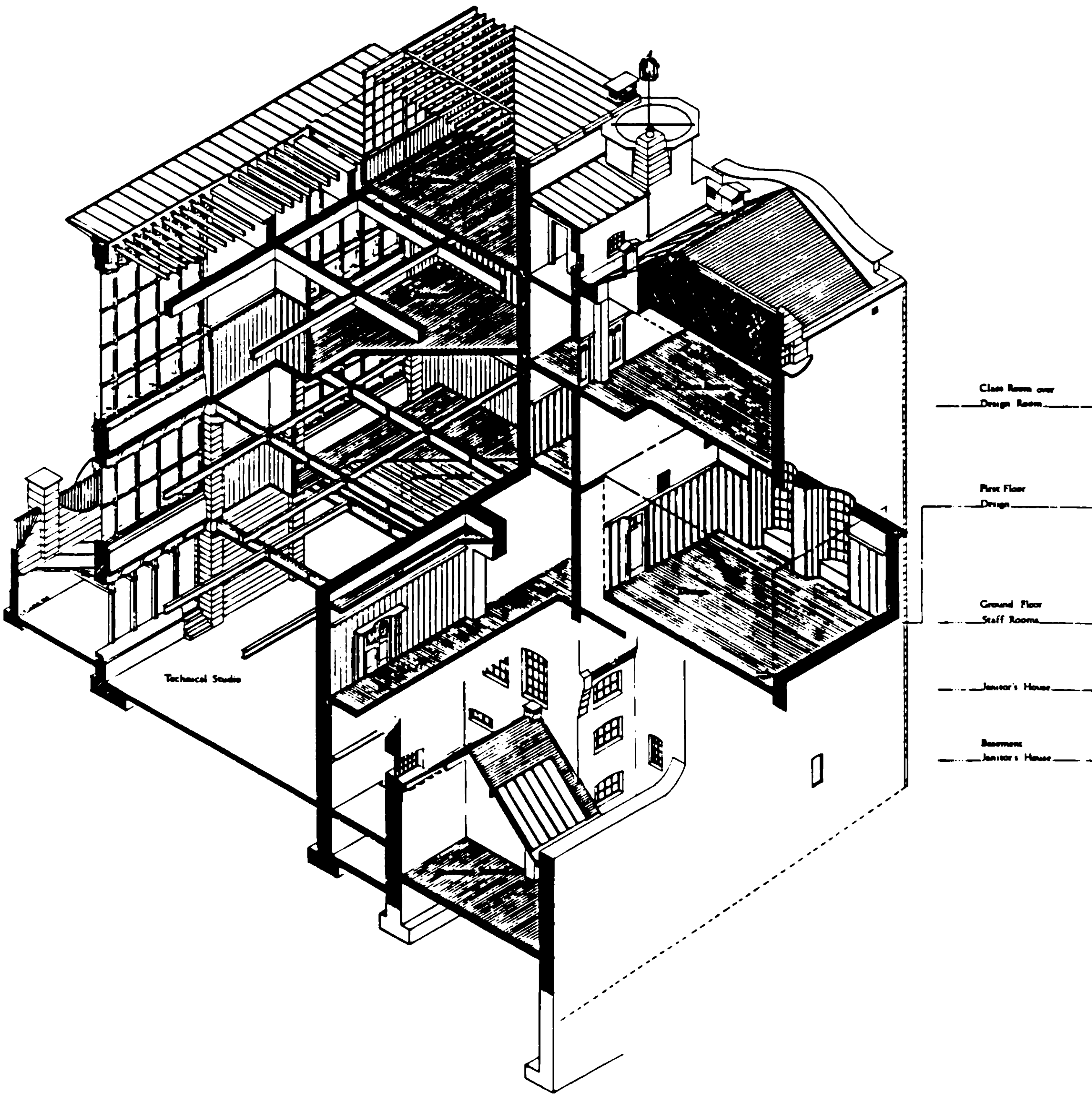
the
Glasgow School
of
Art





the
Glasgow School
of
Art





the
Glasgow School
of
Art

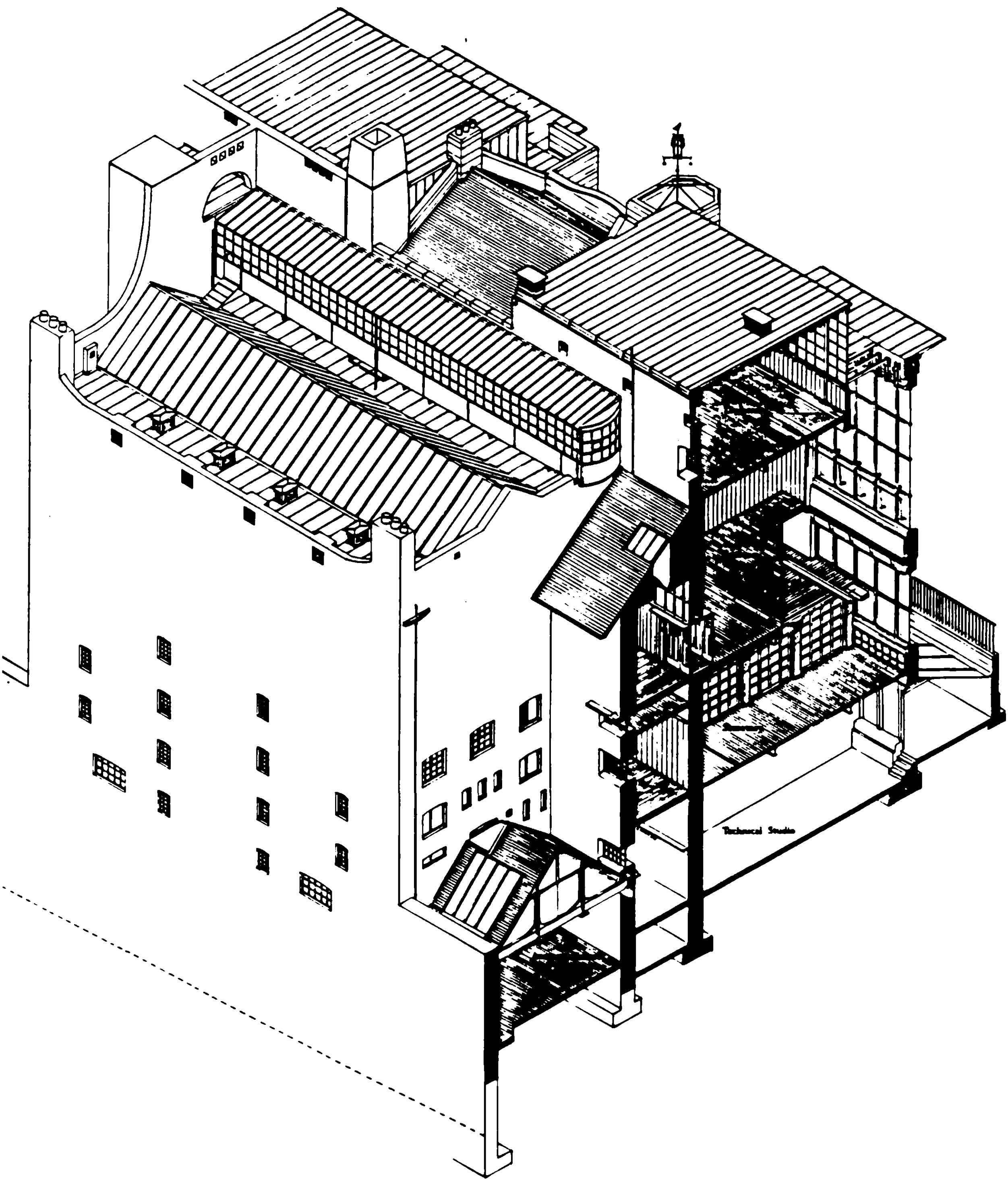
Drawings Nos 6, 7 and 8

These drawings illustrate the centre section of the School, containing the entrance, main stair and Museum, along with the principal administration offices and the plant rooms which served the entire building.

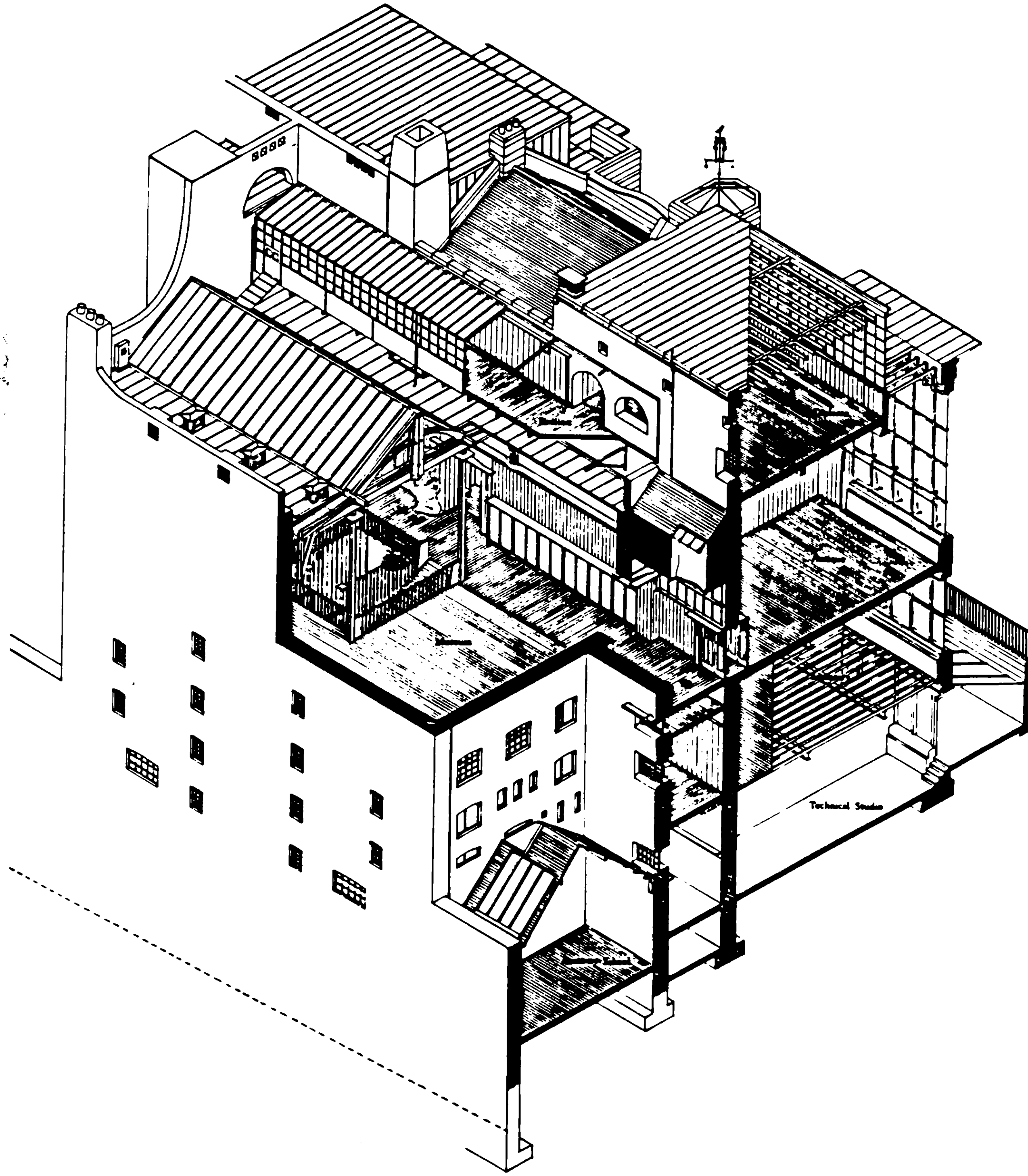
The stack of support spaces, to the south of the main stair, is worthy of note. These are centrally located, readily accessible, and yet are unobtrusive from within the building.

The structure of the Pavilion (or Hen Run) should be noted; cantilevered from the face of the main load-bearing wall during the second phase of construction, in order to link the second floors of the East and West Wings, without disruption to either the Museum rooflights or to the pitched roof over the Director's Studio.

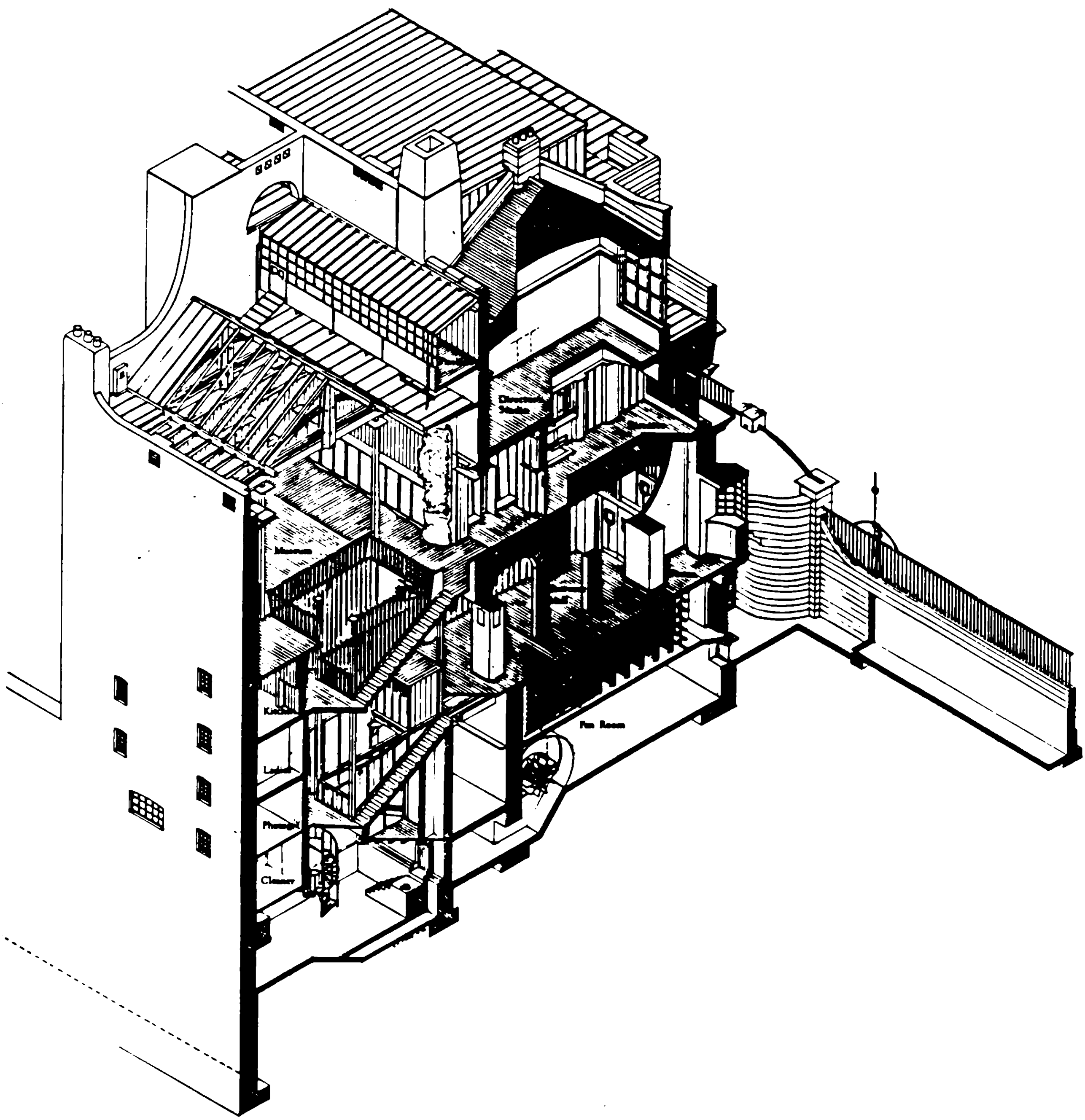
The sculpture, indicated on the drawings in outline, is the 'Ancestors of Christ', dating from around 1155 and removed from Chartres Cathedral. It was incorporated into the space during construction and remains to the present time.



the
Glasgow School
of
Art



the
Glasgow School
of
Art



the
Glasgow School
of
Art

scale of 0 5 10 metres

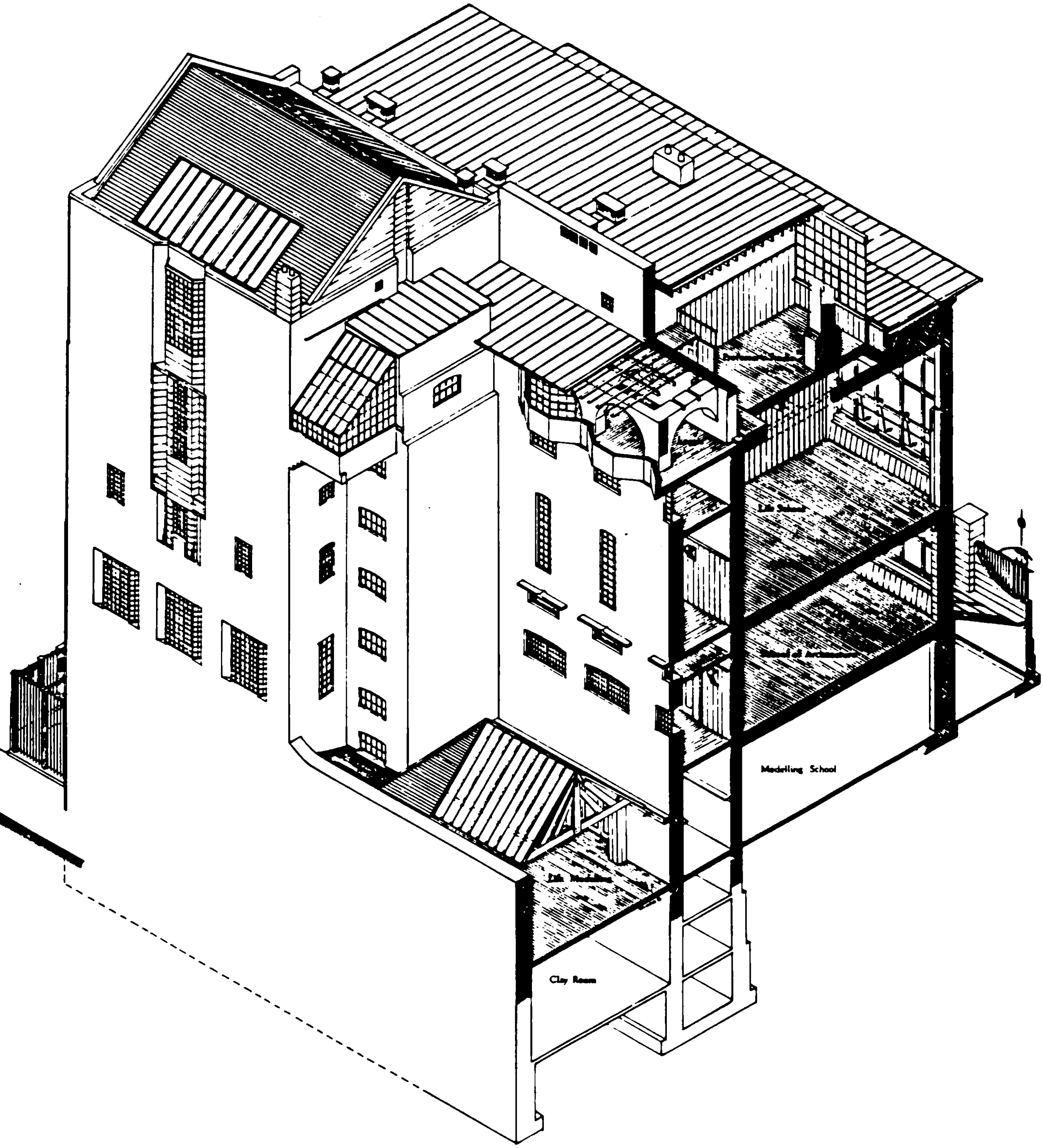
Drawing No 9

This drawing shows the overall massing of the West Wing, the composition of its south facade and west stair.

The arched structure of the Loggia creates an ambience of enclosure and movement, drawing the visitor from the west stair to the views which open out into the individual bays and to the panoramic view south over the City and to the hills beyond.

This concept is in contrast to the openness of the Pavilion, shown earlier.

The architectural detail remains much as drawn, other than the panelling below the main studio windows, which has been removed to accommodate heating installations, and the addition of mezzanine floors to the studios, adjacent the corridor.



the
Glasgow School
of
Art

scale of 0 5 10

Drawings Nos 10 and 11

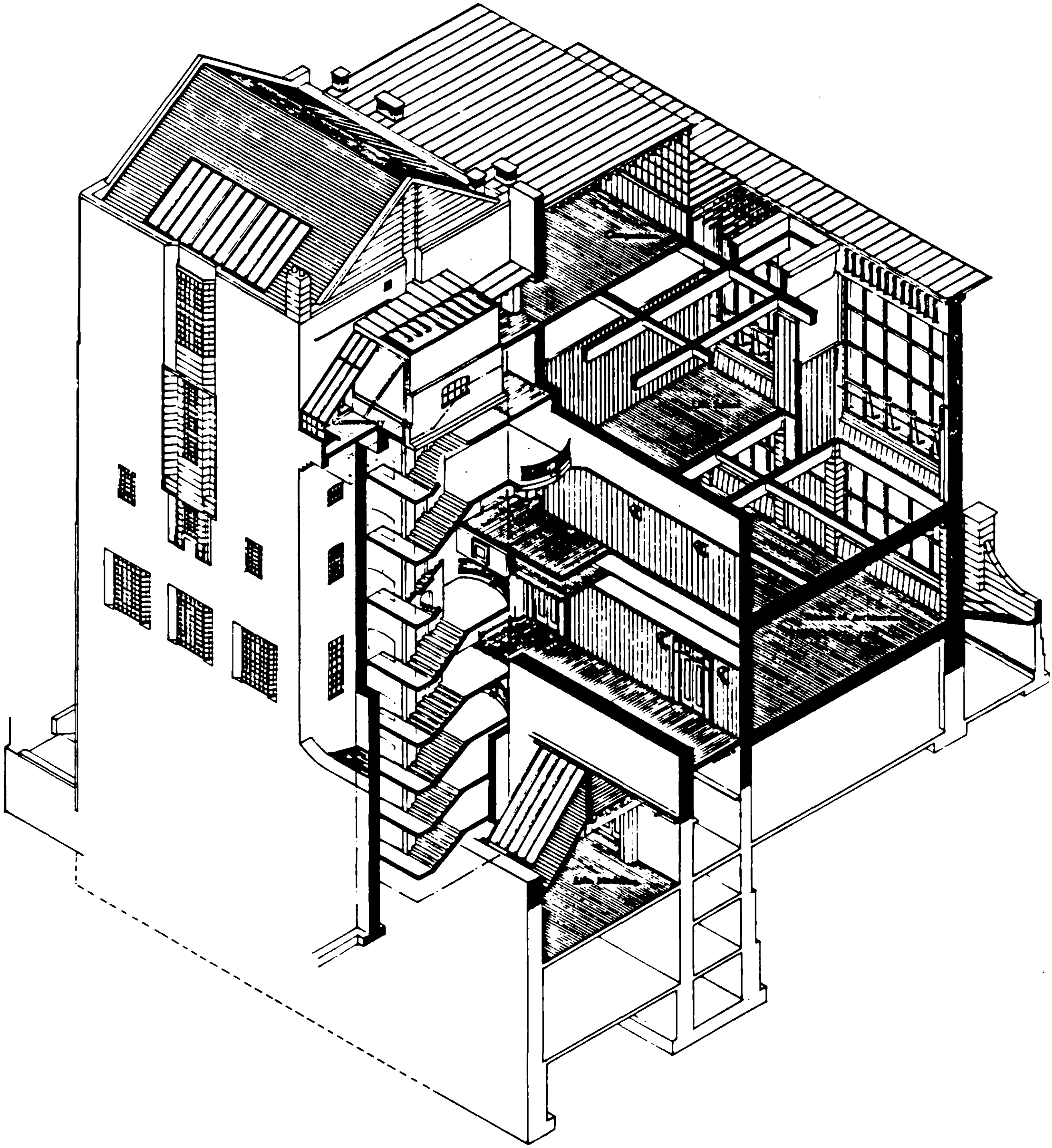
These show details of the structure and construction of the West Wing of the School.

The floor beams of the West Wing, encased in lathe and render, should be compared with the exposed girders of the East Wing.

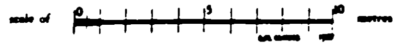
The priority of function over aesthetic is indicated by the intersection of the main air extract duct and the west stair, where the duct cuts across the face of the landing at about waist height, restricting the view into the corridor below but giving easy access to the duct.

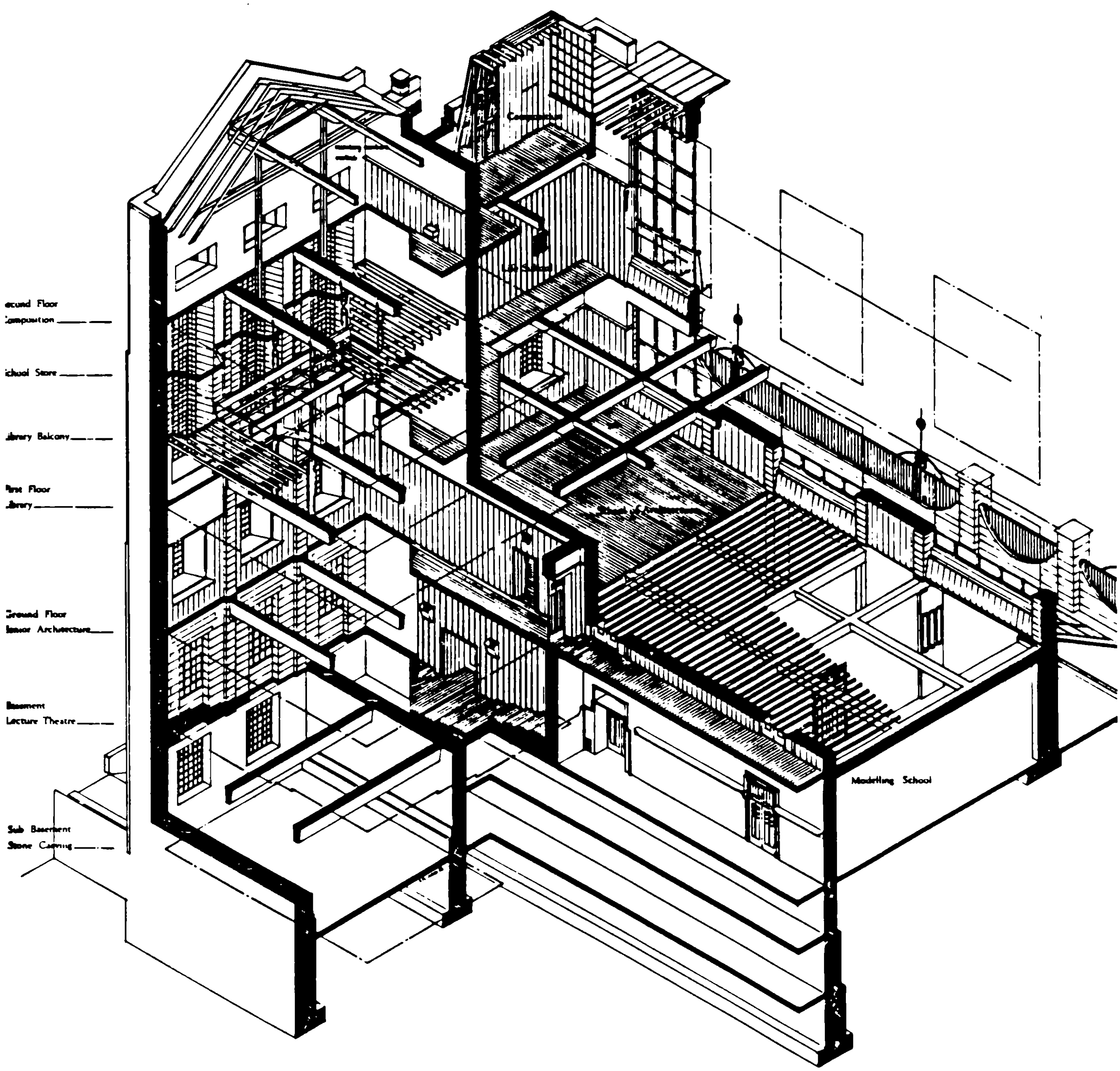
It was originally suggested to the writer that this duct was an addition to the construction of the Wing, but the study of the heating systems shows it to be original.

Drawing No 11 shows the structures to the Library tower, indicating the varying directions of the spans, along with the relationships of beams, columns and stirrups to the upper levels.



the
Glasgow School
of
Art





the
Glasgow School
of
Art

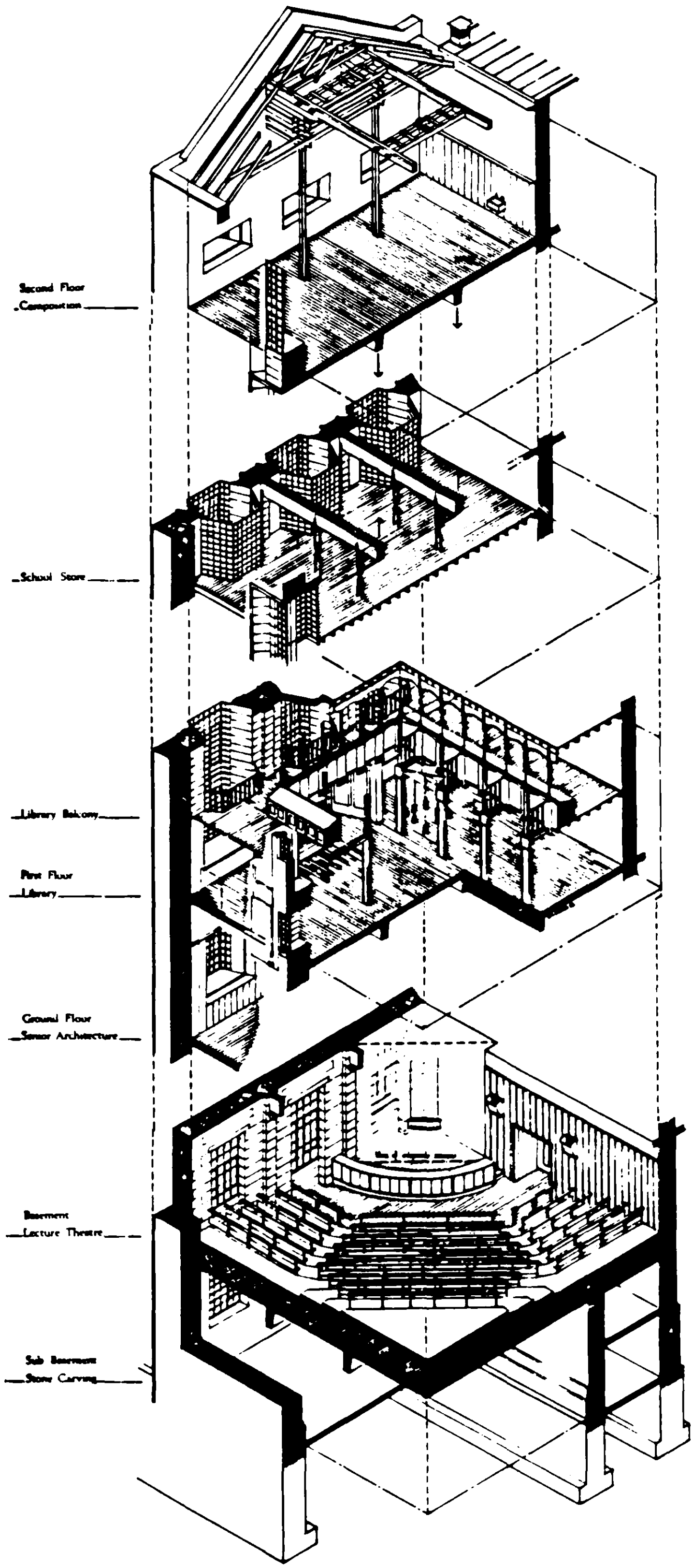
Drawing No 12

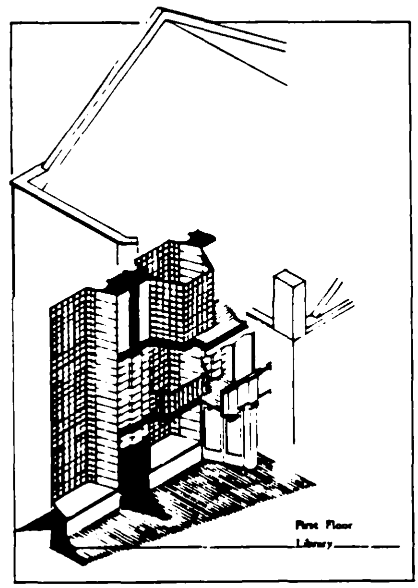
This drawing shows the composition of the Library tower.

The layout and architectural detail of the spaces within the tower is shown to indicate the changes of scale and character achieved within the same plan area, along with the vertical interpenetration of the Library and the spaces over.

The fenestration of the west facade, so much admired for its external composition, towering boldly over Scott Street, is shown to indicate its relationship to the internal spaces, in particular to the magnificent internal composition of the Library.

The strong vertical emphasis of the design and the views which open out through the Gallery and the lanterns to the School Store above confer upon the interior of the Library an atmosphere of suspense and anticipation.





the
Glasgow School
of
Art

Drawings Nos 13 and 14

These show the heads of the east and west stairs, respectively.

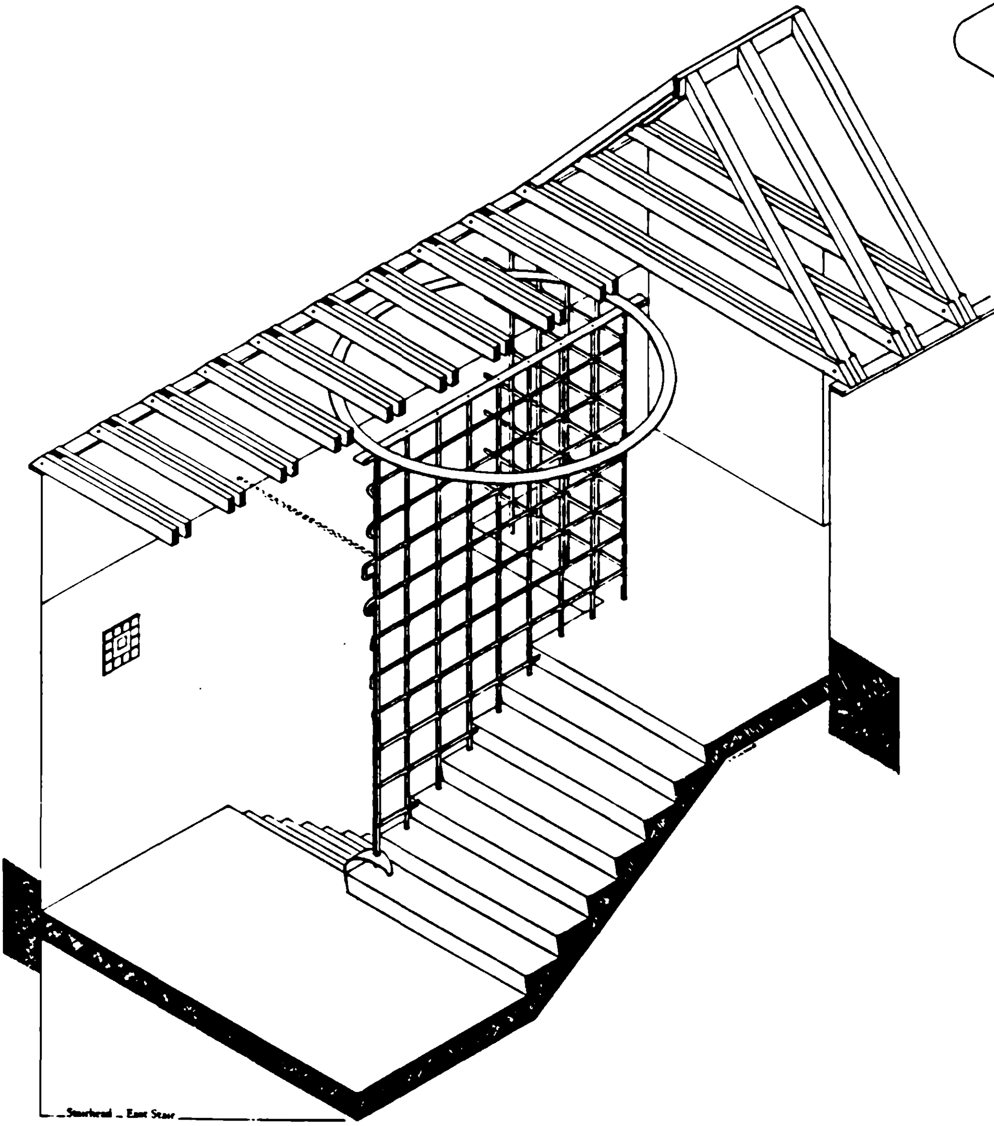
The apparent complexity of the design of this metalwork, particularly to the west stair, conceals what is basically a simple geometric grid of standard sections, jointed with bolted and riveted connections.

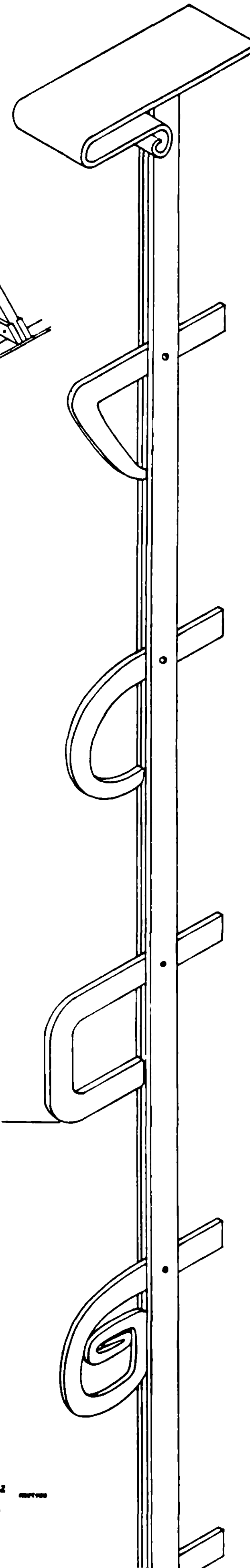
The additional complexity of the west stair metalwork gives a rigidity which is lacking to that of the east stair.

The decorative features are single-curve extensions of the basic materials, rather than ostentatious additions to them, emphasising the basic simplicity of the concept.

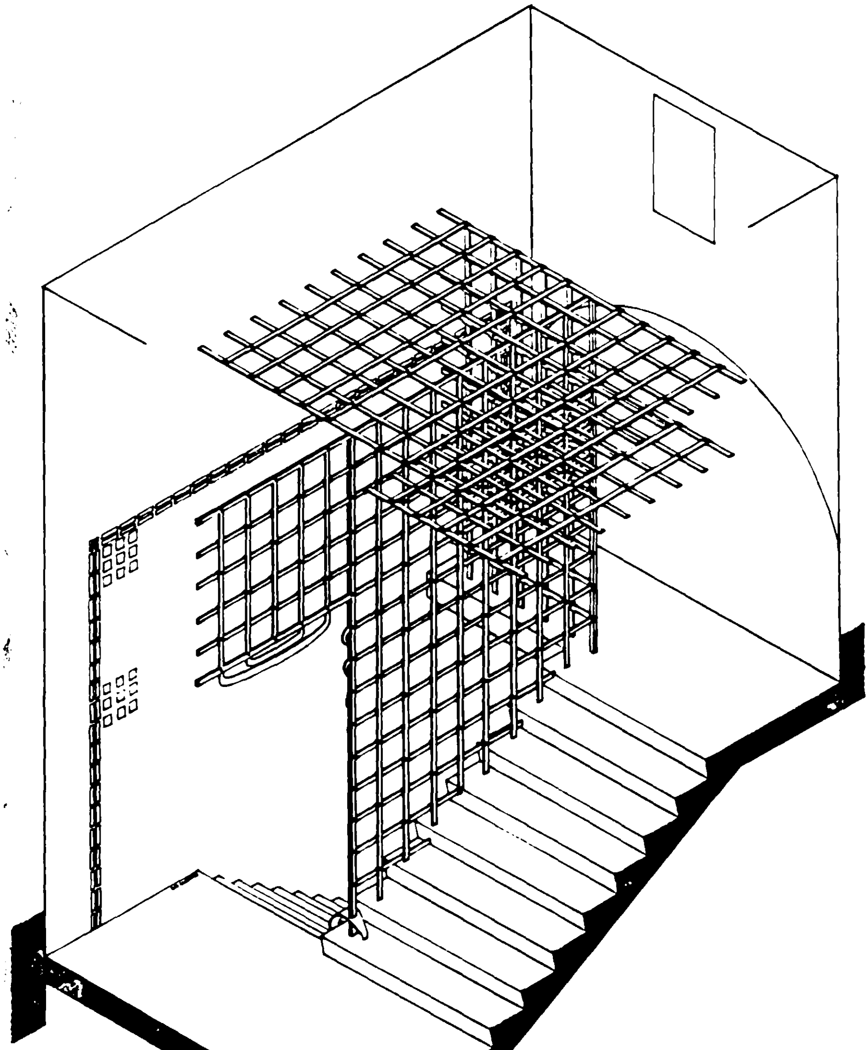
The concept of the use of bold sections of metal, riveted and bolted as in ship or locomotive construction, is discussed in Chapter 2 of this Thesis.

This solution to the architectural detail, although executed some 85 years ago, still stands out in terms of modernity of style and concept.

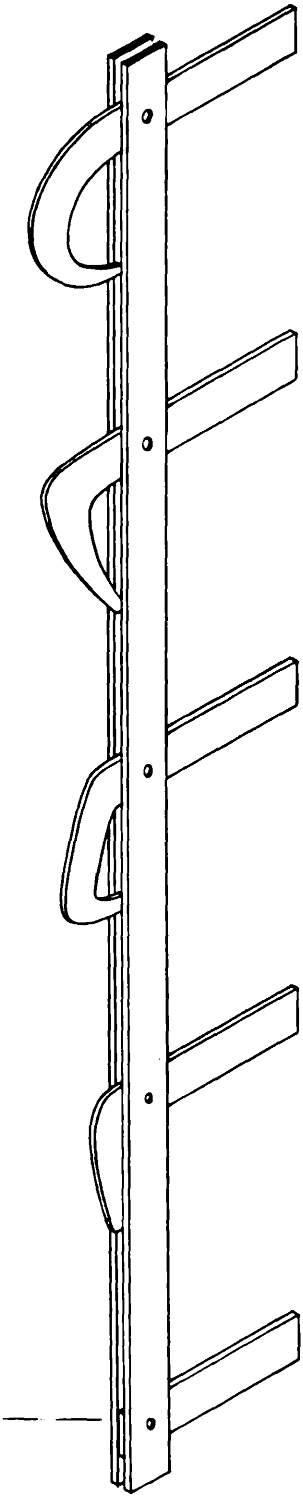




the
Glasgow School
of
Art



Stairhead — West Stair



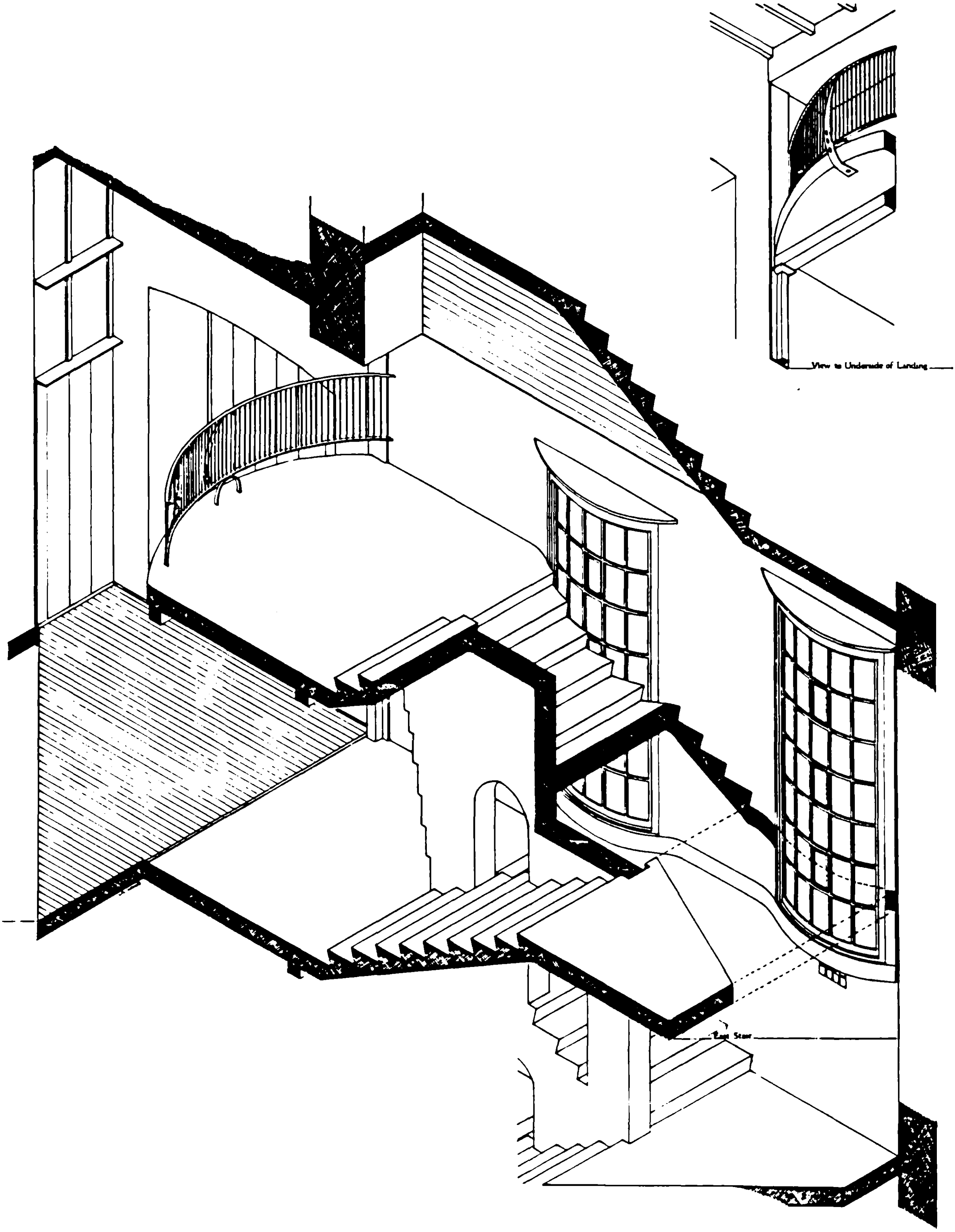
Detail

the
Glasgow School
of
Art

Drawing No 15

This drawing illustrates the relationship of the east stair to the windows of the original Board Room, across which it was constructed during the second phase of construction. The quality of the detailing, and of its execution, in the curve of the stair flights across the face of the windows is impressive.

The detail of the stair passing across the window face, born of necessity in the intersection with the existing, is repeated in the design of the new exterior fenestration of the stair tower, opposite.



the
Glasgow School
of
Art

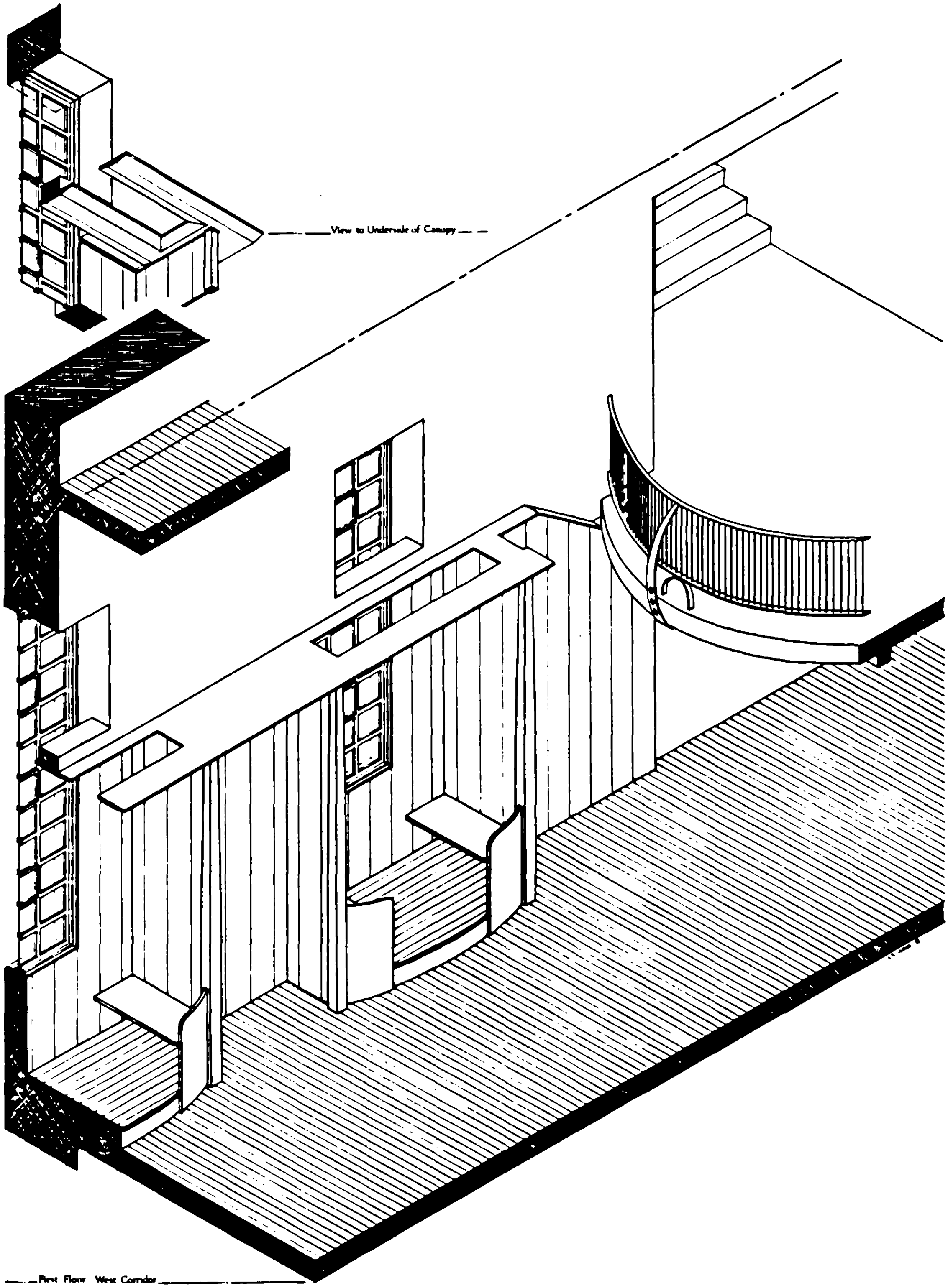
scale of 0 1 2 metres

Drawing No 16

This drawing illustrates the first floor corridor to the West Wing, along with the seating, and shows how every aspect of the building design is considered in relation to the total.

The design of the seating relates internally to the fenestration which is itself part of an exterior composition. The alcove design provides small, intimate spaces as part of open, public circulation route. The alcoves are lowered in apparent height by the canopy over, which is perforated in order to permit the passage of daylight to the corridor beyond.

The detail is a sophisticated use of an archetype common in monastic buildings of the Italian Renaissance and was employed by Mackintosh, to great effect, in his residential works at Windyhill[18] and Hill House.



the
Glasgow School
of
Art

References

1 Thomas Howarth, "Charles Rennie Mackintosh and the Modern Movement", Routledge and Kegan Paul, p91.

2 idem. p80.

3 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p81.

4 D MacGibbon and T Ross, "The Castellated and Domestic Architecture of Scotland"

5 As exhibited in the Exhibition, "C R Mackintosh: The Architectural Drawings", at the Hunterian Art Gallery, Glasgow, 1990, and listed in the catalogue of the Exhibition.

6 Jessie King, Sketchbook of Culross, Fife, held by the Hornel Gallery, Kirkcudbright, Scotland.

7 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p71.

8 Glasgow School of Art, "Charles Rennie Mackintosh and Glasgow School of Art", Glasgow School of Art, p11.

9 Recorded in the Minutes of a Meeting of the Board of Governors of the Glasgow School of Art in July 1909, held by the Mackintosh Library, Glasgow School of Art.

10 Jackie Cooper (editor), "Mackintosh Architecture", Academy Editions, p23.

11 Recorded in the Minutes of a Meeting of the Board of Governors of the Glasgow School of Art in December 1908, held by the Mackintosh Library, Glasgow School of Art.

12 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p61.

13 Recorded in the Minutes of a Meeting of the Board of Governors of the Glasgow School of Art on 6 May 1908, held by the Mackintosh Library, Glasgow School of Art.

14 idem. 30 April 1908.

15 This view was expressed by Leon Krier, speaking at the Charles Rennie Mackintosh Society's Conference, "Aspects of Genius", held in Glasgow in 1990.

16 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p53.

17 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p184.

18 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, pp82-83.

Chapter 2
The Building in Context

Introduction

Initial assessment of the historical context of the implementation of the designs for the Glasgow School of Art will, logically, be influenced by the content of existing major studies on the building. The writer was not unmoved by the theories of the building as a major innovative step in architectural design[1], which would have readily been attributed to Mackintosh, even in the anonymity of the competition procedure.[2]

During investigation of the building technology of the School the writer was, however, to come upon a document which was to inspire further assessment of the building's origins and examination of the local architectural scene into which it was integrated.

This document has not, to the writer's knowledge, been referred to in any previous study.[3]

Period And Location

In a recent major study of the Glasgow School of Art, William Buchanan questioned "....how such a radical building was accepted without someone, such as Newbery, promoting it forcefully?".[4] This question suggests that the Glasgow School of Art, as constructed, was a design which was without precedent; a building not of its own time. This view is supported in other studies of Mackintosh's work, such as in Howarth's commentary on the north facade, of which he says '....One can hardly imagine a more complete deviation from contemporary architectural practice'.[5]

Written commentaries have consistently promoted the theory that the winning entry for the competition to design the new Glasgow School of Art was chosen by Newbery alone, based upon a strong personal relationship with the young Charles Rennie Mackintosh, to the virtual exclusion of other entries.[6]

It is impossible to comment upon the merits of the winning scheme in relation to its competitors, since there is no known surviving record of any other scheme entered. It is, however, possible to comment upon the theory that the chosen design was not of its own time and to question whether it was, in fact, as radical as some commentators would imply. The evidence of contemporary documentation does not support such a theory.

In terms of local architectural context, the surviving output of the Glasgow practices which are known to have submitted entries alongside that of Honeyman and Keppie does not support the view that the winning entry would have been exceptional in terms of style.

The School may, justifiably, be regarded as exceptional in terms of its architectural quality, but it can be considered unique neither in terms of its function nor in the architectural interpretation of that function.

It should be remembered that, by the time that the Glasgow School of Art was designed and constructed, the industrial revolution had re-shaped British industry and society. The nature of society had changed more in the preceding decades than it had in centuries previously and the products of the country's industrial cities were being shipped throughout the world.

Within the United Kingdom, Glasgow was both one of the major centres of manufacturing industry and, also, one of the major ports through which the country's foreign trade was conducted. The City had long established trading contacts with other countries throughout the world and could not be regarded other than as a cosmopolitan metropolis.

During the latter half of the nineteenth century Glasgow had also, established a reputation as a centre of artistic excellence and of architectural ingenuity.

The output of Glasgow artists, such as E A Hornel and George Henry, was unique in its character, combining Celtic and Scottish motifs within a modern style, without precedent. Hornel visited Japan on three occasions, the first being in 1893, and incorporated into his works the same types of

Japanese motifs as are employed in the design of the external railings and the Composition Room roof structure of the Glasgow School of Art.[7]

Within the field of architecture, Glaswegian designers did not follow any particular style to the exclusion of others. During the second half of the nineteenth century they had produced notable works which incorporated French, Greek, Roman and Egyptian features into constructions of considerable originality. In the latter years of the nineteenth century Glasgow architects produced a substantial body of work which was innovative in terms of both structure and construction and several, including James Salmon II and J Gibb Morton, produced works which combined features of Art Nouveau with references to Scottish baronial architecture.

At this time the importance of the relationship between science, art and design and manufacturing industry, later to become central to the theories of modern architecture, was being formulated in the writings of designers such as Rioux de Maillou[8] and Louis Sullivan.[9] The relationship between the various arts and the manufacturing industries of the country was also stressed in documentation relating to the teaching of design subjects within the British higher educational system.

The national higher education system for art and design, into which the building was to be integrated, was based upon the relationship of design and industry, to the deliberate exclusion of, rather than the support of, current fashion. The new Glasgow School of Art might be expected then to contribute to the education of students in support of the local industries; primarily engaged in the production of ships and railway engines rather than of household artifacts.

The boldness of the visual designs of the building and the materials and manner of their execution can be seen to be supportive of such an aim; chunky timber and metal sections, beaten and hewn to shape, with bolted and riveted connections.

On the basis of the conditions which existed both locally, nationally and internationally the Glasgow School of Art can be shown to be a building very much of its time. It is a product of a period when there existed support of art and design education within the field of technology, to serve the future needs of society, rather than to act as a reflection of the current tastes of the period.

Art And Design Education In The 1890's

The provision of a new School of Art in Glasgow during the 1890's was not an event unique to that city. During the latter decades of the nineteenth century there were a substantial number of major British cities in which new Art Schools were constructed, or in which existing Schools initiated schemes for the construction of newer and larger premises. The development of these schemes, in order to increase the provision of places for art and design students within the higher educational system, was supported, encouraged and, in certain cases, made compulsory by various pieces of parliamentary legislation.

The impetus for the injection of large amounts of money into the field of art education in Scotland came both from educational policy, in the form of the Technical Schools (Scotland) Act of 1887 along with the Schools for Science and Art Act and the Technical Instruction Act of 1891, and, also, from the fiscal policies laid down in the Local Taxation (Customs and Excise) Act of 1890. The basic intent of the legislation was similar throughout the United Kingdom, but, in line with parliamentary practice, Scottish legislation was enacted separately from that of England and Wales and there were small, but significant, differences.

The first of these Acts, similar in intent to legislation previously enacted for England and Wales, laid down terms under which local authorities were permitted to borrow capital in order to fund development of new Art Colleges. It was stated that these Colleges were to implement a policy of technical instruction, defined as "instruction in branches of science and art."[10]

This first Act, then, made clear the link between design and technology, which was central to the policy being implemented. It did not, however, provide direct impetus for new development by provision of funds from central government, rather being an initial piece of enabling legislation which laid down ground rules for development.

The two Educational Acts of 1891 allowed local authorities to take over financial responsibility for the running of colleges in private control, under guidelines laid down by the Department of Science and Art.

The most important of the two Acts, in terms of direct financial provision, was, however, the Schools for Science and Art Act. This Act made provision for the implementation of the financial provisions of the Taxation Act and, of specific benefit for the funding of large scale developments, for the carrying forward of any budget provision remaining unspent in one financial year into future years.[11] By this means Authorities were able to accumulate the necessary capital for major educational developments over a number of successive financial years.

The Local Taxation Act of 1890 laid down regulations under which Local Authorities might contribute from their revenue to the establishment of technical education institutes. In England a minimum level of contribution to technical education was made mandatory. In Scotland, however, the expenditure of the amount which was laid down by the Act was discretionary. This discrepancy may account for the earlier development of major new Schools of Art in cities such as Manchester and Birmingham than those in Scottish cities.

At a major conference on technical education, held in Edinburgh in 1891[12], it was reported that 86 out of 88 English authorities questioned had, by that time, given grant allocation to technical education. Of these, all but 3 had given their entire permitted allocation.

The net effect of the terms of this Act was to place Local Authority expenditure on the establishment of technical education institutes on an equal level with expenditure on sanitation and second only to that on police superannuation.[13]

In addition to the expenditure generated by parliamentary legislation, there was major investment in the development of new institutions to be gained from private funding.

A deputation from the Glasgow School of Art, visiting several existing institutes throughout Britain in the early 1890's, recorded that, for the new Birmingham School of Art, "certain gentlemen undertook to give land and build a School of Art, on condition that the town should take over the School when built."[14] That School was noted to be "one of the finest and certainly the best equipped in the three kingdoms."

The deputation also visited the Manchester School of Art. This School was established during the early 1880's, but was expanded significantly in the last decade of the century following the Local Authority's decision to "assume the duties and responsibilities set forth in the provisions of the (Technical Instruction) Act".[15] Prior to implementation of the expansion scheme the board of this School had visited several continental Schools and had taken account of their findings in the commissioning of the new building.

The final form of the Manchester School of Art is remarkably similar to that of the Glasgow School of Art and may have influenced the detailed brief to which the Glasgow competitors had to respond.

The final visit of the Glasgow deputation was to the South Kensington School in London. This School was charged with the responsibility of overseeing government policy in art and technology education and their senior officials' stated views on the aims of art and design education of the period are recorded in the findings of the deputation, which were published in March 1893.

Industry, Art And Technology

De Maillou wrote, in 1895, that

"There is a new decorative aesthetic to be developed from the arrival of industrialisation in the field of art.....science showed how much it could assist art........what art can offer science and what architecture, aided by science, is now in a position to achieve."[16]

This statement records a view of the interdependence of art, design, science and technology which was widespread and which would, in view of the rate of progress of technology at the time, be conducive to similar progress in the field of art, including architecture.

In 1893 the views of General Donnelly and Thomas Armstrong, Secretary and Director of Art for the South Kensington School respectively, had been recorded in the published report of the deputation from the Glasgow School of Art, as follows.

"'Technical Education' could not mean the education of the artizan in art, solely with a view to meet the present market demands but must always be directed to the principles of Art as applied to the various industries of the country.

The purpose for which Schools of Art were founded was not to produce designs which should meet the passing needs of the current market or the prevailing fashion, but to educate the designers in the art of design.

The Authorities would in every way encourage and assist the School of Art in Glasgow to promote instruction in such subjects as designs for....industries of Glasgow and its neighbourhood in which Art is an important factor."[17]

The impetus for the development of an art education system biased towards industrial design, as opposed to fine art, came from the realisation that British industry was being outperformed by its foreign counterparts and was losing markets to its competitors.

In the second half of the nineteenth century British design was initially biased towards the decoration of artifacts and was heavily influenced by the teachings of William Morris and his followers, such as C R Ashbee, who saw no value in industrialised production.[18]

In the latter decades of the century, however, there was a realisation that design teaching and practice abroad, firstly in France and then, more importantly, in Germany and the United States, was becoming based upon the needs of manufacturing industries in supplying the ever-increasing demand for their output.[19]

The need for change was acknowledged in Britain in the 1880's and it was against this background, of art education viewed as part of the field of science and technology and related to the needs of the country's industry, that the competition for the new Glasgow School of Art was initiated.

The Design Competition in Context

As stated previously, a deputation from the Glasgow School of Art had, in 1893, visited existing Art School establishments in several other British cities, including Birmingham, Manchester and London, inspecting the facilities provided and reporting upon the financial arrangements for their construction and management.

The members of this deputation, whose report was published under the names of the individuals involved, included Francis Newbery, the influential head of the School, credited frequently with supporting Mackintosh's design to the exclusion of others.

Other members included Messrs Murdoch and Paton, councilors of the City, and the architects J J Burnet, William Leiper and W Forrest Salmon. Of these, Burnet was probably the most prolific in architectural output, producing a wide variety of unique and highly influential buildings. His Queen Margaret Union[20], completed for the University of Glasgow between 1887 and 1895 (see Appendix VI), shows features which may be seen, also, in the design of the School of Art; the squat tower, virtually devoid of decoration, and the incorporation of Scottish baronial features into a design of unique individuality.

William Leiper, also, was a designer of individuality. He had, in 1889, designed the Templeton carpet factory in Glasgow[21], a unique piece of advertising of the Client's wares in the form of polychromatic brick and tile, with red sandstone dressings. (see Appendix VI)

In 1894 W J Anderson, a student of Leiper's office, was appointed head of the School of Architecture at the Glasgow School of Art.

Anderson was, himself, an architect of considerable talent, with a particular interest in new forms of concrete construction. Like Burnet's Union building, his Napier House[22], constructed in 1897-1899 in Glasgow, shows a lack of applied decoration to the main areas of the facade, along with design references similar to those employed by Mackintosh in the design of the Art School building. (see Appendix VI)

The small, rectangular windows, sitting isolated from the main, larger areas of fenestration, are reminiscent of those which were incorporated into the second phase of the Art School, on the main facades, to serve the life models' changing areas.

In Napier House, completed in the same year as the first phase of the Glasgow School of Art, Anderson employed the design feature which Mackintosh was to instruct to be added to the Art School building immediately prior to completion[23]; the rounding off of the stonework to the window reveals.

1895 saw completion of Orient House in Glasgow, to Anderson's design. This building is again unique in terms of its visual design and was constructed entirely of reinforced concrete, although to a fairly crude structural design, using un-calculated tubular reinforcement to its barrel vaulted slabs.

The architects mentioned above can be shown to have an involvement with the Glasgow School of Art during the 1890's and, in most cases, in the competition for the design of the Art School, either as competitors, as members of the staff or of the Board of Governors.

In addition to the works mentioned above there were numerous other buildings, immediately preceding or contemporary with the Glasgow School of Art, which showed similar ingenuity in terms of both visual and structural design.

Art Nouveau style was not developed to the same free-flowing extreme in Glasgow, or indeed in Britain, as it was on the Continent. Mackintosh's work is frequently held forth as an example of the best in British interpretation of the style. There were, however, other architects in Glasgow who adopted the style more eagerly than Mackintosh, allowing it to dominate rather than being subservient to the Celtic and Japanese influences, as in the Art School design.

The major exponent of Art Nouveau architecture in the City was James Salmon Jnr. His design for the 'Hatrack' building[24], in St Vincent Street, is not only a prime example of the style, but is also an excellent example of the art of functional design; a ten storey office building on a plot, 9 metres (29' 6") wide by 33 metres (109') deep, with maximum area of glazing to the street facade. (see Appendix VI)

Salmon, along with J Gaff Gillespie, was also responsible for the Anderston Savings Bank[25], an example of the Art Nouveau style applied to the Glasgow tenement, and for Lion Chambers[26], in the City centre. The latter building, in a mixture of styles, was constructed using the Hennebique[27] system of reinforced concrete walls and floors, only 100mm (4") thick, rising 27 metres (90') from pavement level.

The works of the architects and artists mentioned above, along with others working in and around the City of Glasgow during the latter decades of the nineteenth century may not exhibit the exceptional visual design talents and ingenuity of Charles Rennie Mackintosh. They do, however,when taken in total, demonstrate similar design influences to those which are combined within the design of the Glasgow School of Art; a recognition and understanding of historical precedent, both to the indigenous architecture of the country and to the styles of Europe and Japan; a willingness and eagerness to adopt new styles and motifs into their work, and the combination of individuality and ingenuity unique to each of the designers.

The combined output of the Glasgow architectural establishment during the period 1890-1910 demonstrates that the production of a design of such individuality as the Glasgow School of Art cannot be considered as unique in itself. The unique quality of the building may only be attributed to the interpretation of many different influences within the coherent and outstanding visual design produced by Charles Rennie Mackintosh.

Summary

In the context of local, national and international design consciousness of the architectural establishment within which it was produced and in terms of the legislation governing the education system into which it was integrated, the Glasgow

School of Art, as originally designed, is very much a product of its time.

The volumetric interplay which is apparent in the building, as completed, and the originality of the style of the west facade, as built in the second phase, are justification of the building's standing as an architectural masterpiece, but cannot support Buchanan's theory relating to the original competition, being radical departures from the submitted design.

References

1 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p51.

2 idem. p17.

3 The report of a deputation appointed by the Board of Governors of Glasgow School of Art, to visit various schools of art in England in March 1893, was discovered by the writer in a collection of assorted documents, related only by age, in the Mitchell Library, Glasgow. The document was indexed by the title "Glasgow School of Art". At the time of finding the report the writer had been referring to the Glasgow Building Regulation Acts, which were bound into the same collection.

4 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p21.

5 Thomas Howarth, "Charles Rennie Mackintosh and the Modern Movement", Routledge and Kegan Paul, p77.

6 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p51.
also
Glasgow School of Art, "Charles Rennie Mackintosh and Glasgow School of Art", Glasgow School of Art.

7 The exhibits and building of the Hornel Gallery, Kirkcudbright, Scotland illustrate the Japanese influence in Hornel's work and, also, his links with John Keppie of the practice of Honeyman, Keppie and Mackintosh. During the first decade of the twentieth century Hornel commissioned Keppie to design a studio extension to his new home in Kirkudbright, which now forms the Gallery. The roof trusses to this space are remarkably similar to those of the Museum of the Glasgow School of Art, completed in 1899.

8 Benton, Benton and Sharp, "Form and Function - a Source Book for the History of Architecture and Design - 1890-1939", Crosby, Lockwood, Staples, pp4-6

9 idem. pp11-14.

10 The Technical Schools (Scotland) Act 1887, HMSO, held by the Mitchell Library, Glasgow.

11 The Schools for Science and Art Act 1891, HMSO, held by the Mitchell Library, Glasgow.

12 The conference on art and science education was held in the Council Chamber, Edinburgh on 29 October 1891. The debate was held under the chairmanship of the Earl of Elgin and the attendance was recorded as being "large and representative". The records of the proceedings are held by the National Library of Scotland, Edinburgh.

13 The Local Taxation (Customs and Excise) Act 1890, HMSO, held by the Mitchell Library, Glasgow.

14 Report by the deputation appointed by the Board of Governors of the Glasgow

School of Art to visit various schools of art, held by the Mitchell Library, Glasgow.

15 idem. referring to the Technical Instruction Act 1891, HMSO.

16 Rioux de Maillou, 'The Decorative Arts and the Machine', "Revue des Arts Decoratifs", volume XV, 1895, Paris, pp225-267.

17 Report by the deputation appointed by the Board of Governors of the Glasgow School of Art to visit various schools of art, held by the Mitchell Library, Glasgow.

18 Nikolaus Pevsner, "Pioneers of Modern Design", Harmondsworth, England, pp24-26.

19 This theme is currently being investigated by George Rawson of the Mackintosh Library, Glasgow School of Art, who is preparing a post-graduate study on Francis Newbery. The writer has exchanged various items of information with George Rawson in the course of the respective studies.

20 A M Young and A M Doak, "Glasgow at a Glance", Collins, item 106.

21 idem. item 114.

22 idem. item 162.

23 Thomas Howarth, "Charles Rennie Mackintosh and the Modern Movement", Routledge and Kegan Paul, p77.

24 A M Young and A M Doak, "Glasgow at a Glance", Collins, item 158.

25 idem. item 159.

26 idem. item 160.

27 A Gomme and D Walker, "Architecture of Glasgow", revised edition, Lund Humphries, p224.

Chapter 3
Spatial Analysis

Introduction

Today the Glasgow School of Art still functions as an operational Art School, accommodating the full range of activities required by its function. The increasing size of the School, along with the physical limitations of the site of the original building, has resulted in a requirement for new buildings to be added to the School's complement of spaces.

In operational terms, as well as in architectural terms, the original building, subject of this study, is still the focal point of the School, accommodating the main administrative functions. The Director's Office and Studio, the Board of Governor's meeting rooms and the central administration offices are all contained within the building, along with major studio spaces for various disciplines.

The general reference Library, along with the School of Architecture and several other faculties are no longer accommodated within the historic building, but have been removed only during recent years and only due to lack of space, not because of any apparent failure of the building to provide the necessary quality of space.

Original Design - 1895

As stated earlier, the original concept of the spatial design of the Glasgow School of Art was relatively simple; the major studio spaces ranged along Renfrew Street, with the main entrance centrally located; the central corridor on each level running parallel to Renfrew Street; the three projecting blocks to the south of the corridor, containing the major support spaces; the central stair serving all levels.

The efficiency of this plan format, in terms of space allocation and the integration of the main services distribution, cannot be faulted to any extent.

The compact plan format of the School, with limited circulation space, is typical of educational establishments of the era and can be seen not only in contemporary Art School developments but, also, in Honeyman, Keppie and Mackintosh's works for the Glasgow School Boards, such as Martyr's Public School and Scotland Street School.[1]

The integration of the main services distribution, for the warm air heating system and force ventilation system, is also notable for its spatial efficiency.

The primary air circulation route for both systems utilised large section ducts located above the central corridors, utilising the height available against the main studios. The branch ducts serving individual spaces run vertically to and from the main ducts, either built into the thickness of the corridor walls or, in some cases, contained within timber duct encasures built adjacent to the corridors.

Although the circulation routes are extremely efficient in terms of space usage, they cannot be viewed as efficient in terms of their functional operation. With only the single vertical circulation route, centrally located at the entrance and Museum, movement between levels, particularly to the extremities of the East and West Wings, would have been a laborious process.

At the time of the initial design, the construction of buildings in Glasgow was governed by the Glasgow Building Regulation Act of 1892[2], which did not lay down conditions for the number and location of exit routes, as would be required today.

The 1892 Act did, in fact, lay down very few regulations for means of escape, requiring only 'easy exit' from all parts of a building. The materials of construction of the exit stairs from buildings was governed in only certain cases. There was a requirement for escape stairs to be constructed of non-combustible materials to tenements and to public buildings. Educational buildings were, however, not classified as public buildings.[3] Accordingly the construction of the main stair from ground to first floor in timber was permissible.

With the Building Regulations making no specific requirement for number and location of stairs forming a means of escape, it is probable that the poor vertical circulation provision proposed in the original design was governed by the limited budget within which the building was to be constructed.[4]

The Completed Building

The Glasgow School of Art building as completed in 1909 varies from the original design in several major areas.

The second floor, containing the senior staff's private studios along with additional general studio space, was added to both the new West Wing and to the original East Wing.

The design of the West Wing incorporated a new stair, providing additional vertical circulation. A similar stair was added to the East Wing during the construction process. As discussed earlier (p28), the provision of this stair was included only after some debate at Board Meetings, with regard to its likely effect upon the lighting of the original Board Room.

Construction of the West Wing also incorporated the provision of a passenger lift, situated adjacent to the Museum, to the south of the central corridor.[5] At the first floor level the lift doors originally gave direct access to the Museum and not to the corridor, as with the present installation.[6]

The view has been expressed in various studies that the provision of the east and west stairs in the second phase of construction was made in order to meet the requirements of Fire Regulations.[7] This view is not supported by records of the discussion which took place at the Board Meetings during the construction period. Similarly, the requirement for a secondary, east stair is not supported by the documentary evidence of contemporary Building Regulations.

The second phase of construction was governed by the updated Glasgow Building Regulation Act of 1900[8], which laid down more stringent regulations for the means of escape and which classified schools and colleges within the 'public buildings' group, from which they had previously been excluded.

These Regulations required that 'from every part of the building there is adequate and safe exit' and that exits should total 'one foot in width for every seventy persons who can be seated within the building'.[9]

The wording of the Regulations is not concise enough to provide clear ruling as to the number and location of stairs which might be required within any building, there being no definitive restriction upon travel distance to the means of exit. There are, however, other factors which influenced the provision, location and construction of the additional stairs.

The 1900 Regulations required that the stairs to the building, being a public building, should be constructed of 'stone, brick or other incombustible material'.[10] The main stair as existing, from ground to first floor, was constructed of timber.

The need for the means of escape from the new Wing and from the new second floor to be constructed to a different specification from the existing stair may have been central to their provision, but the plan format of the building as it existed was of equal importance in determining the requirement.

The original competition design of the School not only excluded any indication of the second floor, but, also, made no provision for its future addition. The main, central stair runs from the entrance foyer to the upper level, arriving within the Museum space and facing the entrance to the Director's Office, with its private Studio situated over.

There is no apparent way in which this stair could have been extended to the new second floor without major alteration and disruption to the existing spaces. It is unlikely, in view of the financial constraints upon the design, that the proposal of such a major upheaval would have been well received by the Board of the School, should it even have been considered by the architect.

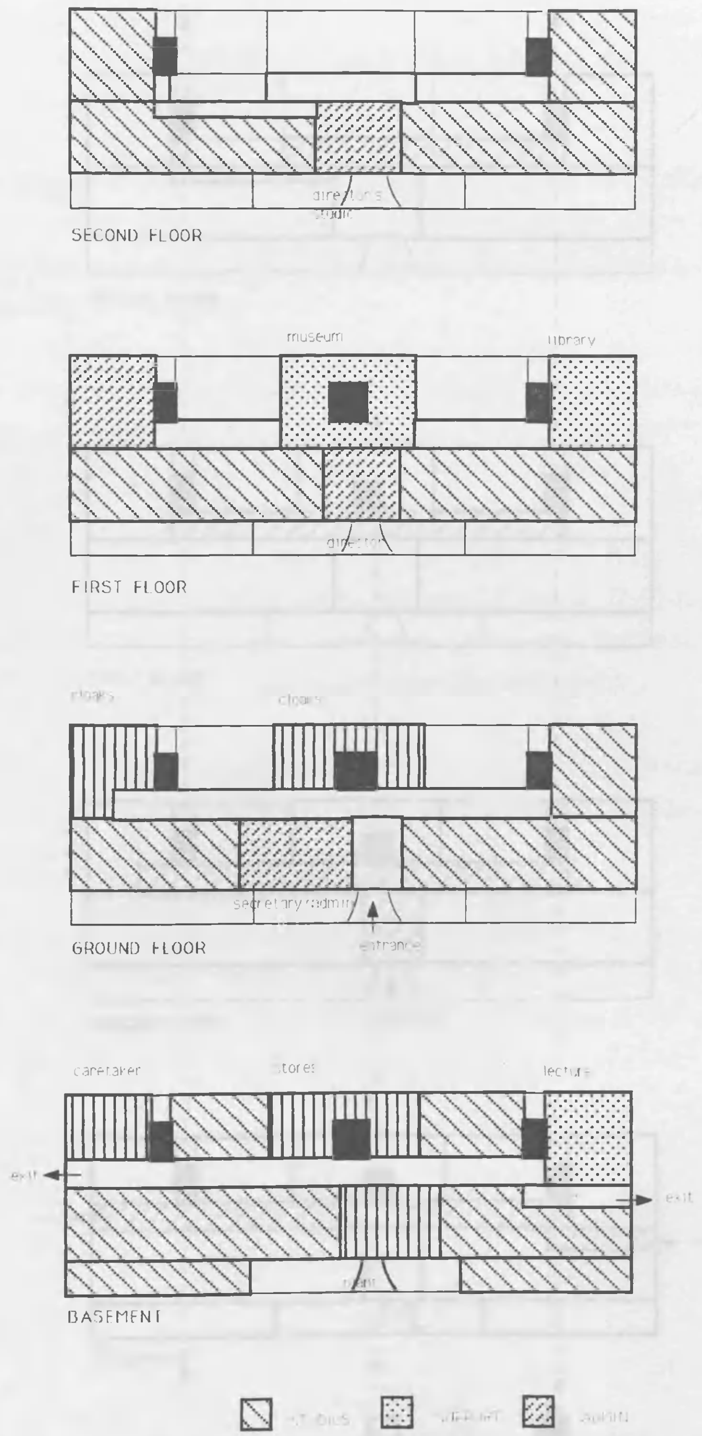
The provision of at least one new stair, located away from the central spaces, was, therefore, a necessity of the provision of the additional floor.

The form of the central spaces was also influenced the need for and form of one of the major features of the School as it now exists; the Pavilion or 'Hen Run'. Study of the location and form of the Pavilion, both on plan and on the 3-dimensional drawings of this study, will show that it is an ingenious solution to a design problem born of the original design; the apparent finality of the roofscape design to the Museum and the Director's Studio.

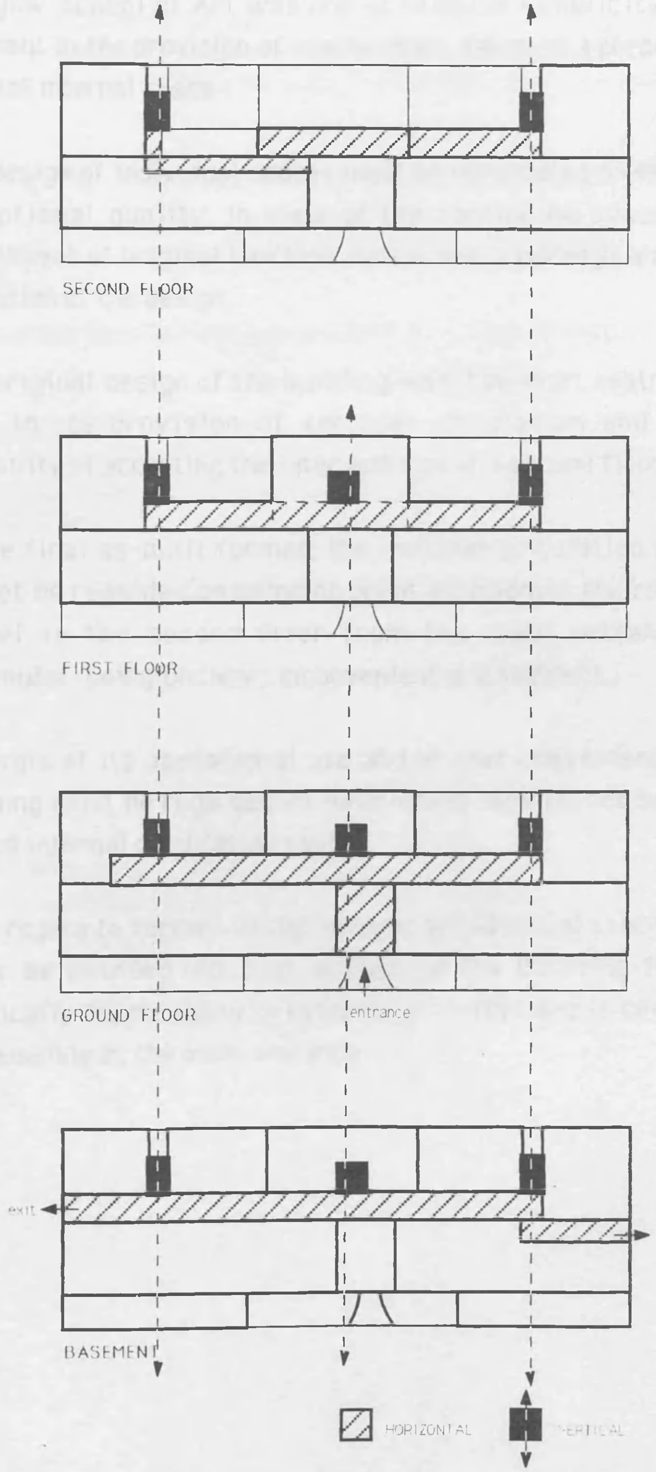
The roof of the Director's studio is central to the composition of the North facade and could not be revised to accommodate the addition of the second floor without major disruption to the visual composition.

The roof of the Museum is not located in a position of similar importance with regard to the external composition, but the timber trussed construction, the rooflight glazing and the natural lighting are central to the character of the space. This ambience would have been severely disrupted by any additional construction directly over.

The construction of the Pavilion, cantilevered from the existing wall head, allows the necessary circulation between Wings at second floor level with no disruption to either the existing roof constructions or to the daylighting of the Museum. (see notes to drawings nos 2A and 2B)



Stacking Plan
Admin. space to first floor, east, is designated Design Room on drawings, but was originally designated Board Room and appears to have spent most of its life in administration use, currently serving for committee meetings, interviews etc.



Circulation Diagram

indicating main, central stair terminating at first floor level, with indirect route of travel to second floor from main entrance.

Summary

In its original, competition-winning format the plan of the Glasgow School of Art was one of relative simplicity; very efficient in the provision of usable space, taken as a percentage of total internal space.

The design of individual spaces must be considered as being of exceptional quality, in view of the continuing successful fulfillment of original function almost one hundred years after execution of the design.

The original design of the building was, however, restrictive both in its provision of vertical circulation and in its capability of accepting the later addition of a second floor.

In the final as-built format, the vertical circulation routes cannot be regarded as being of great efficiency; the route of travel to the second floor from the main entrance, in particular, being unclear, inconvenient and indirect.

In terms of its operational use and of user convenience, the building must be regarded as functioning despite, not because of, its internal circulation routes.

With regard to current design standards and social concerns, it must be pointed out that access to the building for the physically handicapped is extremely limited and is certainly not possible at the main entrance.

References

1 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p114.
Scotland Street School also demonstrates the use of vertically stacked toilet and cloakroom spaces, against the double-height teaching spaces. Similar stacking is employed for corridors, service ducts and cleaner's rooms in Glasgow School of Art.

2 The Glasgow Building Regulation Act 1892, Glasgow, held by the Mitchell Library, Glasgow.

3 idem. Regulation 64.

4 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p51.

5 Refer to plans in Appendix 1.

6 Glasgow School of Art, "Charles Rennie Mackintosh and Glasgow School of Art", Glasgow School of Art, p32.

7 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p119.

8 The Glasgow Building Regulation Act 1900, Glasgow, held by the Mitchell Library, Glasgow.

9 idem. Regulation 99(4).

10 idem. Regulation 99(1).
It is interesting to note that a document lodged with the House of Lords by the Glasgow Institute of Architects in 1899, as one of many objections to the drafts of the new Regulations during their protracted and acrimonious passage through Parliament, recorded the view that timber construction was regarded as being more fire resistant than iron and cement. This may explain the existence of the original stair in timber construction.

Chapter 4
Structure and Construction

Introduction

As with the study of other aspects of the building, analysis of the structure and construction is, to a degree, limited by the lack of detail to the remaining original drawings.

Some of the more interesting and original features, particularly the relationship of beams and stirrups to the Library tower, are concealed within floors or behind decorative timber facings and, as in the case of the stirrups within the School Store, bear little resemblance to the original drawings (see Appendix 11).

The major elements of the structure hold few surprises and are not of great historical interest, in comparison to the building's environmental systems or to several contemporary structures within the City. There are, however, several noteworthy items and the structure must be considered within study of the total architectural design of the building.

Load-Bearing Elements

The School was constructed on a drumlin, a rock outcrop, to the north of Sauchiehall Street in the City Centre, towards the crest of a steep, south-facing slope. In such a location, the foundations of the building are likely laid directly to the surface of the rock and to have, therefore, an excellent bearing surface.

The steepness of the slope, however, results in the foundations being stepped at short intervals where running at right angles to the slope.

The main structure of the School, to the corridors and studios, consists of four parallel load-bearing walls (see drawing no. 9) of brick and masonry, built off mass concrete strip foundations running along the length of the slope, each stepping down from that adjacent to follow the natural rock levels.

Between the north facade and the central corridor the primary structure of the major studio spaces consists of an irregular grid of fabricated steel beams, of double, steel angle top and bottom members, double angle vertical bracing to the web and sheet steel web members sandwiched between. The whole construction is riveted, as visible in the exposed members within the east studios and as indicated on the drawings of the East Wing.

The grid of these primary members sets them in pairs, each beam carried by a masonry pier, with each pair of piers linked by a masonry wall, visible on the north facade between the massive studio windows. At their southern end the beams are carried by the north wall of the central corridor. At right angles to the main spans run two secondary spans of rolled steel joists, onto which the construction of the floors bears.

Both the primary and secondary span steelwork members were constructed to the first phase and originally drawn to the second phase as being exposed.[1] In the later drawings of the second phase and in the actual construction of the West Wing the members are encased within a wire lathe and cement render encasure. This must be assumed to have been done in order to increase the fire resistance of the structure. The Building Regulations of the time did not require such an encasure, but it is possible, as in relation to the original proposed fenestration to the south facade, that the building insurers indicated particular requirements for the design.[2]

The floor structure to the lowest levels of the basement and sub-basement floors is of concrete construction, cast upon fill behind the main load-bearing wall on the lower side of the slope.

At ground floor the floor construction is of timber joists and flooring, spanning between the secondary steelwork members, whereas the upper floors are of concrete slab construction, with timber floors laid on top. There is no structural explanation for this change in the floor construction to the upper levels, and it might, again, be assumed that this was done to give increased fire resistance.

On the second floor of the West Wing it can be seen that the floor levels of the Professors's Studios are raised above the general floor level (drawing no. 9). It might be considered at first that this was done to reduce the floor to ceiling height of these smaller rooms, or to provide "elevated status" to senior members of staff. It can be seen, however, that these rooms contain fairly substantial chimney breasts and hearths. Comparison of floor plans and elevations show that these heavy constructions are not situated centrally over the main floor beams or secondary steelwork below.

Although the structural details are not recorded on any known drawings, it would appear likely that the raised floors conceal additional steelwork to carry these chimneys, particularly when it is remembered that the second floor was an addition to the original design.

Study of the construction of the north facade of the School, from elevations and plans, shows the later, west section, to have less apparent stiffness than the east section. In the West Wing of the building there are no load-bearing walls running north to south within the length of the main run of studios, whereas the studios of the East Wing are subdivided, at ground floor level, by a substantial wall between the east pair of windows. Study of the north facade will show , also, that the ratio of glass to solid is greater in the West Wing than in the earlier construction of the East Wing.

In considering how the structure of the West Wing might withstand the resistance to lateral wind loading, which will be considerable in a building of this height and exposure, consideration must be given to the nature of the construction of the corridor stack, rising through the full height of the building. In contrast, the East Wing corridor stack terminates at the pitched roof over the first floor corridor. It should be remembered, also, that the second floor was an addition to this Wing during the second phase of construction.

The corridor floors are of concrete slab construction, spanning between the two parallel load-bearing walls. In the West Wing the heads of these two walls are tied together and braced by the substantial brick arched structure of the Loggia.

The two walls and their connecting slabs and arches act together to resist lateral forces, including those transferred from the north wall via the main floor beams.

Throughout the building, additional stability is provided to the upper levels of the structure by the three southern projections of the E-form plan. These projections are constructed in box form, having four load-bearing walls, with the main floor beams and roof spanning between, in different directions at different levels, in order to form a rigid structure.

To the West Wing it can be seen from the drawings that the Lecture Theatre and School Store floors, along with the roof, span between the north and south walls whilst the remaining floors span between the east and west walls. This arrangement distributes the loads onto the four walls and ties the entire structure into a rigid box, braced in both directions.

An additional box structure is formed by the West Stair, of concrete flights and landings bearing on its surrounding walls and its central spine wall. The stair is tied into the east wall of the Library tower and the south corridor wall, giving additional rigidity and lateral stiffness to the entire Wing structure.

Study of the central section at the Museum, shows the main roof structure spanning from north to south. The floors also span north to south, but are carried on intermediate steelwork, spanning east to west and tying the external walls to the enclosing walls of the main stair (see drawing no. 8).

Although, as discussed previously, the main floor structures are carried by steel members from the Clyde valley steel works, which were well-established by the time of construction, it was noted that the Bill of Quantities for the School specified cast iron lintols for door and window openings and also fabricated cast iron box beams to span over the large studio windows to the north facade.[3]

At the time of construction there were still in existence specialist fabricators of cast iron sections, despite the widespread use of steel for major structures. The superior qualities of cast iron for resistance to corrosion would be known and, without the benefit of modern finishing systems to protect steel, it is likely that the choice of cast iron for these members was made in order to increase their resistance to corrosion from the city environment.

Structural Appraisal

The structure of the School is relatively simple in concept, bearing more resemblance to domestic construction than to contemporary commercial developments. The use of parallel load-bearing walls, with lateral restraint provided by the floor construction spanning between, is similar in principle to the construction of the typical Glasgow tenement block, whereas a significant number of office developments of the time were constructed of steel or reinforced concrete frames internally, with non-loadbearing partitions.

There were other buildings in Glasgow far more innovative in terms of structure, such as Salmon and Gillespie's Lion Chambers[4] and Anderson's Orient House.[5] (see pp71&72)

There are, however, several features of the School of Art which merit particular attention, the first being the Conservatory adjoining the second floor Composition room to the Library tower.

This room, south facing, with glazed walls and roof, was originally used for growing plants and flowers for still life painting in the adjacent studio. It is constructed on a primary steel beam, cantilevered from the south wall of the Library tower, some 26 metres above ground level, with a secondary beam returning to the west stair wall. These beams carry the concrete slab floor, brick walls and glazed structure above.

The cantilever of the primary beam is secured by the more than adequate back-weight of the tower facade, roof structure and slating onto its rest within the wall.

The concept of the Conservatory appeared on Mackintosh's initial drawings of 1896 and it is reputed to have been a complete innovation at that time.[6] This may have been true in terms of building construction, but was certainly not the case in terms of steel technology.

In the field of civil engineering the Forth Railway Bridge, begun in 1883, showed advanced understanding of large-scale steel cantilevers. In shipbuilding the use of steel structures, introduced by Denny Bros of Dumbarton in 1880, was at a far more advanced stage than in building construction in Scotland. Cantilevered steel deck structures, to give an open hold area, without columns as required in iron ship construction, were in use by 1896 to a pattern similar to that still specified in Lloyd's Register of Shipping.[7]

It should be noted, also, that the original plans indicate a plan form which would, most likely, have been supported on a single direction cantilever, from the east Library tower wall[8], rather than the double cantilever of the actual construction, completed during the second phase.

The second structural feature of merit within the design is that of the Pavilion, or 'Hen Run', over the main roof of the Museum to the central section. In the construction of this cantilevered structure the resemblance to marine technology is particularly marked. The brackets, which are cantilevered from the face of an existing wall rather than built in and supported by the back-weight from above, are remarkably similar in concept to the typical deck structure around the hold openings of contemporary cargo vessels.

The final feature which displays some degree of innovation and ingenuity is the structure to the School Store floor, over the Library.

As with the other levels of the tower the floor of the Store is in three equal spans but, whereas the remaining floors are supported on render-encased steel beams spanning between the main walls, the Store floor is carried by timber-encased beams which, from their depth-to-span ratio, are incapable of a clear span of 11 metres between walls. The intermediate support for these beams is provided by decorative iron stirrups from the steel beams to the Composition room above (drawings nos. 11 and 12). The stirrups were indicated on Mackintosh's section drawings as simple A-frames (see Appendix II) whereas the adopted design, as built, provides not only a more decorative solution, but also gives greater freedom of movement within the Store.

The theory has been expressed to the writer, by one of the advisors for this study, that the upward projection of the Library Gallery support columns (drawing no. 12), all encased in timber facings, conceals additional structural members whereby part of the floor load from the Gallery is transmitted to the Store floor beams and stirrups. This theory is based on the premise that Mackintosh would not have extended the columns upwards for visual effect only.

The structural appraisal given, however, assesses the Gallery columns and main Library floor beams as being more than adequate to carry the entire floor loading.

Any structural members which may exist within the upper columns are considered to serve only the purpose of providing lateral support to the lower columns, carrying the projecting timber beams of the Gallery floor.

Summary

The general structure and construction of the Glasgow School of Art may be considered basic and unadventurous for its time, but it should be remembered that the design was governed by an extremely tight budget. It may well be that the use of fairly traditional, tried and tested construction, particularly in the original competition design submission and in the first phase of construction, would be necessary in order to attempt to meet the cost parameters laid down.

Certainly the second phase construction features, discussed above, along with the practice's other work, from Honeyman's Ca D'oro building of 1872[9] to Mackintosh's design of 1898 for a Concert Hall for the Glasgow International Exhibition[10], show no lack of willingness to investigate innovative structures.

References

1 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p69.

2 Various requirements of the insurers are recorded in the Minutes of Meetings of the Board of Governors of the Glasgow School of Art between December 1908 and July 1909. Other requirements may be recorded in earlier Minutes which were not catalogued at the time of writing. The Minutes are held by the Mackintosh Library, Glasgow School of Art.

3 I M Scott, "Bills of Quantities for the Glasgow School of Art", held by the Mackintosh Library, Glasgow School of Art.

4 A Gomme and D Walker, "Architecture of Glasgow", Lund Humphries, p224.

5 idem. p224.

6 Thomas Howarth, "Charles Rennie Mackintosh and the Modern Movement", Routledge and Kegan Paul, p72.

7 Extracts of the current Lloyd's Register of Shipping and documentation showing the typical deck construction of 1896 were supplied by Fred Walker of the National Maritime Museum.

8 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p22.

9 A M Young and A M Doak, "Glasgow at a Glance", Glasgow, item 47.

10 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, p77.

Chapter 5
Environmental Systems

Introduction

The layout of the Glasgow School of Art was, as widely documented, influenced by the site; its aspect and steep fall to the south. The building design can also be shown to have been influenced by the technology of the services installations. The relevance of contemporary environmental design to the architectural design has not been discussed in depth in published studies of the School and of the work of Charles Rennie Mackintosh.

Macleod, in his book "Charles Rennie Mackintosh, Architect and Artist", makes brief reference to the warm air heating system and its integration with the architectural layout.[1] None of the studies published to date, however, highlights that the total architectural concept of the School, including its huge main studios with large expanses of glass and its basement studios and Lecture Theatre, was to a large extent, dependent upon the advances in building services technology during the second half of the nineteenth century.

Without the development of efficient central heating installations, mechanical ventilation and electric lighting it would have been impossible to provide clean and effective methods of heating and lighting to such a building and, also, of providing efficient ventilation to the subterranean studio and workshop areas.

Although the implementation of new technology was not unique to the School at the time of construction, it is clear that the building's designers were fully aware of the most recent innovations in environmental services technology and paid careful attention to their integration into the total building design.

The first public electricity supply in Scotland was introduced to Glasgow in 1892[2], only five years before construction started on the School. There were, however, private supplies available before this date and the Victoria Infirmary, Glasgow, on which John Keppie worked with James Sellars, is known to have had electric lighting to every bed at the time of completion in 1891.[3]

Mackintosh employed this relatively new technology in the provision of unique and beautiful light fittings to the major spaces, as parts of a total design concept.

The School is also fitted with what is believed to be the first European example of a centrally controlled electrically-impelled clock system.

Users of the building are able to recollect the layout of the original cabling to the power and lighting installations within the corridor areas, in which symmetrical groups of cables were run on the face of the walls, fixed to decorative metal framework which was an integral part of the overall visual design.[4]

The most interesting feature of the services installations is, however, the system of ducted warm air heating and forced ventilation which was installed during the first phase of construction, upgraded during the second phase and, subsequently, taken out of use and, to a large extent, ignored.

This system can be shown to have had a capability for basic, but true air-conditioning, although there is no known record of its operation as such.

The basic form of the warm air heating system employed in the School was patented in 1870 by the Sturtevant Co. of Boston, Massachusetts, USA[5], who supplied the massive twin centrifugal fan assembly installed in the School. This system was totally integrated with the building design, to serve all the major spaces from one central plant area.

Although the major components of the heating system originated in the United States, it is noteworthy that previously unpublished research documentation on the technology of environmental systems and on the importance of environmental design originated in Scotland and was, in fact, cited by the Sturtevant Company in their sales literature during the 1890's.[6]

The report presented to the School Board of the City of Dundee on the subject of heating and ventilating of school buildings, dated 1889[7], explains that the use of mechanical ventilation systems in educational buildings could be clearly shown to produce an improvement in both the quality of work produced and, also, in the health of the users.

By the mid-1890's there was a substantial number of differing forms of mechanical services installation which could be cited in these documents. There was, therefore, widespread use of forced ventilation systems prior to the design of the Glasgow School of Art.

The next major step forward from mechanical ventilation systems was in the development of air-conditioning, the first example of which Reyner Banham credits, in 'The Architecture of the Well-Tempered Environment', as being the Royal Victoria Hospital, Belfast, dated 1903[8]. He does, however, credit the production of fundamental patents for air-conditioning to Stuart Cramer, for those lodged in the United States in 1906[9], describing the Hospital's air-conditioning capability as being incidental to a ventilation system design.

The design of the environmental systems of the Royal Victoria Hospital can, however, be shown to be derived from the previously unpublished patents of Scottish engineers William Key and Robert Tindall, lodged initially in 1890 and approved in 1892.[10] The first recorded installation of technology to Key's design was in the Victoria Infirmary, Glasgow, construction of which was completed in 1890 to the plans of architect James Sellars.[11]

William Key was a member of the board of management of the new hospital and his proposals for the introduction of mechanical ventilation were readily accepted and fully integrated into Sellars' design. Sellars, himself, died prior to completion of the project and the works of his practice were completed under the control of his associates, who included John Keppie, later to be partner in the practice of Honeyman and Keppie at the time when the design of the Glasgow School of Art was being prepared.

The detail of the design of the School's systems and of their place in the history of environmental systems are the subject of this section of the Thesis.

Layout Drawings

The drawings showing the operation of the system to the Glasgow School of Art are drawn to show the West Wing of the building along with the plant room areas, situated below the main entrance to the School and included in the first phase of construction between 1897-1899. It should be noted that the installation to the East Wing follows a virtually identical pattern to that of the West Wing.

As with the structure of the building there are few indications of the original installation on Mackintosh's drawings, and as stated previously, little published information, of only a general nature.

The system was removed from use in the 1920's and two subsequent hot water circulation systems have been installed, using areas of the original plant rooms and ducts. The original boiler room is now used as a workshop.

At the present time, however, sufficient remains of the original fan installations, steam coils and filter banks for an assessment to be made of the method of operation, as shown on drawings nos. 17 and 18 and in the photographs in Appendix 11.

There is no record on Mackintosh's drawings of the chamber over the boiler room (see drawing no. 18), but study of its construction shows it to be original. The appraisal of its function is based upon study of its form and its related ductwork.

Air-Induction System

External air, for heating and subsequent circulation through the building, was drawn, by the suction of the fans, from the wells at basement level either side of the main entrance. The air passed, firstly, through timber louvres, set into the external walls and stair support walls, to a plenum chamber from which it was drawn through the bank of air filters to the steam coil chamber.

Having passed through the heating coils the air was pressurised by the twin centrifugal fans and discharged to the main circulation duct. This duct runs the full length of the building above the sub-basement corridor.

Although the induction system was constructed of materials of the period it should be noted that the basic technology employed is remarkably similar to that of the present time.

The timber louvres of the intake grilles would now be replaced by pressed metal acoustic louvres, to a similar pattern for a low-velocity system such as this.

The filter banks installed during the first phase of construction were described in the Bill of Quantities as being constructed of hung fibre mats, in line with the type illustrated in Key and Tindall's patent of 1892.[12] These were, however, replaced during the period 1907-1909 by a new installation, as billed in the contract documents for the second phase of construction.[13]

This assembly consisted of individual filter units, constructed of horse hair, set between perforated brass sheets, in a cardboard surround. These units were mounted within a timber framework which was fully sealed to the surrounding structure. The filter units were secured by timber locating pegs which allowed removal of individual filters. Modern filters, to a similar pattern, would be constructed of metal, plastic and paper.

The area containing the filter banks appears to have been sealed off at the time of installation of the first hot water circulation system and to have remained unnoticed from then until the present. The last remaining filter unit was recovered from debris during survey work for this study and is shown in the photographs in Appendix 11.

Air Washing Installation

Although there is no visible sign of the installation amongst the current remains, an air-washing installation was specified for the filter banks to both phases of the construction.

The installation included in the first phase of construction included 'fibre or other screens with water spray and everything necessary for the purification of the air to be provided', whilst the second phase construction specification called for the replacement of these filters and sprays with a 'screen of double ply horse hair with 12no Kortings spray nozzles'.[14]

The filters referred to in this section would be those of which an example is illustrated in Appendix 11 to this study. Study of the filter construction shows that the spray nozzles could not have served the purpose of washing the filter assembly. The cardboard surround to the filter units would have rapidly disintegrated under such conditions.

The possible purpose and significance of such an installation is discussed later in this section.

Air Heating

The filtered and, possibly, humidified air was drawn through the filter bank and, then, over the steam coils which raised its temperature from ambient to that required in the building specifications.

The coil banks are located over the fan room and consist of parallel, vertical arrays of steel tubing. Within each bank there are 21 horizontal runs of tube, with alternate rows joined at the ends to form a continuous steam tube.

The major coil banks run east to west, parallel to the filter bank, but there are secondary coil banks at right angles to these, situated over the fan pulley assembly and between the openings through which air passed down into the fan chambers.

The steam supply for the coils came from a coal fired boiler, located in the Boiler Room to the west of the Fan Room, underneath the Ornament Room.

This area is situated within the second phase of the School's construction and the boilers were originally located in temporary accommodation adjoining the first phase at basement level.[15]

There was no additional heating provided to the air either within the main supply duct system or at the room discharges.

Warm Air Supply

Having been drawn from the filter banks, through the steam coil banks to the main circulation duct, the warm air was then fed to the vertical ducts serving individual spaces. These ducts were either built into the main load-bearing walls of the circulation areas, or constructed of timber framing and lining and situated within the working spaces, adjacent to the corridor walls.

The entries into these branch ducts from the main duct were controlled by adjustable dampers. In the East Wing some of these consisted of timber plates which could be adjusted vertically on a series of timber dowels. The remainder of the East Wing ducts and all of those in the West Wing were controlled by horizontally sliding timber doors.

The balancing of the system to give the desired warm air volume in each space would have to be carried out by adjustment of these dampers, since the outlets into the spaces themselves appear to have permitted only full opening or closing, although most spaces had multiple outlets.

This process must have been slow and laborious, due to the distances to be travelled from the upper floors to the main duct, via the Fan Room, to communicate instructions. It is thought likely, therefore, that initial balancing would involve determining optimum summer and winter settings for each damper, with short term control being achieved simply by opening or closing either the room outlets or the many opening windows.

Air-Extract System

These was no form of mechanical assistance to the air-extract system. Air movement was entirely dependent upon the pressure increase created within the building by the warm air supply system, and by natural convection within the spaces. Although the use of pressure and temperature differentials to promote air movement was common in such systems, there was no known use of heat recovery and all waste air was dumped directly to the external environment.

The extract system employed a layout of wall and box ducts similar to the supply system. Those from the basement and ground floors led to a main extract duct located above the ground floor corridor. From this duct the waste air was discharged under pressure to the exterior through the three grilles in the south wall, following the main fenestration pattern. These grilles, with their decorative weathering projections over, are shown on the measured drawings in Chapter 1.(see drawings nos. 1A and 1B) One recent study incorrectly identifies these openings as being air entry grilles.[16]

The extracts from the first and second floors ran vertically to discharge direct to the exterior. The terminals to these ducts were formed either by horizontal discharge grilles set into the main walls below the parapet or by roof penetrations to timber louvred boxes set above. These terminals are also shown on the measured drawings. (see drawings nos 1 and 2)

Fresh Air Circulation And Natural Ventilation

In winter the movement of air through the building, from the warm air supply system and into the foul air extract system, relied upon the building remaining sealed to give the necessary pressure differentials. The building does, however, incorporate opening windows in all spaces, which could be used to provide additional fresh air and localised, short-term temperature control.

In summer these windows could be used to provide natural ventilation to the rooms, provided there was sufficient external air movement. Should, however, external conditions be non-conducive to opening the windows in summer, due either to lack of air movement or, more likely in a city environment of the period, to excessive air pollution, the air circulation plant could be brought into use. With the boilers turned off the fans, powered by electricity, would be used to provide a supply of fresh, filtered air throughout the building.

Additional Heating

In addition to the main warm air circulation system, there were two other forms of heating in parts of the West Wing. The Professors' Studios, on the second floor, had open fires; the massive flues of which still exist as imposing features of these rooms. These would not have been required for purely functional reasons, and it is not clear whether they were a necessary requirement of the client, or a luxury provided by Mackintosh in his design.

The warm air system was designed to provide air at a temperature of 65°F, whereas the life studios were required to be heated to 75°F.[17] In order to achieve this additional temperature a steam radiator system was provided in these studio spaces. The locations of these radiators, which were later to be incorporated into an all-radiator heating system, are indicated on the floor plans, in Appendix I.

Boiler Room Insulation Chamber

As stated, previously, the chamber over the Boiler Room was not shown on any drawings, and its purpose is not recorded in any known documents.

The chamber is open to the north elevation, which enabled air to enter via the boiler room fresh air inlet louvres. At its southern end, a timber box duct exits the chamber and crosses the basement corridor at high level. Within this duct is a flap damper and a pulley system; a pinhole to the soffit indicates the exit location of a control string, the fixing cleat for which is still located on the wall below.

Having traversed the corridor, this duct enters the south wall of the corridor, within which it rises adjacent to the lift. The exit from this wall duct was discovered within the main extract duct above the ground floor corridor.

The only explanation for this system of chamber and ducts is that it formed an insulation layer between the boilers and the Ornament Room, located directly above. The air flow through the system would be regulated, as required, by the flap damper to remove excess heat from the boilers to the external air via the main air extract duct.

There is no similar system above the steam coil room. This is, however, located below the main Entrance Hall, which had no warm air ducts, and would be subject to the entry of cold air from the double entrance doors. The underfloor heating provided by the steam coils would be entirely acceptable in this space.

The effectiveness of the chamber is thrown into some doubt by records of post-completion documentation, where, amongst other complaints relating to unacceptable temperatures, there is record of a complaint of over-heating to the Ornament Room.[18]

The minimal size of the ductwork linking the chamber to the main extract duct would cast doubt upon its effectiveness, particularly since no evidence of fan assistance is to be found.

Original Contract Documentation

The design of the heating and ventilation plant was the responsibility of the heating contractor, based upon a detailed Performance Specification.[19] This document, dated 10 November 1897, was issued by Robert Scott IM and presumably, in the absence of any reference to services consultants, prepared by Honeyman and Keppie.

Tenders and detailed designs for the heating and ventilating plant were invited on the basis of this document, which specified the temperature to be achieved in each of the spaces at a given external air temperature; gave the number of air changes per hour required; described the type of equipment most likely to be suitable within the constraints of the building design and of the air ducts and plant areas designated on the construction drawings. A detailed schedule of volumes and window areas was also given for each of the spaces within the School.

It should be noted that the remainder of the building, along with the alteration to the systems during phase 2, was scheduled by means of a conventional Bill of Quantities, with diagrams for special features, very similar to the standard form of contract documentation in use at present, other than being hand-written in script.

The Architect's use of a Performance Specification for the heating system in 1897 is of considerable note, particularly when it is considered that architecture students in Glasgow in the early 1970's were being lecture on the basis that this form of scheduling works was a recent innovation and was only beginning to offer an alternative to the traditional form of billing.

Technical Appraisal

The fans are a pair of opposite handed, single inlet, radial plate bladed fans, of manufacture by B F Sturtevant Co. around the late 1890's. One fan was installed during each phase of the building's construction.

The earlier fan is plated to show manufacture at the parent company's plant in the United States, although the Sturtevant Company was, by the time of its installation, well established in the United Kingdom.[20] The second fan's plate records its manufacture by B F Sturtevant Company, London, although the British manufacturing plant was located at Birmingham.

The units are of similar pattern to the company's early "MONOGRAM" plate fan, but with a modified blade profile, to give an increased duty. Both impellers are supported on a common shaft, between wick-oiled bearings; this shaft being driven by an electric motor via lay-shafts and flat leather belts.

Although the drive motor no longer exists, the fans themselves, along with the oiling system, lay-shafts and even examples of the belts remain largely intact. (see photographs in Appendix II)

The performance of the fans was estimated, as follows, on the basis of detailed measurement of the units and by comparison with published information on comparable units.[21]

The maximum permissible tip speed for this type of early, riveted impeller construction would be in the order of 31m/s (6000ft/min) which for an impeller diameter of 2413mm (95") gives a rotational speed of 240rpm.

By comparison with modern equivalents a duty of 18-21m /s (38000-44000cfm) against a static pressure of 870-1000 Pa. (3 1/2"-4") could well have been achieved at maximum speed by each fan. This duty would produce an inlet velocity of 7.6-9m/s (1500-1750ft/min), which is consistent with this particular fan design.

Relating this duty to the volume of the School gives an air change rate of between 6-10 air changes/hr, which is in accordance with the requirements of the Performance Specification.

It is estimated[22] that the coil configuration, still existing above the fan chamber, would, when fed by a steam boiler, be more than capable of raising the ambient air temperature from 22° F to 65° F at this rate of air change, again in accordance with the specified requirements.

Historical Appraisal

In his book "The Architecture of the Well-Tempered Environment", Reyner Banham compared the School heating system with that of the Royal Victoria Hospital, Belfast, stating that the Hospital is ".....less progressive in architectural style, but more advanced environmentally".[23]

This comparison appears to be based mainly upon the fact that the air induction system to the Hospital was recorded as permitting a degree of adjustment to the relative humidity of the warmed air. This adjustment was made possible due to the use of water sprinklers washing over the air filters, which were formed of hanging coconut rope. The relative humidity of the air within the wards was known to be monitored and adjusted, by control of the water temperature to the sprinklers, prior to 1920.[24]

Banham records that the Royal Victoria Hospital is '....the first major building to be air-conditioned for human comfort.'[25] He notes, however, that the building was constructed in 1903, three years before fundamental patents for "air-conditioning" were lodged by Stuart Cramer.[26]

Cramer's patents are pre-dated by 14 years by the previously unpublished patents of Scottish engineers William Key and Robert Tindall, who described a means whereby a system of filters and water sprays might "....regulate the moistness or dryness of the air being heated."[27] Humidity control was not to be limited to the addition of moisture to dry air. This patent describes how "....moisture on entering will be dried in passing through the wet cords by having the moisture condensed out, and air too dry for respiration will have a natural humidity restored to it."[28] Further sophistication of control, if not of the means of achieving it, is demonstrated by the proposed use of "....blocks of ice with salt....in the current of air....to cool the incoming air."[29]

In the year 1892 Key and Tindall are seen to have demonstrated all the attributes of true air- conditioning, albeit using fairly crude technology. They describe control of air temperature and of humidity both upwards and downwards from the values of those of the external air. The system described in the patent is in line with the general principles of the system installed to the School some seven years before the Victoria Hospital's construction.

As noted earlier, the provision of water sprays was included in the Bills of Quantities for both phases of the School's construction and, certainly for the second phase, these were unlikely to have been specified for the purpose of cleaning the filter installation. The use of the sprays might be supposed to meet the requirements of Key and Tindall's patent if the patent can be shown to be directly linked to the design of the School's systems.

Banham mentions Key in relation to the School of Art, only as sharing 'home towns', but relates his information to no bibliographical reference.[30] He also mentions Key on one other occasion, linking his name to the Birmingham General Hospital, but, again, giving no clue to the source of this information.[31]

The Birmingham Hospital construction was commenced in 1893 and the environmental systems can be shown, by reference to contemporary documentation, to have been based directly upon the design principles laid down in Key and Tindall's patent.[32]

The architect for the Birmingham Hospital was William Henman, who was later to design the Royal Victoria Hospital, Belfast.

The plenum system of ventilation was not, however, part of the original design of the Birmingham General Hospital and its incorporation into the construction was not instigated by the architect or by the services consultant.

After construction had commenced on Henman's competition-winning design, Sir John Holder, chairman of the Building Committee, received a letter from a friend suggesting that he visit Glasgow to see 'a hospital in Scotland that had been ventilated in 1889 by William Key, Civil Engineer'.[33]

The hospital concerned was the Victoria Infirmary, designed by the Glasgow architect James Sellars. Sellars had died in 1888, however, and construction had continued after his death under the control of the surviving members of his practice, which included John Keppie. Keppie had, by the time of the visit, joined John Honeyman, to form the practice of Honeyman and Keppie, winners of the competition to design the new Glasgow School of Art.

Keppie's personal involvement with the Victoria Infirmary project is not documented, but his contact with the client appears to have been such that, in partnership with Honeyman, he secured the commission for the Bellahouston Dispensary from the Victoria Infirmary Board of Management during the 1890's.[34]

Five members of the Birmingham Hospital visited the Victoria Infirmary in November 1894, four years after its completion, reporting that the wards accommodated 25% more patients because of the more efficient ventilation.[35] This committee decided that the system should be incorporated into the construction of the Birmingham Hospital and, due to problems which arose with the works, arranged for Key to oversee the installation.

William Key had been directly responsible for the incorporation of the plenum system of heating and ventilating into the design of the Victoria Infirmary, after Sellars death.

As one of the Workmen's Governors, provided for in the Victoria Infirmary Act of 1888[36], Key was able to promote the adoption of the system of forced ventilation which he had developed, as described in the patent. The minutes of the Infirmary's Committees note that '....his zeal and devotion to the interests of the Infirmary, to which he had sacrificed so much of his leisure for many months, could not be too warmly acknowledged.'[37]

By the mutual involvement of Key and Keppie in the implementation of the Victoria Infirmary, the link between Key and Tindall's patent and the design of the environmental systems of the Glasgow School of Art is established beyond reasonable doubt.

The Victoria Infirmary, Glasgow is the antecedent of both the Glasgow School of Art and the Royal Victoria Hospital, Belfast. The School is, however, the earlier installation and the one in which the architect showed greater initial interest in and knowledge of the plenum system.

Despite his early lack of support for the plenum system, William Henman was later, along with Birmingham engineer Henry Lea, to profess great enthusiasm for it and was to speak at the Royal Institute of British Architects in favour of its adaptation wherever possible.[38] Lea had worked with Henman on the design of the Birmingham Hospital prior to the adoption of the plenum system and would have been involved in overseeing the installation, along with Key.

Documentation dating from the first decade of the twentieth century implies that Lea's was the major design input to the plenum system of ventilation; a view which is not disputed by the publication produced by the Company which still bears his name.[39]

There is no record of Key disputing Henman and Lea's claims to the design of the system, but the writer has been unable to trace any reference to Key after 1901.

The air distribution system to the Royal Victoria Hospital's heating system is examined in great detail by Banham.[40] This system was fed from a plant room located at one end of the main block, into a main duct over 160 metres long, requiring secondary heating coils at its branches to the distributor ducts.

In the Art School, however, the central plant room fed into the mid-point of the main duct, about 80 metres long, and no secondary heating of the air was necessary, other than additional room heating to those studios required to be at a higher temperature.

Banham devoted considerable space in his book to studies of the Victoria Hospital and also to Frank Lloyd Wright's Larkin Office building, Buffalo, New York[41] which he considered to be "..... about the only building contemporary with the Royal Victoria Hospital whose environmental architecture can really be compared with it in radicalism and ingenuity".[42] It is worthy of note, however, that whereas the Hospital consists basically of a horizontal distribution of identical spaces and the Larkin building of a vertical stack of similar work areas, the Art School comprises a far more complex grouping of spaces, both horizontally and vertically, of varied volume and function.[43]

Summary

In view of the fact that the School heating and ventilation system was initially constructed with the first phase, of 1897-1899, and not in 1904, as stated by Banham , it predated both the Victoria Hospital and the Larkin Building, which were constructed after 1900.

Taking into account the date of construction, the complexity of the system and the technology of the installations, such as the air filters, the writer considers that the Glasgow School of Art is of greater importance in the history and development of environmental systems related to architecture than either of Banham's key examples.

If one applies Reyner Banham's criteria for judgment of the history of environmental design the writer considers that the Glasgow School of Art must be considered the first building to have the technology fully integrated into its design which would have permitted air-conditioning for human comfort.

The School's future importance is enhanced by the loss of the Larkin Building to the demolisher's hammer in the 1940's, by the threat of demolition which hangs over the Birmingham General Hospital without the protection offered by statutory listing and by the lack of surviving installations to the Victoria Infirmary, Glasgow.

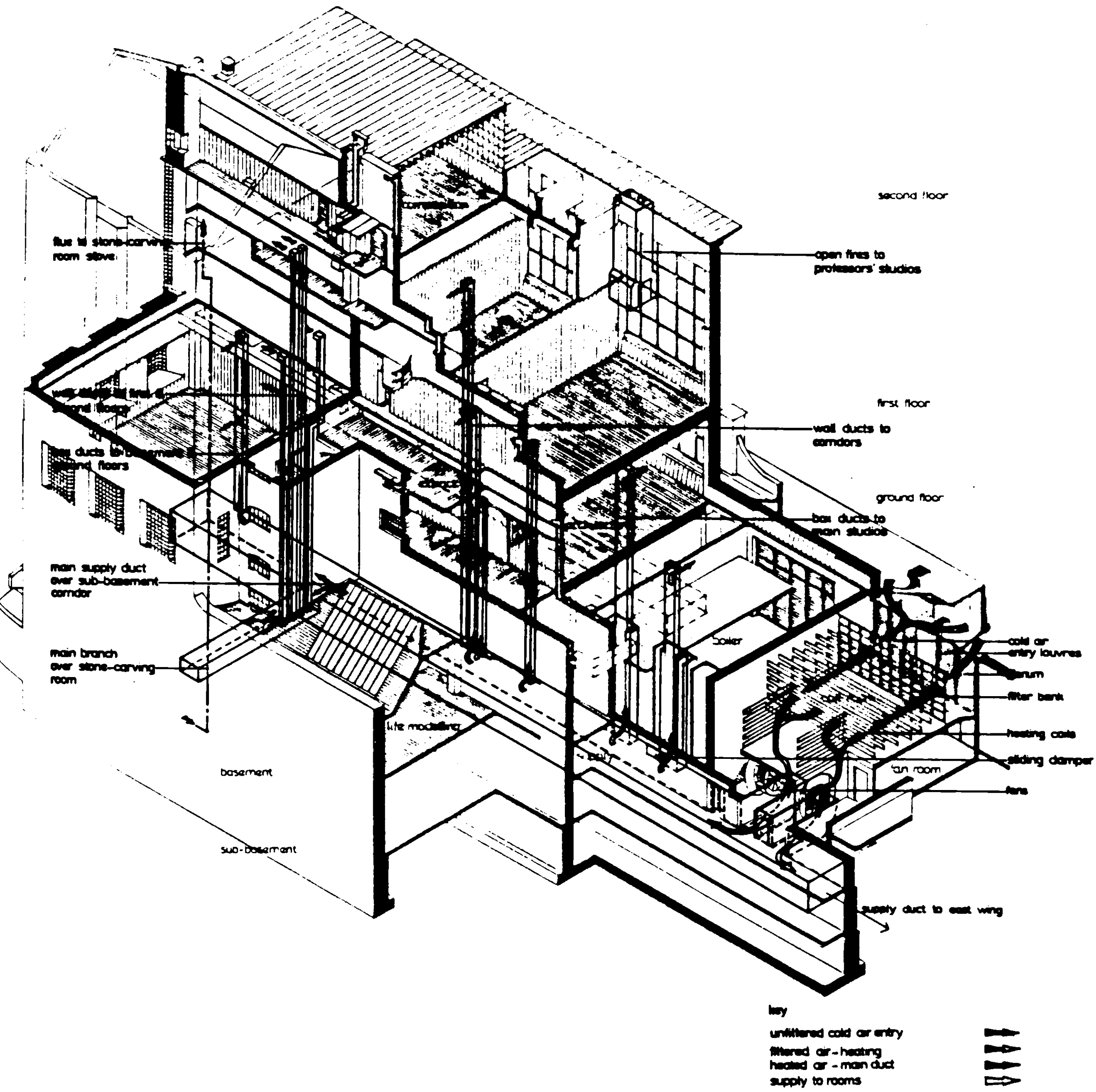
Drawing No 17

This drawing illustrates the original fresh air induction, filtering and heating and systems, along with the propulsion and circulation systems.

External air is drawn, by the suction of the fans, from the external well, through the filter bank and over the steam coils.

The heated air is then passed through the fans and into the main horizontal duct, above the basement corridor.

The timber control dampers, described in the text, are located at the exits from this duct to the vertical shafts.



FRESH AIR INDUCTION, HEATING
AND CIRCULATION

the
Glasgow School
of
Art

scale 0 5 10 15 metres

g m cairns 87

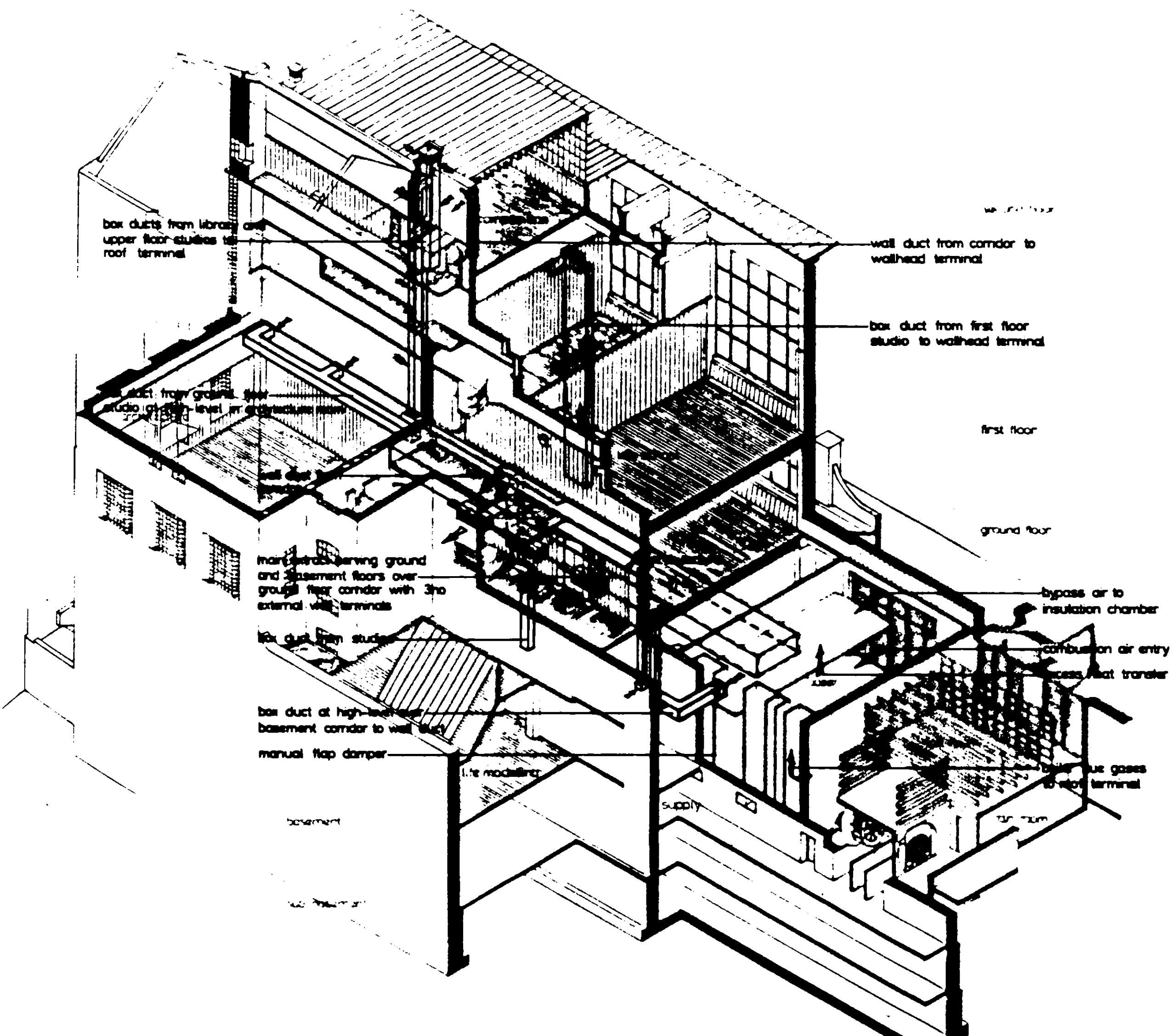
Drawing No 18

This drawing illustrates the original foul air exhaust system, along with the presumed operation of the Boiler Room Insulation Chamber.

The extract ducts from the basement and ground floor levels discharge to the duct above the ground floor corridor and hence to the exterior by way of the decorative openings shown.

Similar openings for an identical system to the East Wing are shown of drawing no 1B, in Chapter 1.

The cleat for the control string to the flap damper in the Insulation Chamber exit duct is to be found on the corridor wall, directly below the location of the duct exit from the Chamber.



key

fresh air inlet	
boiler excess heat exhaust	
individual room exhaust	
exhaust to main duct	
exhaust to external air	

BOILER ROOM INSULATION AND FOUL AIR EXHAUST

The Glasgow School of Art

scale 0 5 10 15 metres

g m cairns '87

References

1 Robert Macleod, "Charles Rennie Mackintosh, Architect and Artist", Collins, pp59-63.

2 Information supplied to the writer by Scottish Power, Glasgow.

3 S D Slater and D A Dow, "The Victoria Infirmary of Glasgow 1890-1990", The Centenary Committee, pp18-19.

4 Professor Andrew MacMillan has recounted to the writer his recollection of the detail of the installations.

5 B F Sturtevant, "Heating and Ventilating Apparatus", United States Patent No 100 211.

6 B F Sturtevant Company, "The Ventilation and Heating of School Buildings", Trade Catalogue, Boston, Massachusetts.

7 Thomas Carnelley, "Report on the Cost and Efficiency of the Heating and Ventilation of Schools", Report to the School Board of Dundee, held by Dundee Public Libraries Local Collection.

8 Reyner Banham, "The Architecture of the Well-Tempered Environment", the Architectural Press, p82.

9 idem. p82.

10 William Key and Robert Tindall, "Improvements in and Relating to the Heating of Air for Heating and Ventilating School-houses, Churches, and other Buildings, and in the Apparatus therefor", British Patent No 19 900.

11 S D Slater and D A Dow, "The Victoria Infirmary of Glasgow 1890-1990", The Centenary Committee, p27.

12 William Key and Robert Tindall, "Improvements in and Relating to the Heating of Air for Heating and Ventilating School-houses, Churches, and other Buildings, and in the Apparatus therefor", British Patent No 19 900.

13 I M Scott, "Bills of Quantities for the Glasgow School of Art", held by the Mackintosh Library, Glasgow School of Art.

14 idem.

15 illustrated in the contemporary pen and ink drawing reproduced in; Glasgow School of Art, "Charles Rennie Mackintosh and Glasgow School of Art", Glasgow School of Art, p2.

16 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p88.

17 As recorded in the Performance Specification for the heating system within; I M Scott, "Bills of Quantities for the Glasgow School of Art", held by the Mackintosh Library, Glasgow School of Art.

18 Recorded in the Minutes of Meetings of the Board of Governors of the Glasgow School of Art in 1910. The Minutes are held by the Mackintosh Library,

Glasgow School of Art.

19 I M Scott, "Bills of Quantities for the Glasgow School of Art", held by the Mackintosh Library, Glasgow School of Art.

20 The Company opened a manufacturing plant in Birmingham in 1890 and its Trade Catalogue of 1895 included illustrations of 4 examples of installations to buildings in England.

21 Analysis of the fans' performance was carried out for the writer by Joe Kennedy, mechanical engineer, and John Hooson of Woods of Colchester. John Hooson had previously worked with the Sturtevant Company and had access to archive literature which provided information on the design and performance parameters of the Company's products. The performance figures quoted in this Thesis were kindly supplied by Woods of Colchester, through the use of their computer modelling facility.

22 Joe Kennedy measured the approximate length and surface area of the coil installations in order to feed the information into the computer model.

23 Reyner Banham, "The Architecture of the Well-Tempered Environment", the Architectural Press, p75.

24 idem. p82.

25 idem. p82.

26 idem. p82.

27 William Key and Robert Tindall, "Improvements in and Relating to the Heating of Air for Heating and Ventilating School-houses, Churches, and other Buildings, and in the Apparatus therefor", British Patent No 19 900.

28 idem.

29 idem.

30 Reyner Banham, "The Architecture of the Well-Tempered Environment", the Architectural Press, p84.

31 idem. p76.

32 The British Architect, April 7 1893, London, p238.

33 This information was supplied to the writer by John Tovey who has researched the works of Henry Lea, services engineer for the Royal Victoria Infirmary, Belfast. In so doing Mr Tovey has collected various archive materials related to the adoption of William Key's system for the Birmingham General Hospital, on which Lea first worked with the architect of the Belfast Hospital. Mr Tovey's researches are published by the Company which still bears Lea's name (see Bibliography)

34 I Murray, "The Victoria Infirmary in Glasgow: history of a voluntary hospital 1890-1948", C L Wright, pp85-89.
Appendix entitled "The architects of the Victoria", covering the full lifespan of the Hospital.

35 John Tovey, "Henry Lea: Consulting Engineer 1839-1912", Hoare Lea and

Partners, p26.

36 S D Slater and D A Dow, "The Victoria Infirmary of Glasgow 1890-1990", The Centenary Committee, p19.

37 The Glasgow Herald, 15 February 1890, Glasgow.
This edition of the Glasgow newspaper carried a lengthy report on the official opening of the new Victoria Infirmary along with a detailed description of the Hospital buildings, the environmental systems and the means of their implementation.

38 Journal of the Royal Institute of British Architects, 19 December 1903, RIBA, London, p110.
This edition carried a report of Henman's talk at the RIBA. A further discussion on the subject was held on 6 June 1904 which was to lead to protracted debate on the subject of plenum ventilation in the pages of the Journal over the following 6 months (see Bibliography).

39 John Tovey, "Henry Lea: Consulting Engineer 1839-1912", Hoare Lea and Partners, pp27-28.
Although the pages prior to this mention William Key and the Victoria Infirmary, Glasgow, there is an implication that Lea and architect William Henman had adopted an incomplete design and had later perfected it in the Royal Victoria Hospital, Belfast. What was in fact lacking from the early installations at the Glasgow and Birmingham Hospitals was the integration of the system into the building at the design stage. This was achieved at the Glasgow School of Art before Lea and Henman carried their own works forward from the Birmingham Hospital into the design of the Royal Victoria Hospital, Belfast.

40 Reyner Banham, "The Architecture of the Well-Tempered Environment", the Architectural Press, pp75-84.

41 idem. pp86-92.

42 idem. p86.

43 The diagrams in Banham's book illustrate the basic principles of both systems and the building configurations. The Larkin building is illustrated in greater detail in Jack Quinan's book and the Victoria Hospital in John Tovey's study of Lea (see Bibliography).

Chapter 6
Conclusions

The Preface of this Thesis sets out the aim of contributing to a picture of the total architectural process of the design and implementation of the Glasgow School of Art.

The status of Charles Rennie Mackintosh as sole designer is questioned and, in relation to the School's environmental systems, the Thesis demonstrates that it was most likely John Keppie who provided the knowledge of the design and operation of the plenum system of heating and ventilation, to a degree which enabled its full co-ordination with the spatial and constructional design.

If one accepts Howarth's view that John Honeyman provided input into the evolution of the building plan[1] then a picture emerges of a total design concept, based upon consideration of spatial requirements, building technology and visual attributes, produced by a team, each of whom contributed according to his expertise and experience.

This initial design concept was then developed and refined over the lengthy period of its implementation, culminating in the end product which, in terms of visual design, is clearly the product of the mature Charles Rennie Mackintosh.

The challenge to the theory of the School as being a building not of its own time is central not only to a rational, non-emotive assessment of both the quality of the design and of the talent of its main designer, Charles Rennie Mackintosh, but, also, to a realistic view of the society and geographical location into which it was introduced. This Thesis questions the view that the building might be considered as 'emptied of specific social content from any particular time, speaking only of its own formal conditions.'[2]

Contemporary documentation shows that the building was certainly not unique in terms of its function and study of the local artistic output demonstrates that the initial design did not incorporate any influences, either of Celtic, Art Nouveau or Japanese origin, which were not to be seen in the works of other Glasgow artists or architects of the period.

In terms of the function which it was to fulfill within the higher educational system, the Glasgow School of Art was typical of a type which was introduced in substantial numbers during the latter years of the nineteenth century, providing places for students of art and design within a curriculum based upon the study of those subjects as related to science and industry.

It provided accommodation similar in type and layout to its contemporaries and, in line with the expressed views of those responsible for the formation and implementation of policies on art and design education, avoided reference to contemporary fashion in visual design.

The visual references of the building design are derived from both national and international aesthetics and their production is related to the skills of the engineering industries which were prevalent in the region.

The environmental technology of the building is sophisticated in its use of advanced technology, based upon local research and the previous experience of its designers.

That the Glasgow School of Art is unique in terms of the quality of the design may not be disputed, but the claim that it is not of its own time bestows upon it and its designer a mysticism which diverts attention from the rational analysis of the means of its procurement and of the development of its design over a period of some 12 years.

The Glasgow School of Art is a building which is born entirely of the age in which it was conceived; an example of the highest quality against which its contemporaries might be judged.

The visual picture of the School, as presented in the 3-dimensional drawings, is one which does not exist in the drawing and photographic records presently available. The record is, also, more comprehensive and accurate than any existing model, either physical or computer generated.

The study presents, therefore, a valuable additional contribution to the visual record of the Glasgow School of Art, available, hopefully, to students and admirers who may be unable to visit the building or not be afforded the degree of freedom of inspection bestowed upon the writer.

The preparation of the drawings was, also, an invaluable tool in the analysis of the building. Without the survey work required for the drawings and the visual record available within them it would not be possible to analyse and discuss the function of the environmental systems or of the building technology to such a degree of detail.

The detailed study of the environmental systems of the Glasgow School of Art presented in this Thesis is of importance not only to the history of the School but to the history of environmental design in relation to architecture.

Reyner Banham's book 'The Architecture of the Well-Tempered Environment' is shown by this study to be flawed, in particular his claim that Frank Lloyd Wright '....must be accounted the first master of the architecture of the well-tempered environment'.[3]

The question must be asked as to whether Banham's view that '....the development of practical systems is a purely American story.... (since) ....Americans appear to have been more aware of what they were doing....(and the)advances achieved at the Royal Victoria Hospital seem rather accidental'[4] was a pre-conception which influenced the manner in which he conducted his study rather than a conclusion arising from it.

Banham's book remains, however, a work of crucial importance to the history of environmental design in relation to architecture, having been the first, and remaining the major one of very few works on the subject.

This Thesis enlarges the field of knowledge of the history of environmental design, by its reference to previously unpublished documents. Similar study by Jack Quinan, in his publication on the Larkin Building[5], provides additional detail and correction of error in Banham's work in relation to that building.

These studies, read in conjunction with Banham's work, and not in isolation of it, will provide a more accurate record of the history of architectural, environmental design during the period 1890 - 1910, along with information on the key links between the designs of the major buildings of the period.

In presenting a study of the Glasgow School of Art based more upon technical analysis than previous studies, it is the writer's hope that similar studies of other buildings will appear in future.

Study and presentation of the spatial and technical design of buildings such as le Corbusier's Unite d'Habitation, Marseilles, Piano and Rogers' Centre Pompidou, Paris, and of the nature of the society into which they were implemented, might provide greater understanding of their place in the history of architectural design and of the lessons which they hold for other architects, beyond the simplistic reproduction of their more striking visual symbolism.

References

1 Thomas Howarth, "Charles Rennie Mackintosh and the Modern Movement", Routledge and Kegan Paul, p79.

2 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p57.
Professor Andrew MacMillan quotes Anthony Vidler, from 'The Third Typology', 'Oppositions', Winter 1976-7, p2. He states that the Glasgow School of Art 'uncannily approaches Tony Vidler's definition'.

3 Reyner Banham, "The Architecture of the Well-Tempered Environment", the Architectural Press, p70.

4 idem. pp26-27.

5 Jack Quinan, "Frank Lloyd Wright's Larkin Building - Myth and Fact", MIT Press.

Postscript
Post Occupancy Changes

Introduction

Since its completion in 1909, the School has remained, throughout its life, a working Art School. Despite its acknowledged importance to the history of architecture and the large numbers of visitors who visit it each year, the building has never been considered a museum by its Board of Governors.

As a working building, the School has, of necessity, been subject to alteration at numerous times throughout its life, in order to provide the best environment for those who study and work within it and in order to make the most effective use of the space provided. Even within a short period of time after its completion there were alterations carried out, as to the second floor east studios, where the enclosure of the circulation space was extended at several times, eventually being completed to the full length, connecting the Pavilion to the east stair.[1]

Many of the changes made during the School's lifetime have improved its operational efficiency, as in the case above, and some, such as the additional exit to the basement Lecture Theatre, are difficult to distinguish from the original design, having been carefully executed in the original style.

There, are, however, changes which have been made during the past 80 years which, despite the best intentions of those who instigated them, have improved neither the quality of the space nor the environmental conditions within the building and which do, in fact, detract from the original design concepts of the building.

In several fields relating to the environmental systems and to the likely fire performance of the building it would be possible to apply recently developed technology in order both to improve the performance of the building and, also, to reinstate certain areas to a condition nearer to that of the original construction.

Such changes might be considered as improving both the efficiency of the building in terms of its function as an Art School and its authenticity as a major architectural monument.

Consideration of these changes is included here, related to the totality of the design of the building; its present, continuing fulfilment of its original function and the future continuation of this process.

Proposed Re-Instatement Of Warm-Air Heating

The principal reason for consideration of the possibility of reinstating the original heating system is in order to prove the feasibility of removing the unsightly pipework which has been added to the building to serve the present hot water circulation system. The radiators which are not original fittings would also be removed, enabling features such as the window panelling to the main studios to be reinstated and the Library window bays to be made accessible once more.

The installation of new plant to provide warm air heating to serve the building as it is now and to maintain acceptable modern day room temperatures in the order of 18° C with an ambient temperature of -1° C is a perfectly feasible proposition. In such a reinstatement, the basic principles of the original system would not require to be changed; only the plant would be updated to provide greater efficiency and economy.

The air ducts, although not utilised for their intended purpose for over sixty years, remain virtually intact and the main plant areas are available for re-use.

The sequence of operations for reinstatement of the system would be as follows:-

The existing filter banks, heating coils and coil chamber floor slab would require to be carefully removed, with protection of the existing fans during this operation. The coil chamber and fan room under would then be utilised to house the air-handling units.

The original external louvre panel openings within the basement well area, at present partially bricked up, should be opened up, with installation of new acoustic louvres, of colour and pattern to suit aesthetic requirements.

Installation of 2 no. air-handling units, as scheduled in Appendix III, would be completed within the fan and coil chambers. These would be detailed to run simultaneously, serving the entire building.

All pipework etc for the hot water circulation system, located within the air circulation ducts, should be removed and it should be ensured that all ducts and room outlets are clear.

Overhaul of the original timber shutter dampers to the duct entries would be undertaken. Some of these would require renewal, but many remain in full working order. These dampers would still provide a more than adequate means of regulating air flow to the individual spaces.

Since it would not be acceptable in the present day to allow the warm air from the building to be dumped direct to the external air, it is necessary to consider a means of heat recovery, which was not part of the original system design. The simplest method of achieving this is to utilise the main extract ducts, over the ground floor corridors, as return air plenums.

The room extracts from basement and ground floors already discharge to this duct and may, therefore, be retained as built.

The upper floor extracts would, however, required to be re-routed downwards to this plenum. It is anticipated that these ducts could mostly be installed within the existing box framing to the studio spaces, with minor extensions and alterations, constructed to match the existing. The upward ducts would be sealed above the room outlets, leaving the unused sections vented at their present external outlets.

The return air plenums would require to be sealed by building up, internally, the 3 no. discharge grilles on the south facade of each wing. Installation of a new return air duct from each plenum to the air-handling unit would be required. In the West Wing this duct would be installed running from the plenum into the original boiler flue, which is adjacent its east extremity, dropping to the level of the boiler room insulation chamber, through which it would pass to the air-handling unit.

In the East Wing a new duct route would be required, possibly running via the spaces adjacent to the Secretary's Office.

Control of this heating system would be achieved by means of suitably located room thermostats with frost stats and low-level room stats to give protection to the building fabric during periods of unoccupation. Initial balancing of the system would, as originally, be achieved by determining optimum summer and winter settings for the dampers in the main supply duct.

The installation of a heat-recovery system would not only enable a high proportion of usable heat to be reclaimed prior to air discharge, but would also permit air cooling in summer, when the ambient temperature exceeded the desired internal temperatures.

In order to achieve the fire resistance which would be required under current Building Regulations, electrically or pneumatically controlled fire dampers should be installed at each floor level, within the air ducts. These dampers would close automatically in the event of the fire alarms being operated, simultaneously with the air-handling unit fans being shut down.

The present system of smoke detectors, liked to the alarm system, would be extended by the addition of detectors within the main feed and return air ducts.

It would be possible, also, to incorporate an over-ride facility into the control panels, enabling the fire authority to open pre-determined dampers and operate the air-handling unit extract fans, to give a capability of smoke extract.

It is estimated[2] that the existing electrical supply, fire alarm system and heating plant are adequate for incorporation into the proposed installations.

Retention of Existing Fans

Due to the previously stated historical significance of the original heating system, it is considered desirable to retain the existing fan installation, which is a rare and almost perfectly preserved example of 19th century technology.

Although the new air-handling units would pass warm air through the fans to the main duct, it would be feasible to retain and operate them at slow speed, without detriment to the efficiency of the system.

It is proposed that a viewing gallery be constructed over the fans, with access from the east basement.

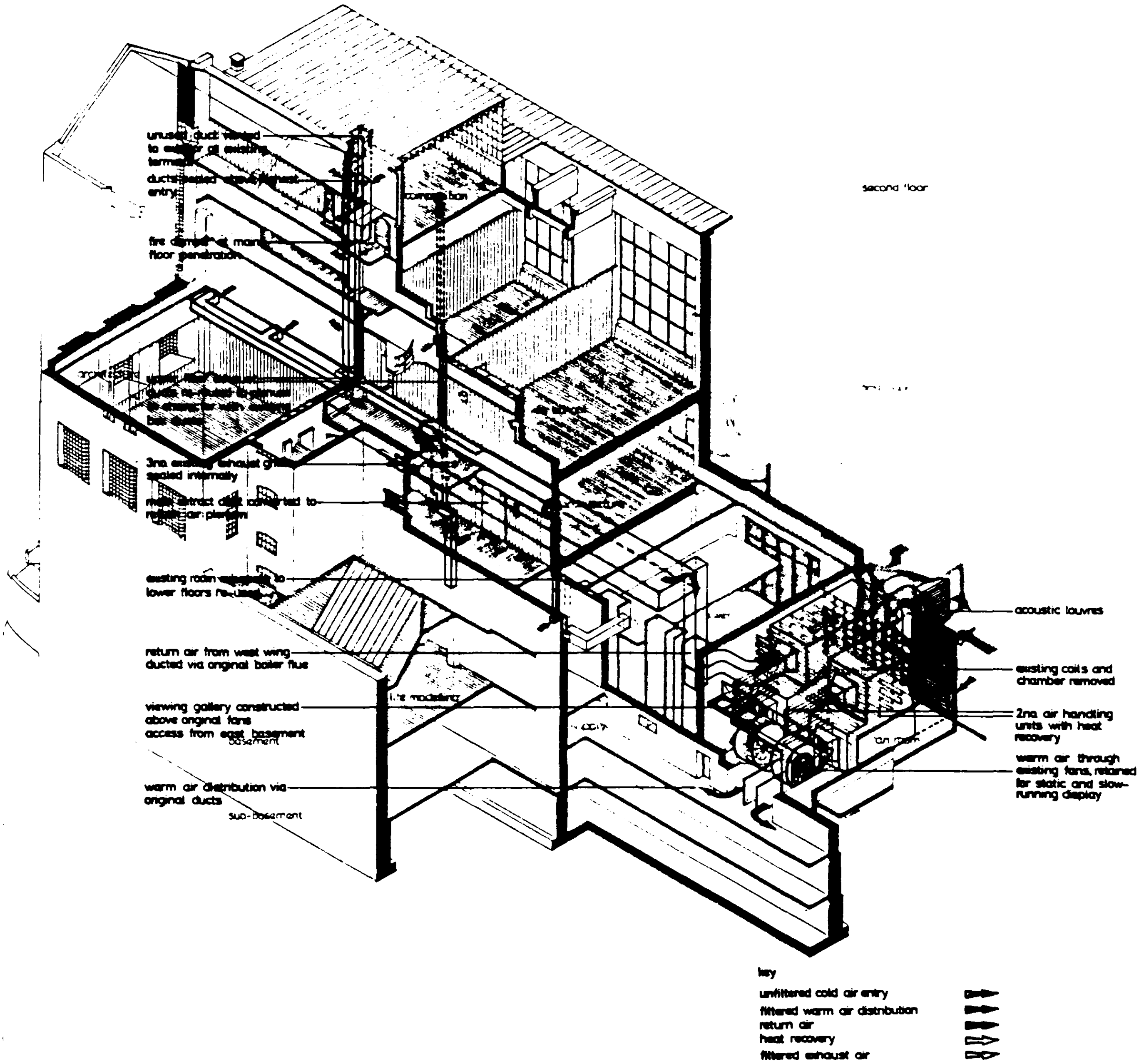
Detailed recording of the coil and filter installations during removal would enable drawings and models to be constructed which, along with demonstration of the fans, would provide an excellent and unique facility.

Drawing No 19

This drawing illustrates the proposed reinstatement of a warm air, circulation heating system, utilising the existing ducts and chambers wherever possible

The air handling units are installed in the space occupied by the original motors and the steam coils. It is unfortunate that the coils, which still exist, require to be removed, but they should be recorded in detail prior to removal.

The fans, which are the most significant items of plant, are retained and overhauled.



PROPOSED REINSTATEMENT OF
WARM AIR HEATING SYSTEM

the
Glasgow School
of
Art

scale 0 5 10 15 metres

Analysis of the Fire Performance of the Building

As recorded in Chapter 3, the addition of the two secondary stairs during the second phase of construction cannot be shown to have been made in order to provide means of escape as a primary concern. Their existence is, however, essential in terms of current legislation, in order to provide safety for the occupants.

The enclosure of the stairs has been the subject of previous attempts to upgrade the fire separation of sections of the building and to increase margins of safety for exit. These attempts have not, however, been entirely successful and, in the light of current knowledge and technology, it is possible to propose additional measures which will greatly increase fire resistance and improve escape provisions.

Escape Route Enclosure - Analysis

As indicated on the measured drawings and recorded in contemporary photographs the stairs and corridors of the School were not originally separated by doors and screens, giving a spatial flow and changes of scale without interruption.[3] There was, therefore, no fire separation or smoke control, as would be required by modern Building Regulation standards.

At a later date, around the early 1960's, doors and screens were installed to the stair and corridor intersections in an attempt to upgrade the building's fire resistance. (see photographs to Appendix 11) Although an effort was made to emulate Mackintosh's detailing in their construction (see drawing no. 20), they lack the attention to detail and proportion of the originals and destroy the spatial flow of the original design.

These doors and screens are almost totally ineffective in achieving their purpose. It is estimated by the Fire Research Station that, due to the lack of frame rebates and intumescent seals, the doors would fail when exposed to fire for no more than twenty minutes.[4] The glazing of the doors and screens in wired glass also offers no resistance to the transmission of thermal radiation.

To the West Wing the location of the screens at first floor level and on the intermediate landing over the corridor gives separation of the stair and studios, but in the ground floor and basement levels here and in the east stair the screens are located within the corridors. At these locations the unprotected doors to studios and workspaces discharge directly into what should be termed the "protected zone". This arrangement is contrary to the requirements of Section E of the current Building Regulations[5], which would require enclosure of the protected zone by means of fire-resistant doors and walls.

In the West Wing there are two discharges from the stair, to the corridors at basement level, past the Lecture Theatre and Modelling School, and at sub-basement level, past the Stone Carving room. Both corridors exit to the west to Scott Street.

Again, at both levels, the enclosure of the stair and exit routes does not meet the requirements of current Regulations. The Lecture Theatre, for example, has single unprotected doors onto the escape corridor whereas the Regulations would require a protected lobby between the spaces.

A similar arrangement of doors to exit route exists in the lower levels of the East Wing, where the route leads to the external doors on Dalhousie Street.

It must be concluded that the addition of the doors and screens has detracted from the spatial qualities of Mackintosh's design whilst contributing little to the safety of the occupants in the event of fire. Should a fire break out in one of the lower levels, such as the ground floor Senior Architecture room within the West Wing, the occupants of the upper levels could find themselves travelling towards the heart of the fire with no protected doors to prevent rapid break out of smoke and fire into the path of their exit.

Proposal for Replacement of Screens

It should be noted that, under the terms of the Building

Regulations, notice may be served by a Local Authority requiring an existing building to comply with the requirements of Section E.[6]

Current Regulations require resistance to the passage of thermal radiation in wall construction, although not in doors. Intumescent glass, a laminated product in which the inter-layers turn opaque when exposed to heat, is the only glazing product which fulfills this requirement.

Re-appraisal of the location and construction of the doors and screens, in the light of current Building Regulations and with consideration of modern fire-resistant materials technology could give a considerable improvement to the fire-rating of the stair enclosure, along with an opening up of the views which existed in the original design.

Such a design proposal should not seek to emulate Mackintosh's designs to appear part of the original building, but should give the maximum clear glass area and the simplest form of detailing consistent with the requirements of fire-resistance. The screens will then be an obvious addition to the original design, but will detract from it as little as possible.

The current manner of assessing the fire rating of screens and doors, to BS 476; Part 8[7], requires that complete assemblies are tested and it is the entire unit which is rated accordingly.

The proposal shown to the lower section of drawing no. 20 employs the maximum available glass sizes in conjunction with minimum frame assemblies, which are certified as having passed the required tests for this application.

The design does not, however, provide an aesthetically acceptable solution to the problem, being poorly proportioned due to the restrictions of available materials; still reducing the size of the opening and restricting the through visibility.

An alternative approach to the problem was adopted; investigating the theoretical uses of fire-resistant glass in a frameless construction, to give a fire rating which would hopefully exceed the estimated twenty minute rating of the existing screens. If the construction did not, however, achieve the required 1 hour rating, Relaxation of the Building

Regulations could be sought, on the grounds that the existing situation was being improved and that due attention must be paid to the importance of the building.

It is agreed, by the Fire Research Station and glass manufacturers, that intumescent glass, being a Class A or B impact resistant, laminated glass, may be used in a frameless construction, provided that care is taken to prevent moisture penetration to the intumescent inter-layers.[8]

Although the intumescent properties of this expensive material are not required for the door, which need not resist the passage of thermal radiation, none of the other available fire resistant glasses are considered suitable for this application.

Borosilicate glass is not acceptable in a frameless construction, having only a class C impact resistance. Although polished wired glass may be laminated to other glasses to provide the necessary fire resistance and impact resistance, it is considered that the wire reinforcement would make it visually unacceptable alongside the clear intumescent glazing to the screen.

The use of intumescent seals and smoke seals between units, along with rigid location to the structure, would give the required continuity of fire-resistant construction for the entire door and screen assembly.

Drawings nos. 20 and 21 show details of the existing screen installations and of proposed frameless screen constructions, to give a fully glazed separation of the stair and corridor. The intention of the proposals is to achieve a design which will reinstate, as closely as possible, Mackintosh's visual concept of the intersection of the spaces.

The initial proposal, on drawing no 20, uses materials which have achieved current test approval for compliance with Building Regulations. They do not, however, achieve an acceptable level in terms of aesthetics.

Drawing no 21 illustrates a more acceptable design solution, based upon the theoretical use of new materials. The construction details of this proposal are shown on drawing no 22.

The theoretical possibilities shown in these drawings would require to be subject to test of a full scale mock-up, under British Standard conditions, to establish their true fire-resistance, prior to any scheme being initiated to carry out installations within the School.

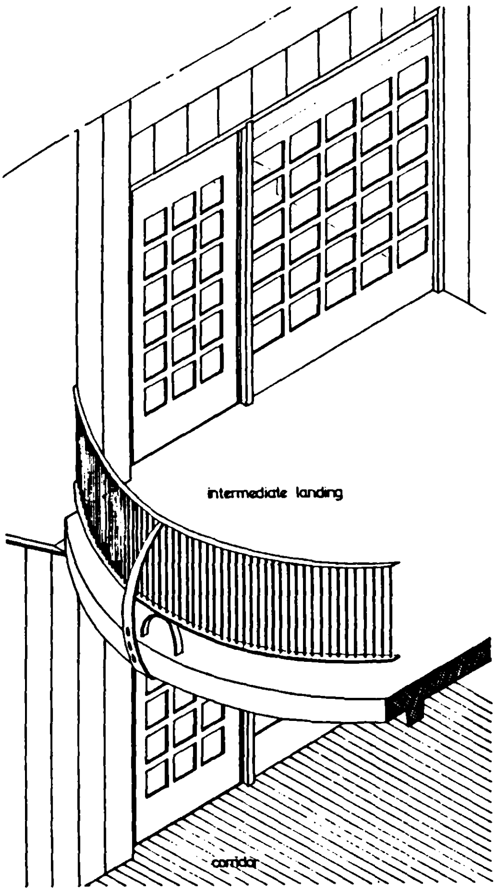
The screens should be situated across the stair landings, at the south corridor wall, at all levels, excluding all working spaces from the stair enclosure. At the ground and upper floor levels these spaces will then have two means of escape, into the stair enclosure or along the corridor to the central stair area, which should be enclosed to a similar standard.

Although aesthetically less acceptable than a symmetrical screen layout, the doors to the stair must be located to one side, opening against the wall, as drawn, in order to minimise the obstruction to the stair when opened in the direction of escape.

At the basement and sub-basement exit routes from the West Stair it would not be practical or aesthetically acceptable to alter features such as the Lecture Theatre access to comply with current Regulations. By the insertion of unobtrusive intumescent seals into the door edges and by treatment of the doors with intumescent varnishes, however, it would be possible to increase the fire resistance of the doors and also the safety margins for escape from the building.

Drawing No 20

Existing screen construction and frameless screen construction complying with existing test approvals.

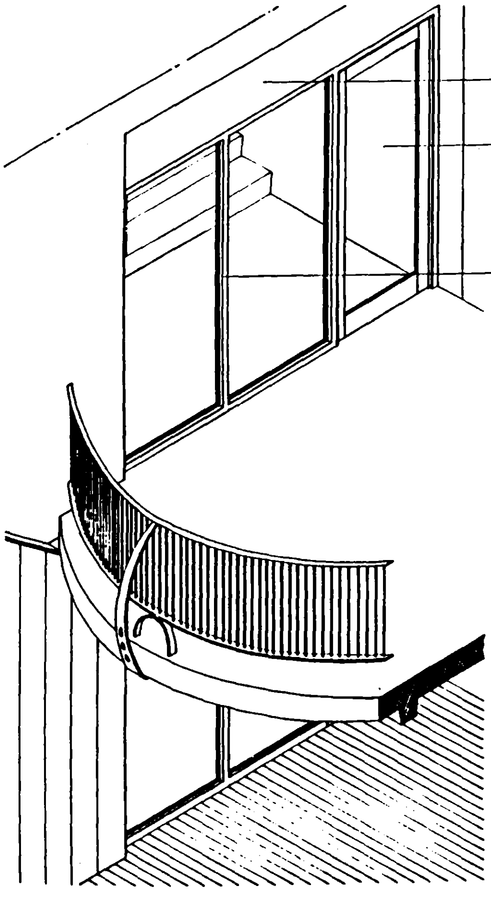


screens and doors of timber construction
glazing of georgian wired glass with
timber glazing beads
doors are double-swing, self-closing,
with no checks, smoke seals or
intumescent strips

FIRST FLOOR WEST STAIR / CORRIDOR INTERSECTION

AS EXISTING JANUARY 1988

AS PROPOSED TO COMPLY WITH BUILDING REGULATIONS



over panel of 12.7mm glassfibre reinforced
plasterboard on metal stud
1 hr fire resistance

door of 44mm hardwood framed construction
glazed in single pane 6mm borosilicate fire-
resistant glass. metal channel glazing system
with hardwood cover beads. intumescent seals
to sides and top.
1/2 hr fire resistant, self-closing

screen of 92x40mm hardwood, bedded in
intumescent mastic to walls. glazed in 20mm
intumescent, fire-resistant glass. metal angle
glazing beads with hardwood cover beads
1 hr fire resistance

note - over panel and mullion included only
due to restricted available glass sizes

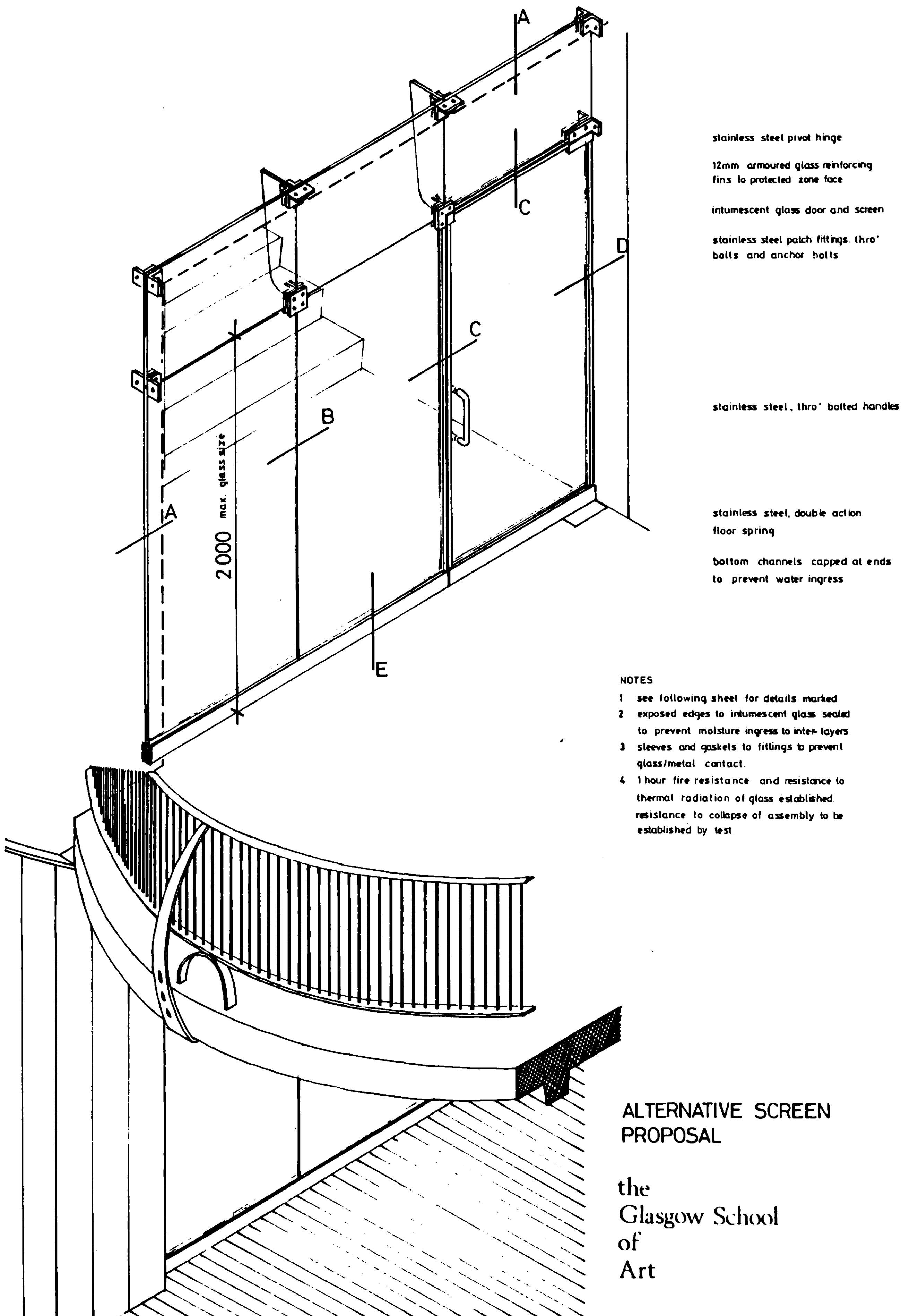
the
Glasgow School
of
Art

scale 0 0.5 1 1.5 2 metres

g m cairns 88

Drawing No 21

Screen design based upon the theoretical use of intumescent glass.



NOTES

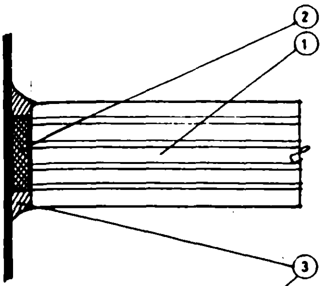
1 see following sheet for details marked.
2 exposed edges to intumescent glass sealed to prevent moisture ingress to inter-layers.
3 sleeves and gaskets to fittings to prevent glass/metal contact.
4 1 hour fire resistance and resistance to thermal radiation of glass established. resistance to collapse of assembly to be established by test.

ALTERNATIVE SCREEN PROPOSAL

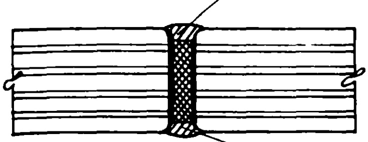
the Glasgow School of Art

Drawing No 22

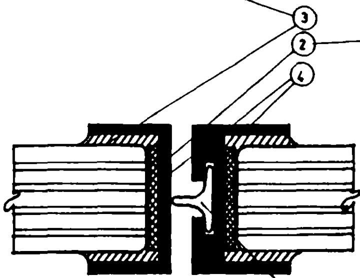
Details of the proposed construction of the screen indicated on drawing no 21.



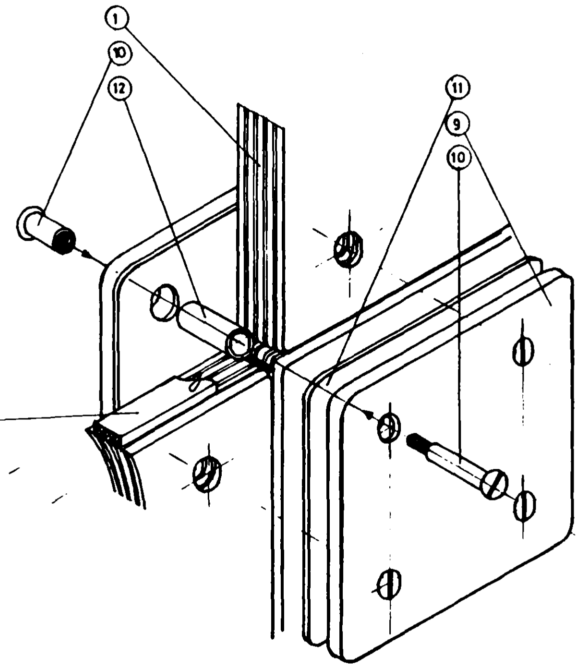
DETAIL A



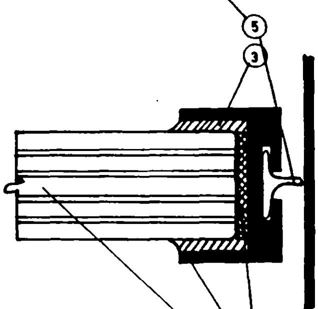
DETAIL B



DETAIL C



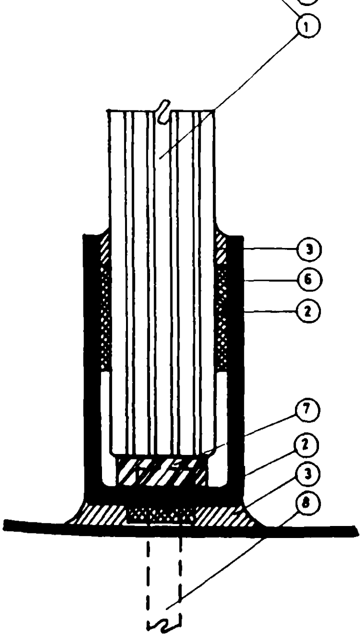
PATCH FITTING - 1/2 FULL SIZE



DETAIL D

KEY

1. 18-20mm intumescent glass, class A or B impact resistant, laminated.
2. intumescent strips, sized to suit.
3. water-resisting, bonding sealant.
4. stainless steel channel edge protection.
5. smoke seal.
6. stainless steel channel bottom frame.
7. hardwood blocking pieces.
8. stainless steel anchor bolts and packers to level.
9. stainless steel patch fitting.
10. stainless steel, countersunk thro' bolt.
11. gasket.
12. sleeve.



DETAIL E

FULL SIZE DETAILS

ALTERNATIVE SCREEN DETAILS

the
Glasgow School
of
Art

Smoke Detectors and Fire Dampers

There is at present a system of smoke detectors to the major spaces of the School. The proposals for reinstatement of a warm air heating system incorporate provisions for extension and upgrading of this system to provide smoke containment in the event of fire.

Since the technology did not exist at the time of construction, there would be no provision of fire dampers at the floor penetrations of the air circulation ducts. It is highly unlikely that these were sealed when the original heating system was taken out of use.

There is no requirement under Section D of the Building Regulations for the floor penetrations to be upgraded to an existing building.[9] Alteration to reinstate a warm air circulation system would, however, require consideration of this aspect and proposals would be incorporated in the design for reinstatement of the heating system.

Structural Fire Precautions

As noted previously, the main structure of the West Wing is generally encased within mesh and cement render, giving fire resistance to the steel structure.

The main members of the East Wing have never had this protection added retrospectively and to do so now would, of course, have a considerable effect upon the character of these spaces, with particular respect to the visual 'dating' of them within the construction programme.

Present day technology does, however, offer the possibility of upgrading the fire resistance of the steelwork to meet current standards by the addition of intumescent coatings, which will not detrimentally affect the overall appearance of the areas.

Such coatings are also available in forms which might be applied to the soffits of timber floor constructions, again upgrading their fire resistance and increasing the fire separation of adjacent floor spaces.

Summary

The application of the most up-to-date technology, in accordance with the most recent Building Regulations, would enable the performance of the building to be upgraded and would also enable more faithful reproduction of the original design.

In particular, the opening up of the views between spaces in the circulation areas would enable the visitor to the building to appreciate the original design concept of the interplay of scale and enclosure.

References

1 Glasgow School of Art, "Charles Rennie Mackintosh and Glasgow School of Art", Glasgow School of Art, p49.

2 Estimated as part of the computer model of the environmental systems by Joe Kennedy and Woods of Colchester, as discussed at Chapter 5.

3 William Buchanan (editor), "Mackintosh's Masterwork; the Glasgow School of Art", Richard Drew, p107.

4 Information supplied to the writer by Mr Richardson of the Fire Research Establishment.

5 The Building Regulations (Scotland) Act, London.

6 idem.

7 British Standard test deemed to satisfy the requirements of the Building Regulations.

8 The writer's conversations with Mr Richardson of the Fire Research Establishment covered the theoretical use of intumescent glass, the known and likely limitations of its use and the form of construction which would be likely to achieve test approval or, at least, a standard which would be accepted under relaxation as being an improvement upon the existing situation.

9 The Building Regulations do not allow for the upgrading of the construction to be required by a Local Authority where no other associated works are being undertaken. Any works to the environmental systems, such as reinstatement, would require to conform fully to current regulations, including the installation of dampers.

Bibliography

Books

Banham, Reyner — THE ARCHITECTURE OF THE WELL-TEMPERED ENVIRONMENT
London, 1969

Benton, Benton and Sharp — FORM AND FUNCTION: A SOURCE BOOK FOR THE HISTORY OF ARCHITECTURE AND DESIGN 1890 - 1939
London, 1975

Buchanan, William (Editor) — MACKINTOSH'S MASTERWORK: THE GLASGOW SCHOOL OF ART
Glasgow, 1989

Cooper, Jackie (Editor) — MACKINTOSH ARCHITECTURE: THE COMPLETE BUILDINGS AND SELECTED PROJECTS
London, 1977

Games, Stephen — BEHIND THE FACADE
London, 1985

Glasgow School of Art — CHARLES RENNIE MACKINTOSH AND GLASGOW SCHOOL OF ART
Glasgow, 1961

Glasgow School of Art — IRONWORK AND METAL WORK AT GLASGOW SCHOOL OF ART
Glasgow, 1968

Gomme, A and Walker, D — ARCHITECTURE OF GLASGOW
London, 1968, revised 1987.

Howarth, Thomas — CHARLES RENNIE MACKINTOSH AND THE MODERN MOVEMENT
London, 1977

Ingels, M — WILLIS HAVILAND CARRIER, FATHER OF AIR CONDITIONING
1952

MacGibbon, D and Ross, T — THE CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTLAND
1887 - 1892

Macleod, Robert — CHARLES RENNIE MACKINTOSH: ARCHITECT AND ARTIST
London, 1983

Moffat, Alistair and Baxter, Colin — REMEMBERING CHARLES RENNIE MACKINTOSH
Lanark, 1989

Murray, I — THE VICTORIA INFIRMARY OF GLASGOW - HISTORY OF A VOLUNTARY HOSPITAL 1890 - 1948
Glasgow, 1967

Nuttgens, Patrick (Editor) — MACKINTOSH AND HIS CONTEMPORARIES
London, 1988

Pevsner, Nikolaus — PIONEERS OF MODERN DESIGN
London, 1960

Pevsner, Nikolaus — SOURCES OF MODERN ARCHITECTURE AND DESIGN
London, 1968

Robertson, Pamela (Editor) — CHARLES RENNIE MACKINTOSH - THE ARCHITECTURAL PAPERS
Glasgow, 1990

Sinclair, Fiona — SCOTSTYLE - 150 YEARS OF SCOTTISH ARCHITECTURE
Edinburgh, 1984

Slater, S D and Dow, D A — THE VICTORIA INFIRMARY OF GLASGOW 1890 - 1990
Glasgow, 1990

Quinan, Jack — FRANK LLOYD WRIGHT'S LARKIN BUILDING - MYTH AND FACT
Cambridge, Mass., 1987

Young, A M — CHARLES RENNIE MACKINTOSH (1868 - 1928) ARCHITECTURE, DESIGN AND PAINTING
Glasgow, 1968

Young, A M and Doak, A M — GLASGOW AT A GLANCE - AN ARCHITECTURAL HANDBOOK
Glasgow, 1965

Periodicals

Alison, Filipo — "C R Mackintosh"
CASABELLA, No 37, Volume 8/9
Milan, 1973

Futagawa, Y and MacMillan, A — "Charles Rennie Mackintosh, The Glasgow School of Art, Glasgow, Scotland, Great Britain. 1897 - 1899. 1907 - 1909"
GLOBAL ARCHITECTURE
Tokyo, 1979

Harbison, Robert — "Masters of Building - Glasgow School of Art"
THE ARCHITECTS' JOURNAL, 14 June, pp 40 - 59
London, 1989

Henman, William — "Notes on the Plenum System of Ventilation"
JOURNAL OF THE ROYAL INSTITUTE OF BRITISH ARCHITECTS, 11 June, pp 427 - 430
London, 1904

Henman, W and Cooper, T — "Discussion - Plenum Ventilation and the Royal Victoria Hospital, Belfast"
JOURNAL OF THE ROYAL INSTITUTE OF BRITISH ARCHITECTS, 25 June, pp 462 - 464
London, 1904

Howarth, Thomas — "Mackintosh and the Scottish Tradition"
MAGAZINE OF ART, pp 264 - 267
London, Nov. 1948

Kimura, Hiroaki — "Charles Rennie Mackintosh"
PROCESS ARCHITECTURE, No 50
Tokyo, 1983

Taylor, E A — "A Neglected Genius - Charles Rennie Mackintosh"
THE STUDIO, Vol. 105, pp 345 - 352
London, 1933

Tovey, John — "Hospital Design - Ventilating the Royal Victoria Hospital"
RIBA JOURNAL, October
London, 1981

Unknown — "The New General Hospital, Birmingham"
THE BRITISH ARCHITECT, April 7
London, 1893

Unknown — "Discussion on the Foregoing Papers" (Environmental Systems)
JOURNAL OF THE ROYAL INSTITUTE OF BRITISH ARCHITECTS, 19 December, pp 110 - 113
London, 1903

Unknown — "Discussion on the Plenum System of Ventilation"
JOURNAL OF THE ROYAL INSTITUTE OF BRITISH ARCHITECTS, 11 June, pp 431 - 442
London, 1904

Unknown — "Victoria Infirmary - Inauguration by the Duke of Argyll"
GLASGOW HERALD, 15 February
Glasgow, 1890

Walker, D — "The Early Works of Mackintosh"
ARCHITECTURAL REVIEW, Vol. 144, pp 355 - 365
London, 1968

Note — In addition to the articles quoted above, there was a protracted correspondence on the subject of the Royal Victoria Hospital, Belfast in the pages of the Journal of the Royal Institute of British Architects during the period June - December 1904. This correspondence does not relate directly to the subject matter of this Thesis, but is of interest in assessment of the Hospital's systems.

Unpublished Sources

Cairns, George	THE WEST WING OF THE GLASGOW SCHOOL OF ART Dissertation and Technical Study presented to the Mackintosh School of Architecture 1988
Carnelley, Thomas	HEATING AND VENTILATING OF SCHOOLS Report to the School Board of Dundee 1889
Cramer, Stuart	IMPROVEMENTS IN AND RELATING TO HUMIDIFYING AND AIR CONDITIONING APPARATUS British Patent No 17 247 1907
Glasgow School of Art	BOARD OF GOVERNORS MINUTE BOOKS NOS 4 - 7 BUILDING COMMITTEE MINUTE BOOK Glasgow School of Art Glasgow, 1895 - 1911
Glasgow School of Art	REPORT BY THE DEPUTATION APPOINTED BY THE BOARD OF GOVERNORS TO VISIT VARIOUS SCHOOLS OF ART Glasgow School of Art Glasgow, 1893
Key, William and Tindall, Robert	IMPROVEMENTS IN....THE HEATING....AND VENTILATING SCHOOL HOUSES.... British Patent No 19 900 1892
Key, William	IMPROVEMENTS IN THE VENTILATING OF BUILDINGS British Patent No 23 435 1901
Key, William	MECHANICAL VENTILATION AND EXTERMINATION OF SPORES AND GERMS OF DISEASE Paper presented to the Sanitary Association of Scotland, 24 August Glasgow, 1894
Kimura, Hiroaki	CHARLES RENNIE MACKINTOSH: ARCHITECTURAL DRAWINGS CATALOGUE AND DESIGN ANALYTICAL CATALOGUE PhD Thesis, University of Glasgow, No 6563 Glasgow, 1982
King Jessie	CULROSS, FIFE Sketch Book, copy held by Hornel Art Gallery, Dumfries, Scotland

Scott, I M — BILLS OF QUANTITIES
for the Glasgow School of Art, held by the Mackintosh Library, GSA
Glasgow, 1897 and 1907

Sturtevant, B F — HEATING AND VENTILATING APPARATUS
United States Patent No 100 211
1870

Sturtevant, B F, Company — THE VENTILATION AND HEATING OF SCHOOL BUILDINGS
Catalogue No 83
Boston, 1895

Tovey, John — HENRY LEA CONSULTING ENGINEER 1839 - 1912
Private publication by Hoare Lea and Partners
Birmingham

Legislative Documents

Corporation of the City of Glasgow — GLASGOW BUILDING REGULATION ACT
Glasgow, 1892

Corporation of the City of Glasgow — GLASGOW BUILDING REGULATION ACT
Glasgow, 1900

H M Government — LOCAL TAXATION (CUSTOMS AND EXCISE) ACT
London, 1890

H M Government — SCHOOLS FOR SCIENCE AND ART ACT
London, 1891

H M Government — TECHNICAL INSTRUCTION ACT
London, 1891

H M Government — TECHNICAL SCHOOLS (SCOTLAND) ACT
London, 1887

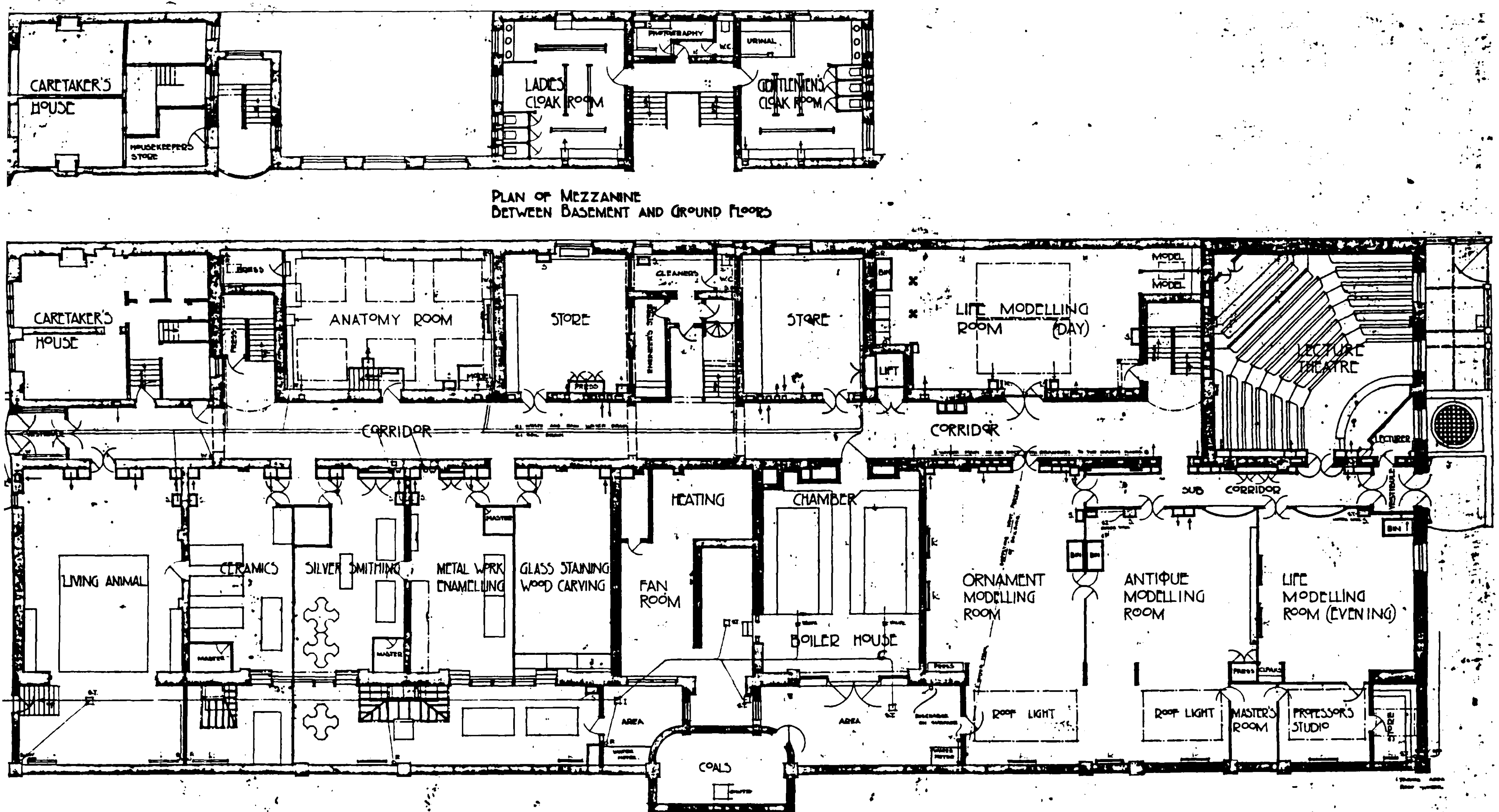
H M S O — THE BUILDING REGULATIONS (SCOTLAND) ACT
London, 1990.

Appendix 1
Charles Rennie Mackintosh
Original Drawings

The main floor plans, from the series of drawings completed in Mackintosh's hand in 1910, are shown on the following pages for reference.

These drawings were supplied by Mr Drew Perry of the Glasgow School of Art.

Although completed after the construction period, these drawings do not provide a fully accurate as-built record of the building. In particular, the identification of the air-flow from the ducts is not accurate. This information is not recorded elsewhere, to the writer' knowledge.

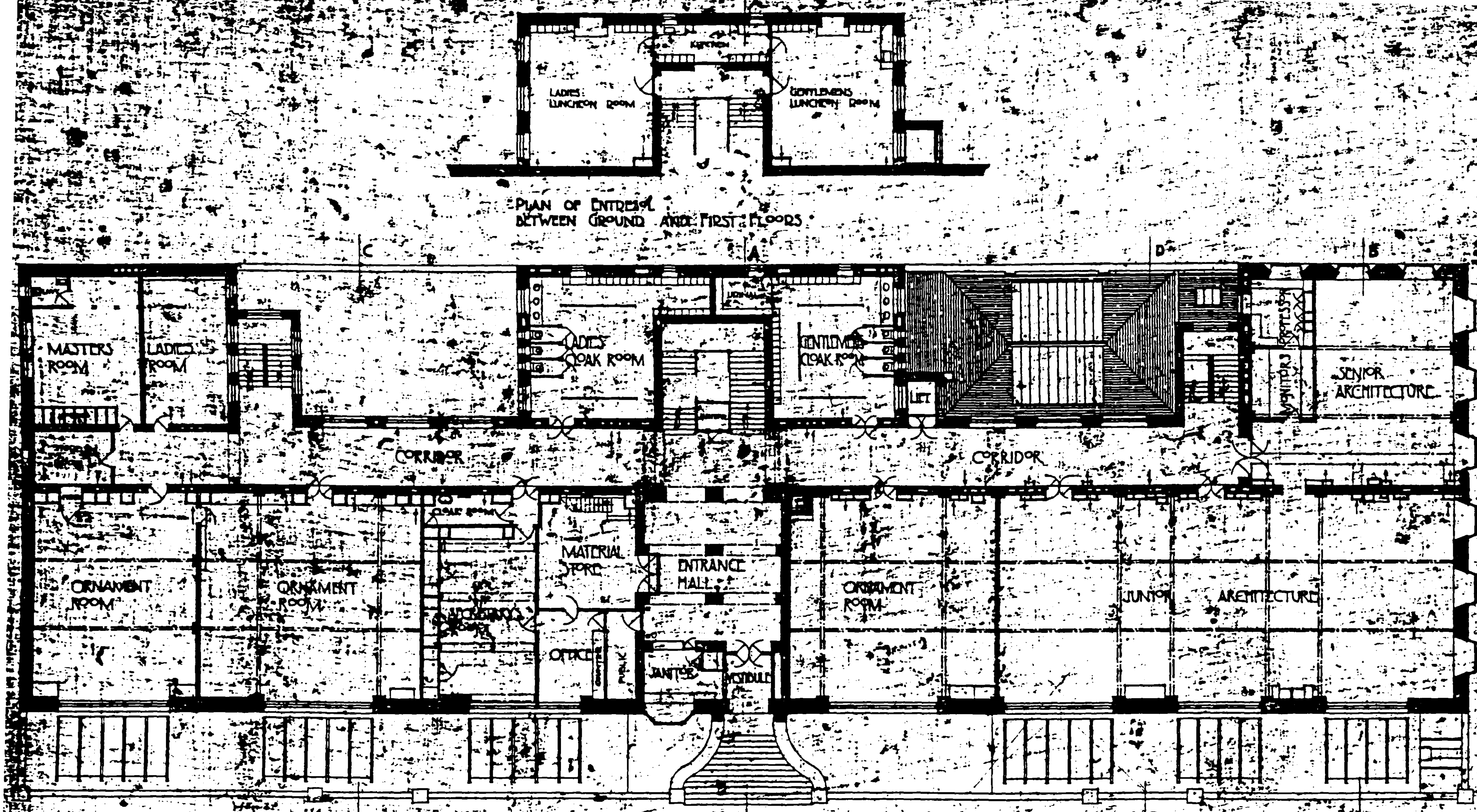


PLAN OF MEZZANINE
BETWEEN BASEMENT AND GROUND FLOORS

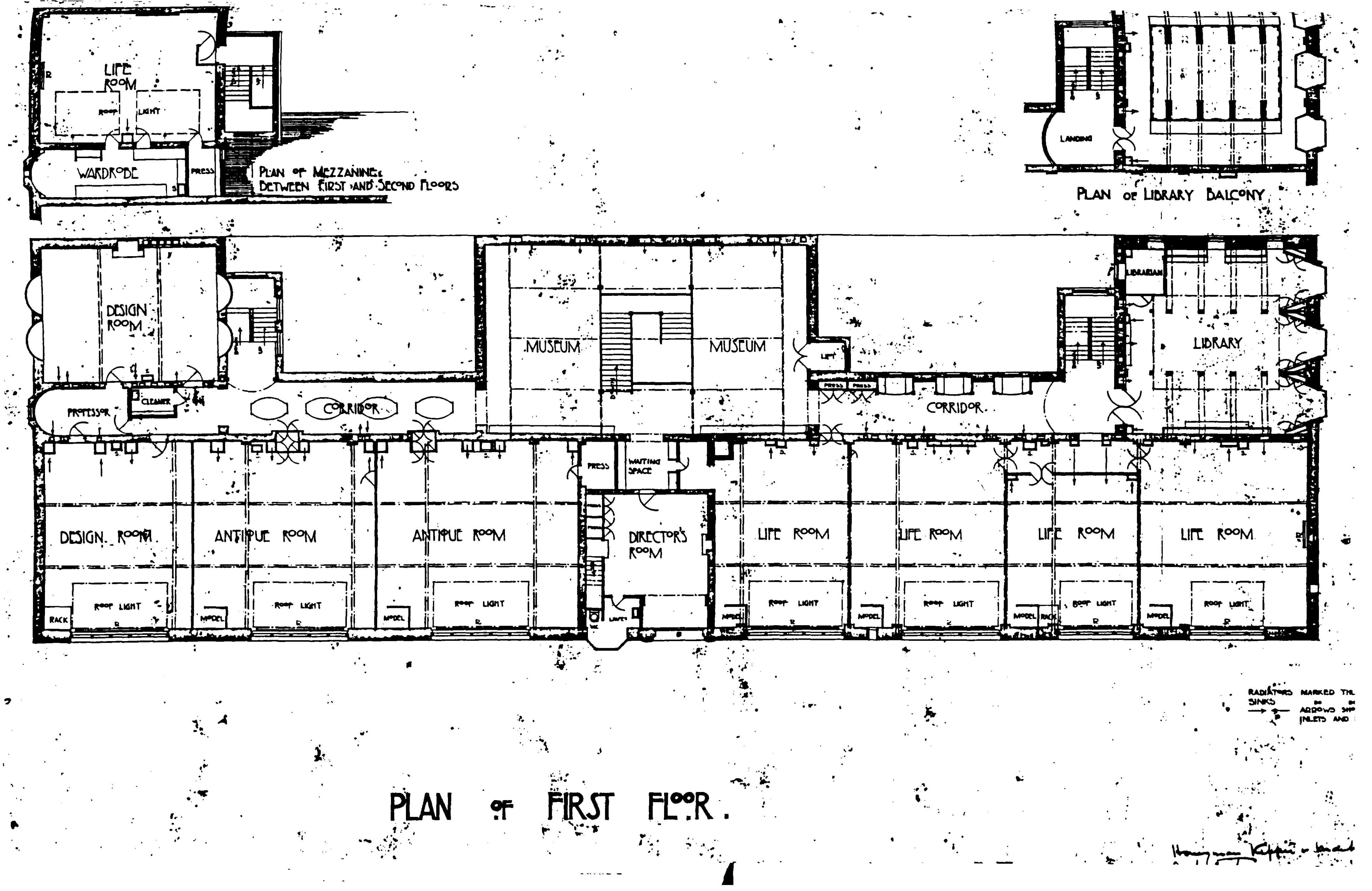
PLAN OF BASEMENT FLOOR.

RADIATORS MARKED THUS
SINKS
ARROWS, DRAW INLETS AND EXTR

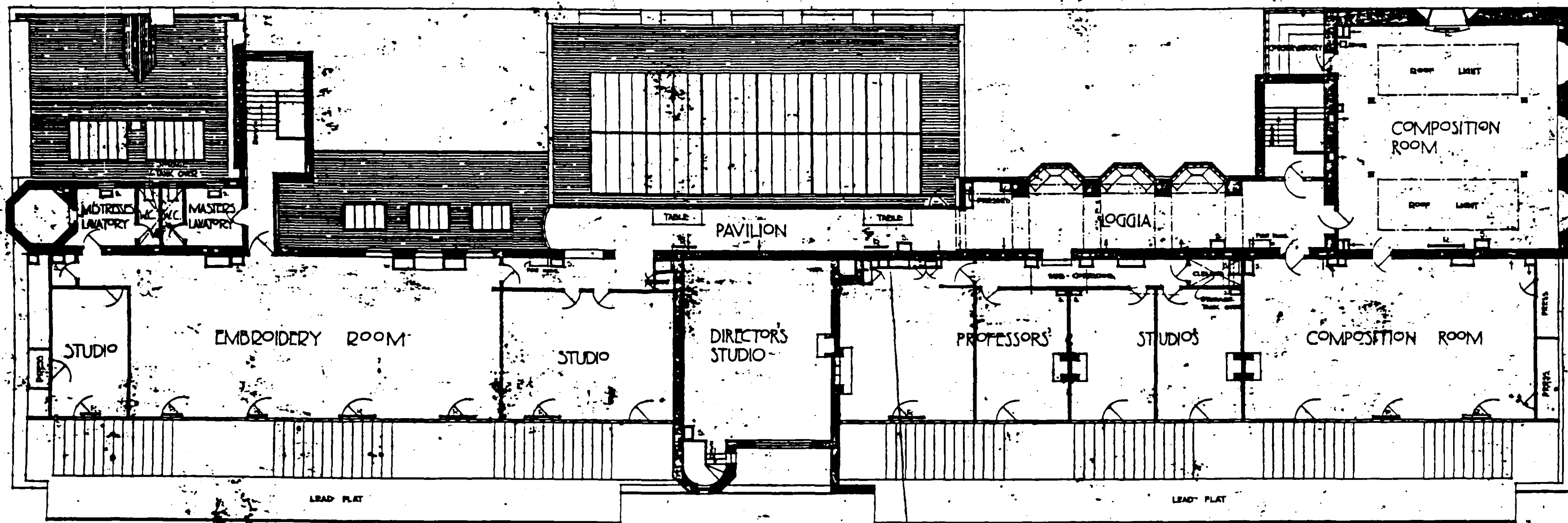
DRAINAGE SYSTEM
SOIL PIPES MARKED TH
RAIN AND WASTE PIPES
I = INSPECTION CHAMBER
ST = SURFACE TRAP



PLAN OF GROUND FLOOR.



PLAN OF FIRST FLOOR.



RADIATORS MARKED THU
SINKS
ARROWS SH
INLETS AND

PLAN OF SECOND FLOOR.

Appendix II
Survey Information and Photographs

The following pages show details recorded in photographic and sketch format during survey work for preparation of this Thesis.

The sketches included are typical examples of the survey notes made of the School as existing during the period of this study, from 1987 to the present. Since, as discussed in the study, much of the architectural detail of the building has never been drawn previously, the survey work required was extensive and the accuracy had, therefore, to be commensurate with the scale of the final drawing to which it was related.

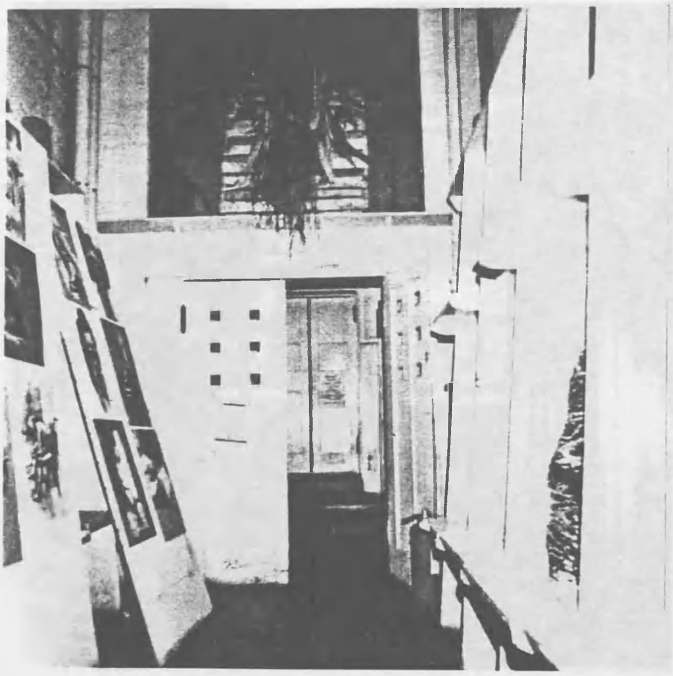
The survey notes related to the large scale details are seen to be to a greater degree of accuracy than those related to the 1:100 drawings.

Where variations from Mackintosh's drawings, or discrepancies from previous studies were found, these were noted on the survey information.

The first set of photographs are included to show the extent to which alterations to the building, in particular the installation of heating pipes to the corridors, has detracted from the original design of the spaces.

The second set of photographs show remains of the warm air heating system which forms a major part of this study. Although the boilers and fan motors have long since disappeared, the fans themselves; the most interesting and valuable items of plant; remain in almost perfect order, along with the steam coils situated above and examples of the leather drive belts to the fans.

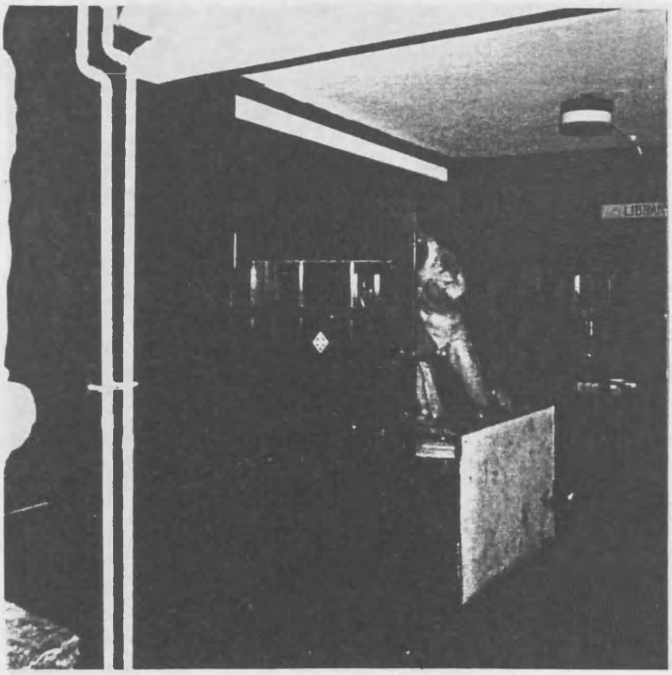
Due to the limitations of access, it was impossible to record the filter bank framework as it exists. The last remaining example of a filter unit, from the second phase construction installation, is illustrated here. The unit is shown as found, other than partial cleaning of the brass plates.



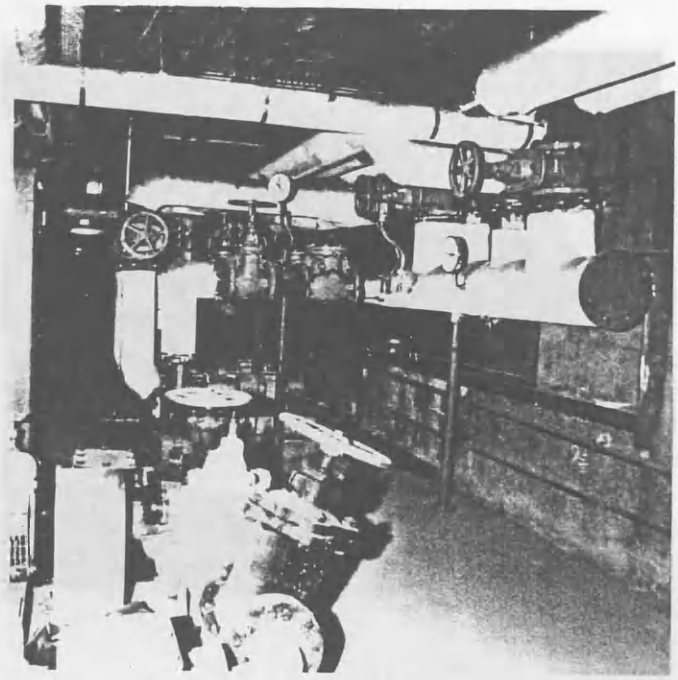
Fire screen added across basement corridor. Doors beyond, to Lecture Theatre, are not original and lead directly to 'protected zone.'

Screen added across ground floor corridor. Note heating pipes to right hand side for radiator system.

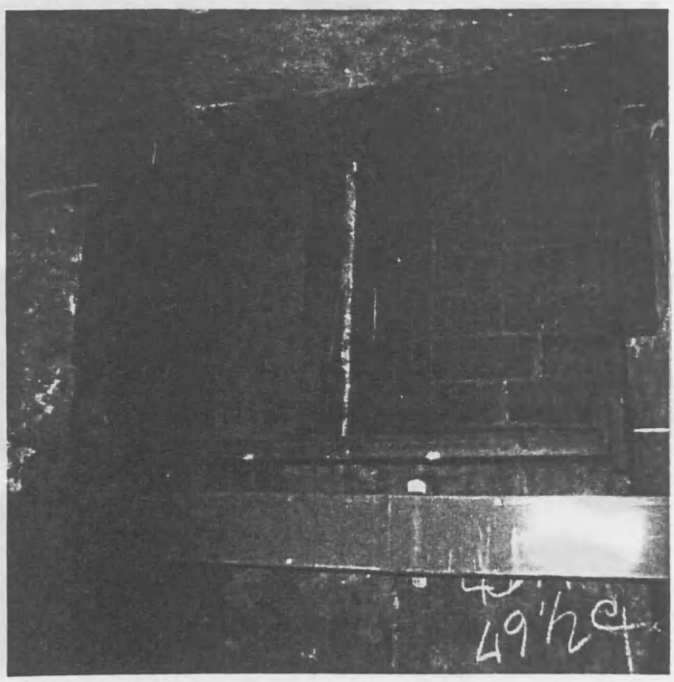
Screen added to West Stair at first floor, separating spaces which originally flowed together. Note replication of original detail, poorly proportioned.



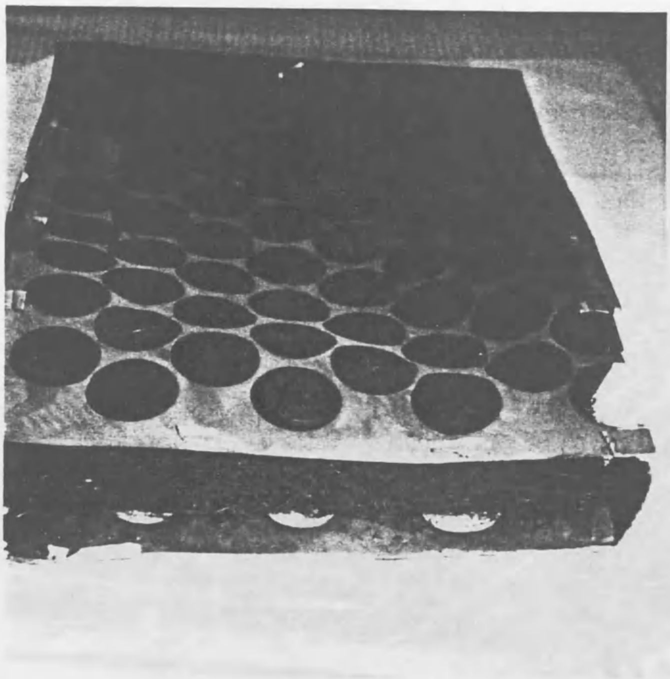
Screen obstructing view to Stair from Corridor. Note insensitive heating pipes.



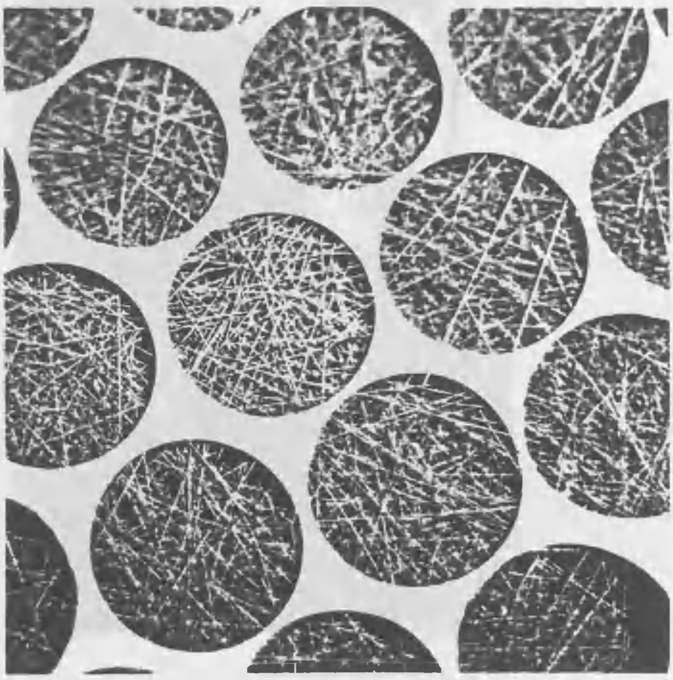
Interior of main warm air supply duct. Plant is related to current system. Note sliding timber damper to right hand wall. Compare with same view at an earlier date in Macleod, p63.



Typical sliding damper and branch duct entry. This example would require only minor repair to be made operational.

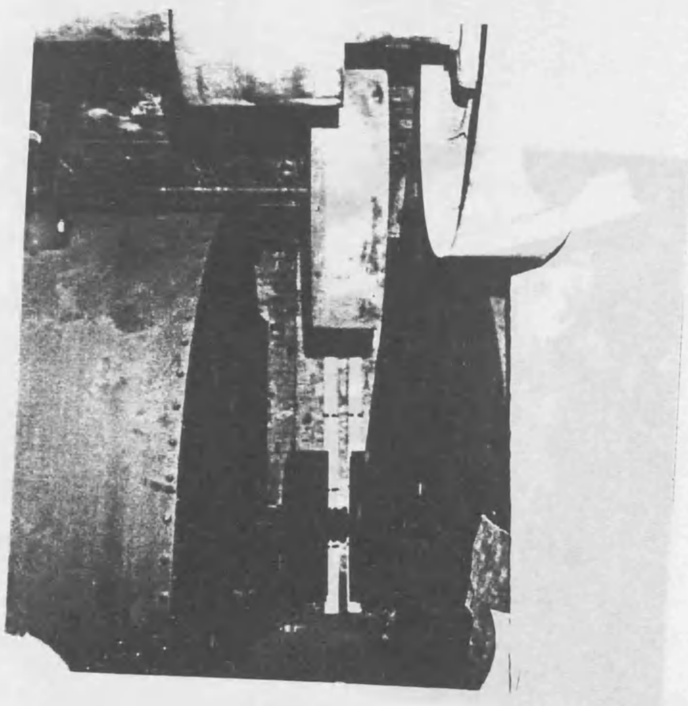


Last remaining air filter unit, as found, except for partial cleaning of plate. Dimensions are 500x375x50mm.

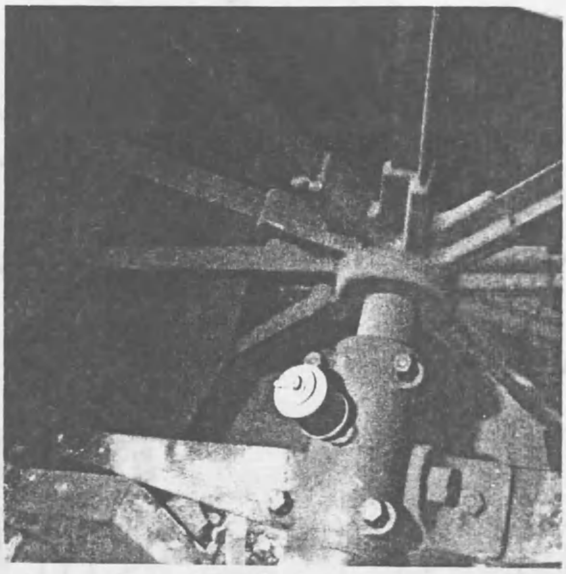


Detail of horse hair element and perforated brass plate.

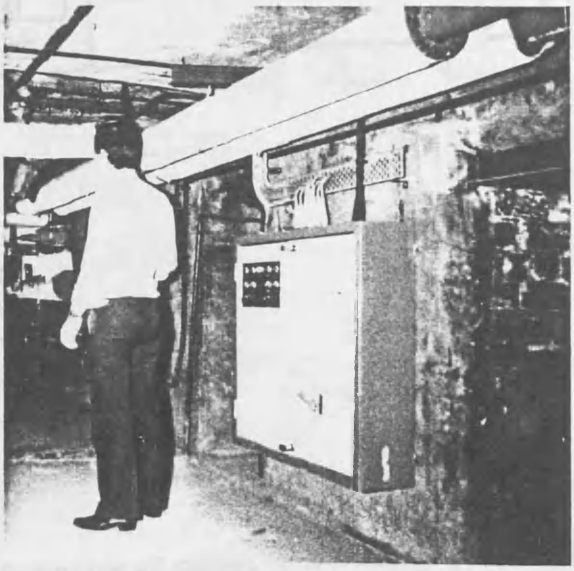
View up into steam coil chamber from fan chamber.



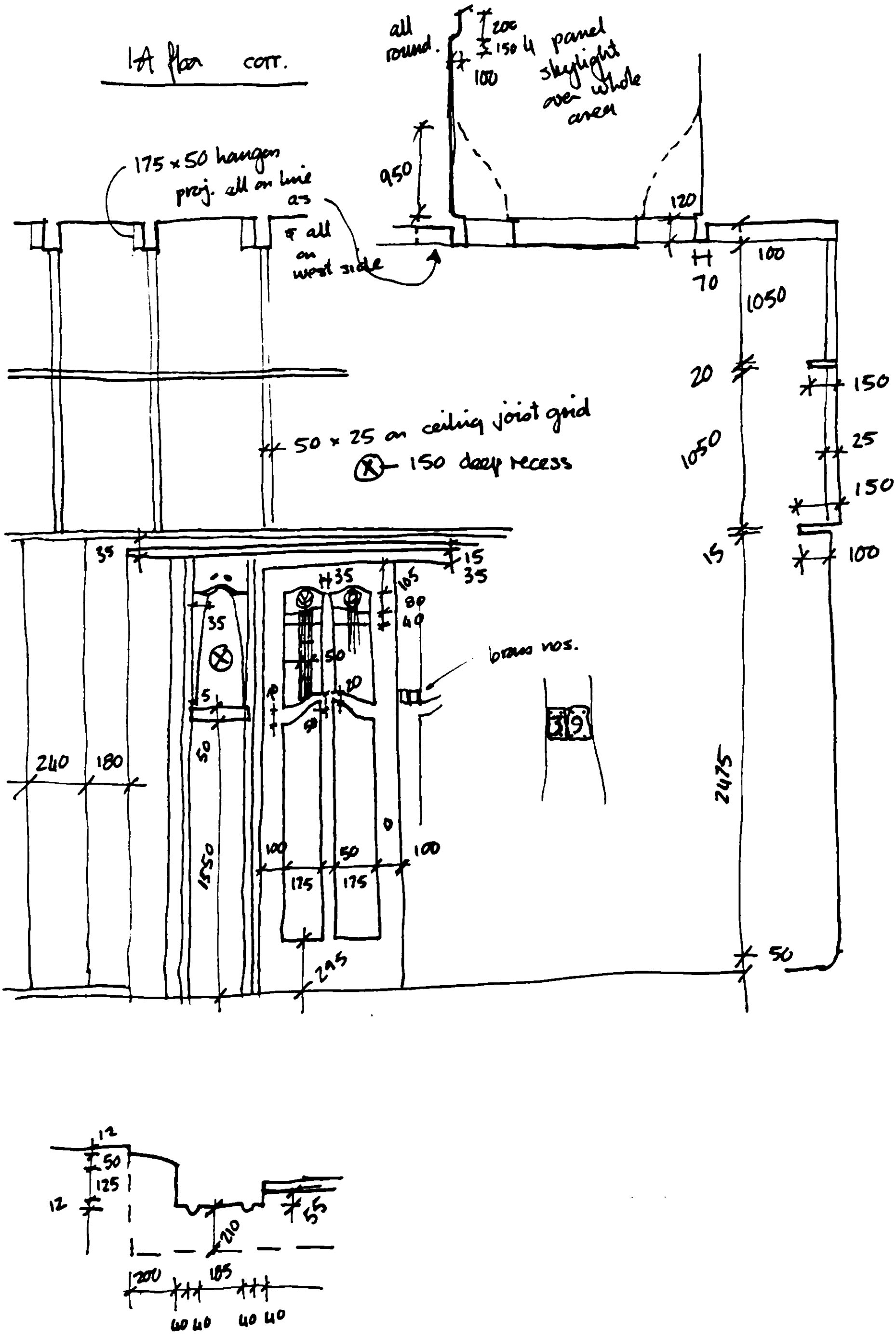
Fan casings,common shaft and remaining leather drive belts. Wick-oiled bearing to top left.



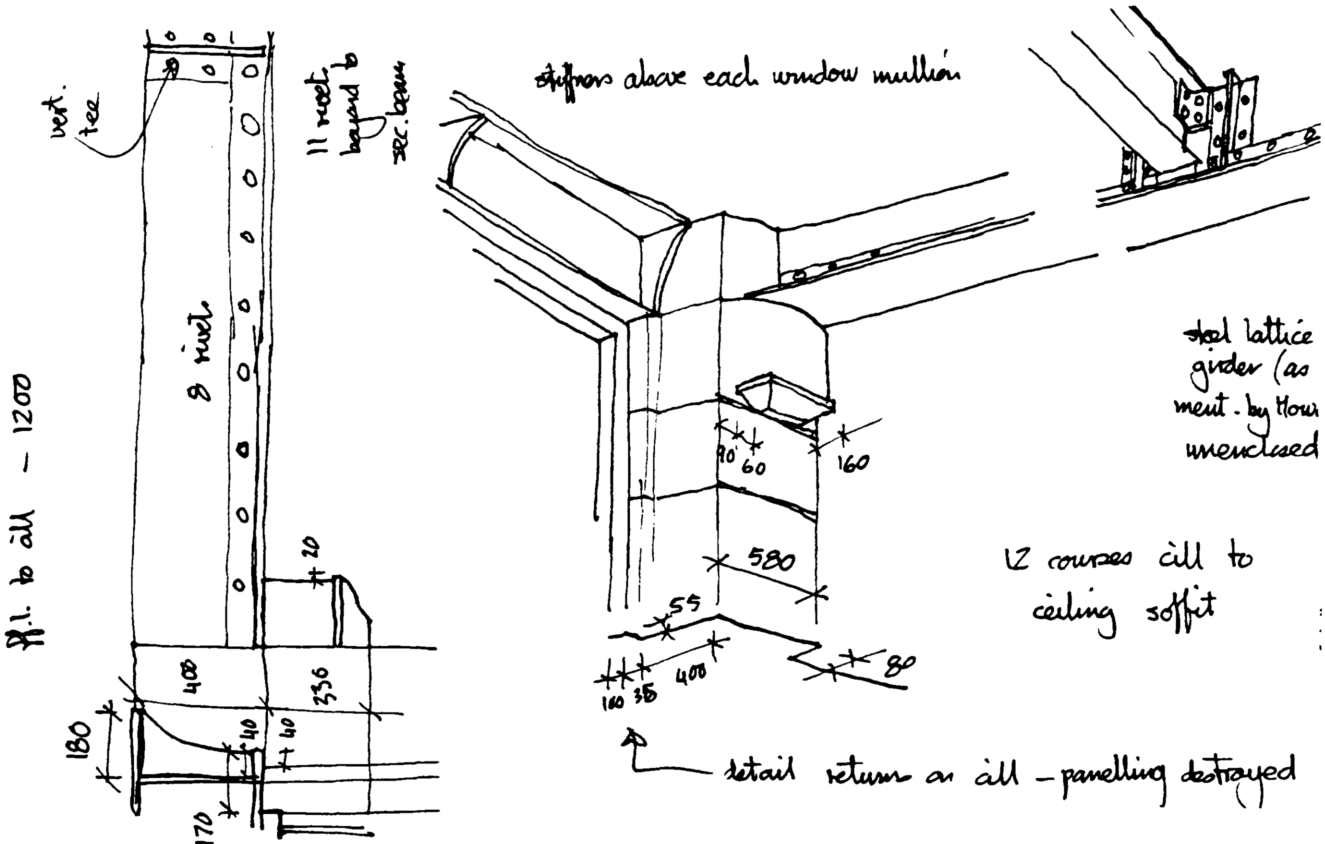
View into centrifugal impeller, showing blade profile.



Scale of main circulation duct. Fan entries are situated to either side of modern switchgear unit.

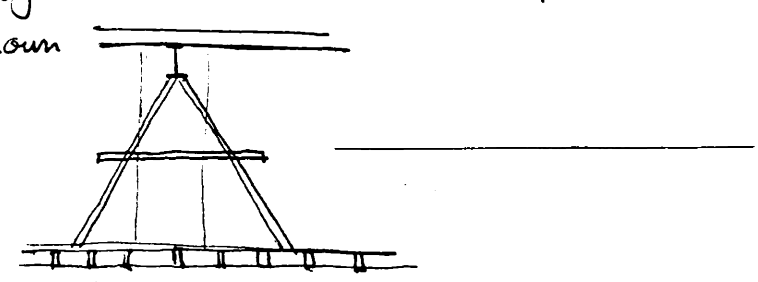


Examples of survey notes for 1:100 drawings. Nature of notes and dimensions is commensurate with number and accuracy of drawings.



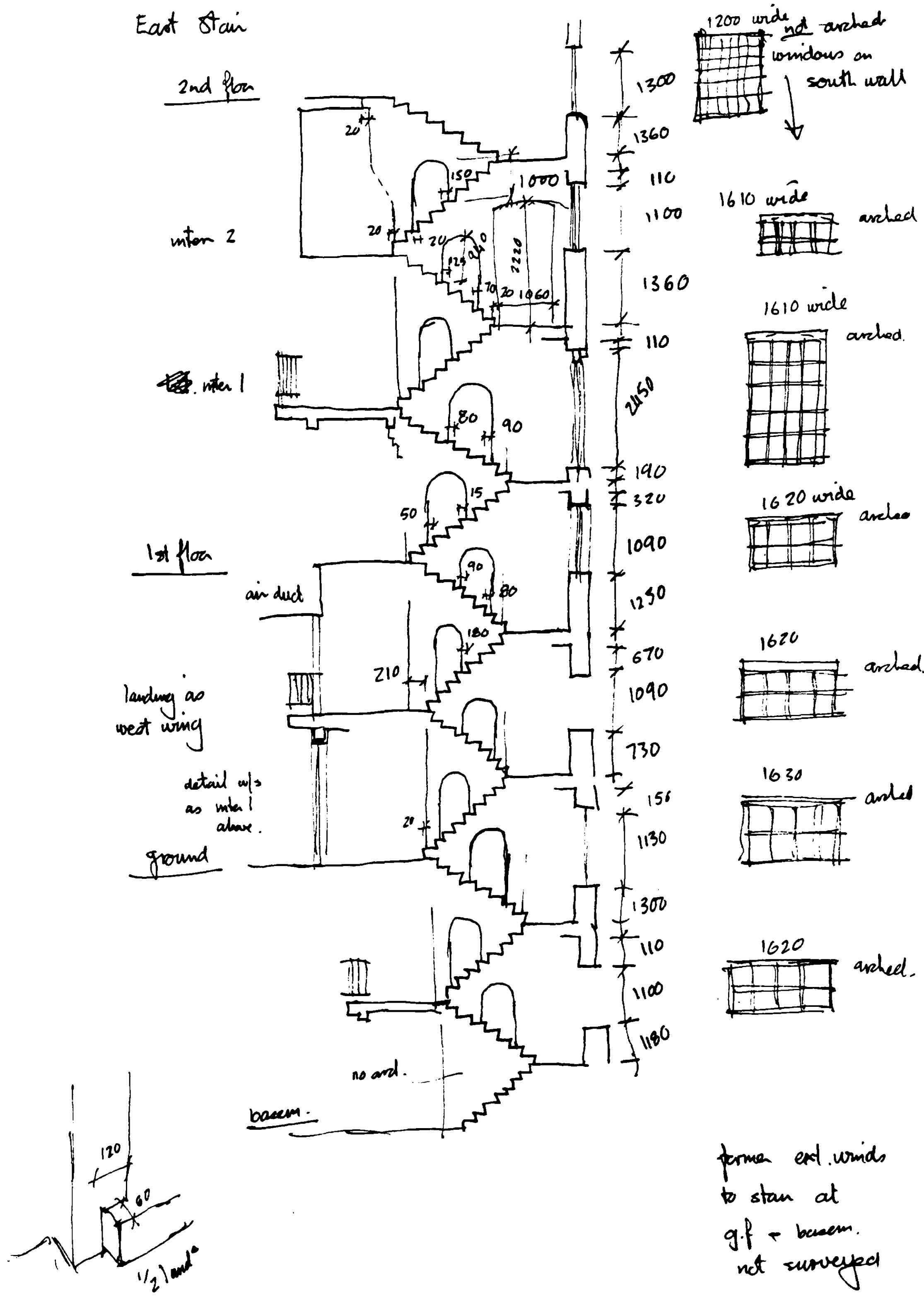
6 Section B.B - Sheet 9. duct in ceiling - sub-base marked warm air duct

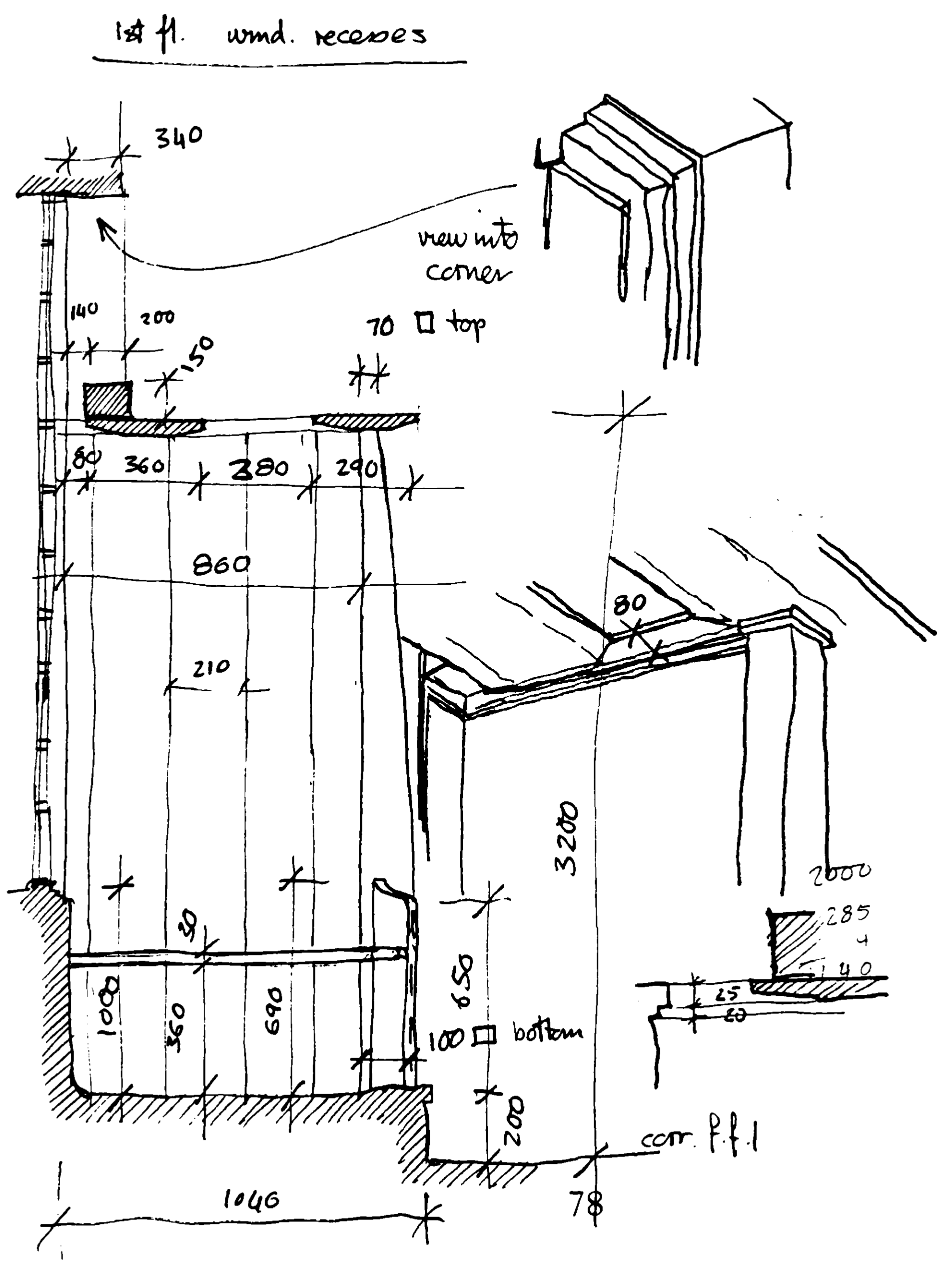
7. Dwg as above school store support shown



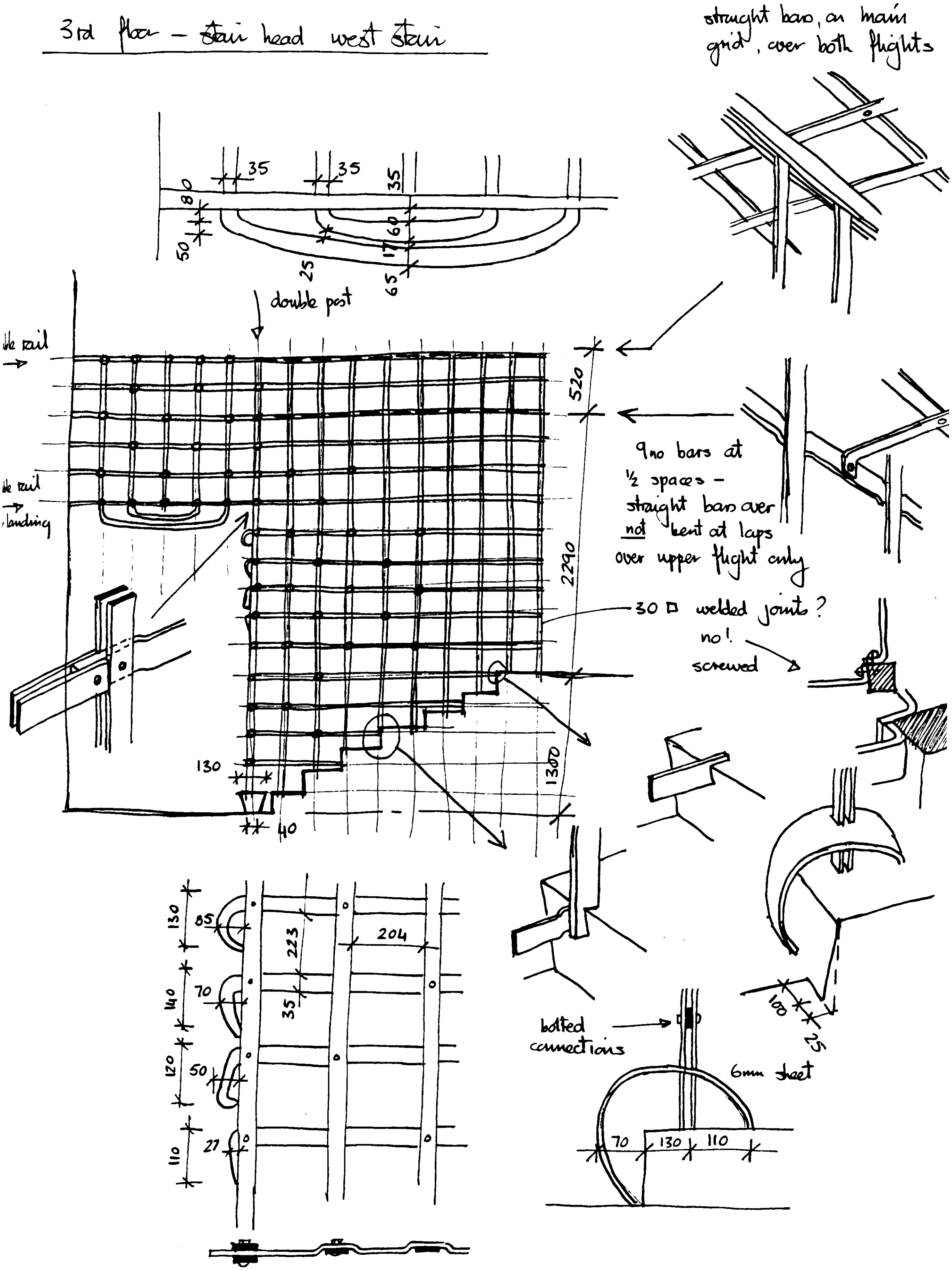
8 Sect. D.D dwg. 10 — duct above g.f. corridor - extract duct - discharging thro grille

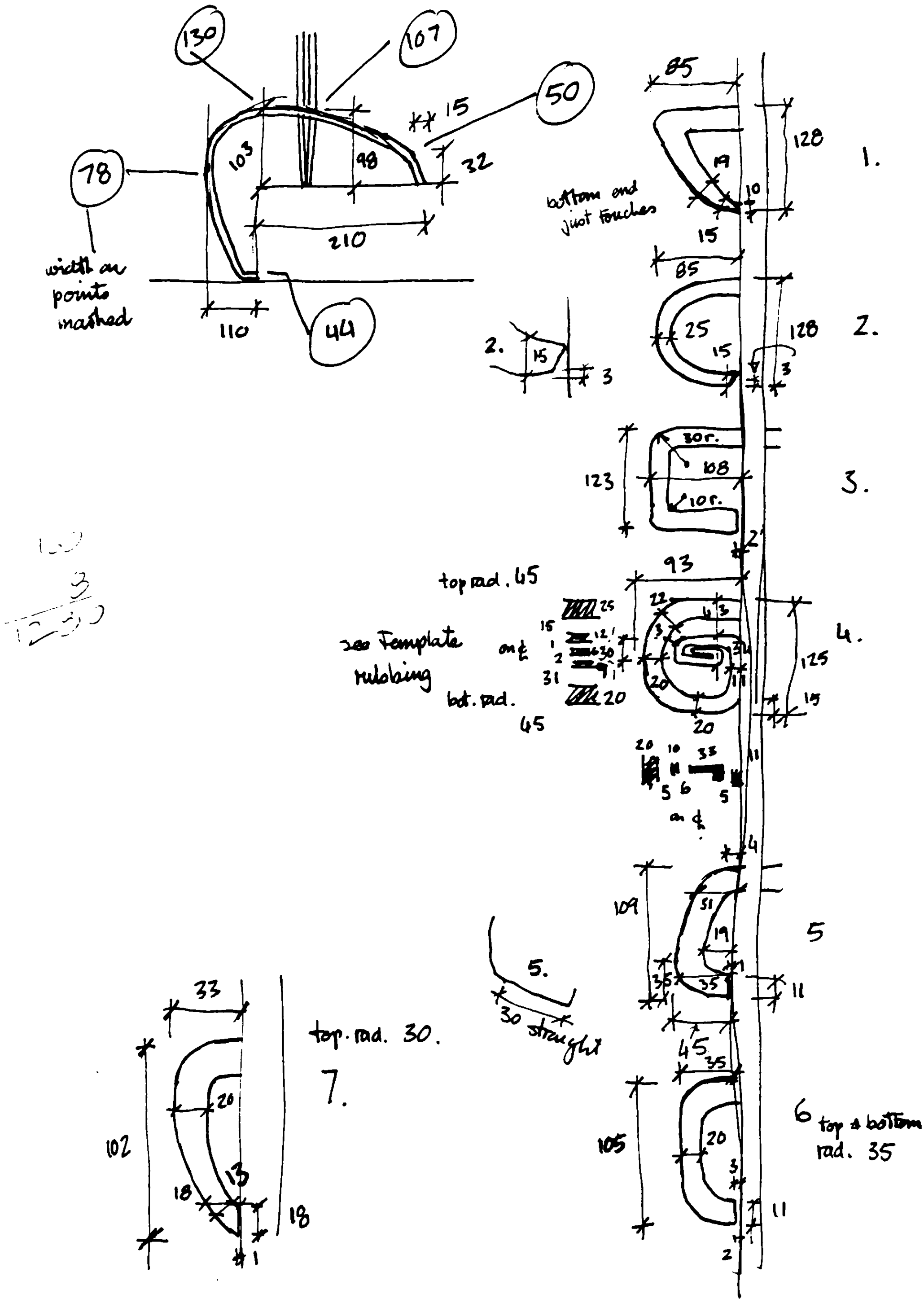
Additional survey information and notes. Original design for School Store stirrups should be compared with twisted iron stirrups, as built.


East Stair
2nd floor
inter 2
inter 1
1st floor
air duct
landing as west wing
detail w/s as inter 1 above.
ground
no arch.
basem.
1200 wide not arched windows on south wall
1610 wide arched
1610 wide arched.
1620 wide arched
1620 arched.
1630 arched
1620 arched.
1300
1360
110
1100
1360
110
2450
190
320
1090
1230
670
1090
730
150
1130
1300
110
1100
1180
1000
2220
1060
120
60
1/2 round
former ext. winds to stair at g.f + basem. not surveyed



Extracts from survey notes for large scale detail drawings.


3rd floor – stair head west stair
straight bars, on main grid, over both flights
35
35
35
80
50
60
17
25
65
double post
rail
rail
landing
520
9no bars at
½ spaces –
straight bars over
not bent at laps
over upper flight only
2290
30 □ welded joints?
no!
screwed
130
40
1300
130
85
223
204
140
70
35
120
50
110
27
bolted
connections
6mm sheet
100
25
70
130
110


width on points marked
bottom end just touches
see Template rubbing
top rad. 45
bot. rad. 45
top. rad. 30.
30 straight
top & bottom rad. 35
1.
2.
3.
4.
5
6
7.

Appendix III
Air Handling Unit Specifications

The following pages show the summary information supplied by Woods of Colchester on completion of their computer modelling of the original heating installation and appraisal of the possible reinstatement of a warm air system with heat recovery.

Tufnell Way, Colchester CO4 5AR
Telephone: 0206 44122. Telex: 98422
Telegrams: Aerofoil Colchester
Telefax: 0206 574434

WOODS AIR MOVEMENT

AIRPAC MODEL 6 SERIES SPECIFICATION SHEET — Issue D/3 / 25.09.87

Framework

The penta-post framework is manufactured from hollow extruded aluminium sections(International Aluminium Standard 6063A), -assembled without welding using special corner joints. these allow design flexibility without compromise to the rigidity of the unit.

Panels

Panels are double-skinned, 25 mm thick, and comprise a 0.6 mm inner and outer tray internally insulated by injection of rigid expanded polyurethane foam.

Density 45 kg/m3.

Panels are secured to the framework using rivets giving a positive airtight fixing.

Sound reduction through panels 63 Hz to 8 kHz :-

-22 -19 -24 -28 -31 -25 -42 -45

External Finish

The following external finishes are available.

1. Colorcoat pre-finished steel, colour blue

2. Galvanised steel.

Construction Details

Double-skin inspection doors secured to framework by injection moulded hinges.
The aluminium alloy handles are internally fitted with a cam lock.
An internal handle can be fitted when required.
Baseframes manufactured from steel sections adequately sized to ensure unit stability and ease of transport.
Supporting legs of heavy gauge galvanised steel, when required.
Lifting by baseframe and strops.
Inspection windows 200 mm diameter can be provided.
Bulkhead lamps can be provided.
The units are generally manufactured as transportable modules for site assembly, and when bolted together, display flush external lines.
Sandwiched between each module joint is a gasket material, resulting in a unit that complies with the maximum allowable rates stated in the HEVAC Document on air handling unit leakage.

Coils are generally integral with the Airpac casing, copper tubes copper headers with aluminium fins being the standard construction.

Units can be manufactured suitable for external or internal installation.

GLASGOW ART SCHOOL QUOTE REF ABM/WS/G35000

SYSTEM REFERENCE	SUPPLY	EXHAUST
QUANTITY	2	2
MODEL REFERENCE	290/290	290/290
VOLUME FLOW (M3/S)	20	18
EXTERNAL PRESSURE (PA)	1500	1215
WEATHER LOUVRE	INLET/BIRD G'D	DISCHARGE/BIRD G'D
PANEL FILTER	INCL.	N/A
SILENCER	1500	1500
PLENUM	N/A	300
FAN SECTION		
TYPE	BACKWARD CURVED	BACKWARD CURVED
MOTOR KW	75	45
FAN RPM	1220	1060
ELECTRICAL SUPPLY	415/3/50	415/3/50
PLENUM	300	N/A
BAG FILTER	90-95%	N/A
HEAT RECOVERY COIL		
SYSTEM EFFICIENCY %	32	32
CAPACITY KW	177.7	177.7
AIR ON (C)	-1	22
AIR OFF (C)	6.36	14.67
FLUID	20% GLYCOL/WATER	20% GLYCOL/WATER
FLUID FLOW RATE (L/S)	4.41	4.41
FLUID PD. (KPA)	6.9	6.9
ROWS	8	8
CONNECTIONS	2.5 INCH BSP	2.5 INCH BSP
PANEL FILTER	N/A	INCL
ACCESS SECTION	INCL	N/A
HEATER BATTERY		
MEDIUM	WATER 82/71 C	N/A
AIR ON/OFF (C)	-1/23	N/A
DUTY (KW)	579	N/A
MEDIUM PD. (KPA)	7.85	N/A
ACCESS SECTION	INCL	N/A
SILENCER	1500	1500
DISCHARGE/INLET PLENUM	FLANGED	FLANGED
	reduced to give	
DIMENSIONS		
O/LENGTH (MM)	~~11550~~ 8135	~~9250~~ 6600 to fit spaces, usin original chambers as plenums.
WIDTH (MM)	2900	2900
HEIGTH (MM)	COMBINED	6004
WEIGHT (KG)	COMBINED	11482
NUMBER OF SECTIONS	7	6
BUDGET		
PRICE EACH (POUNDS)	COMBINED	49500

GLASGOW ART SCHOOL QUOTE REF ABM/WS/G35000

NOISE DETAILS

SUPPLY FAN

MID FREQ. BAND (HZ)	63	125	250	500	1K	2K	4K	8K
SOUND POWER LEVEL (dB)	112	106	107	101	97	95	90	86
ATTENUATOR REDUCTION (dB)	8	16	28	46	54	54	38	51
INDUCT PWL (dB)	104	90	79	55	43	41	52	35

EXTRACT FAN

MID FREQ. BAND (HZ)	63	125	250	500	1K	2K	4K	8K
SOUND POWER LEVEL (dB)	109	103	104	98	94	92	87	83
ATTENUATOR REDUCTION (dB)	8	16	28	46	54	54	38	51
INDUCT PWL (dB)	101	87	76	52	40	38	49	32

NOTE: INLET AND DISCHARGE FLANGES WILL NOT BE DRILLED
INCLUDED EXTRAS : LOCKING DOOR HANDLES AND EXTERNAL TERMINAL BOX ON FAN SECTIONS , INCLINED MANOMETERS ON FILTER SECTIONS

Appendix IV
Document Extracts

The following extracts from historical records are shown here in order to illustrate the extent of coverage of matters related to environmental design in documentation dating from the period.

The coverage is drawn from trade documentation, as in the Sturtevant Catalogue, from research papers and professional journals, such as the Report to the Dundee School Board and the Journal of the Royal Institute of British Architects and, most notable, from the general press, as in the extract from the Glasgow Herald relating to the Victoria Infirmary, Glasgow.

The documents appear to indicate a depth of interest in developments in environmental design across the full spectrum of society which is probably unparalled to this day, despite the current reported global interest in 'environment'.

In the case of the schools not personally visited the information was obtained by sending a number of printed forms (see Appendix I.) to the Clerk of the several Boards with the request to fill them in as far as possible, there being one form for each school. As a general rule this has been done in a most satisfactory manner, and I therefore take this opportunity of thanking most cordially the various Boards for the efficient and ready manner in which they have supplied us with the information required. I would also include the Clerks of those Boards whose schools I personally visited, and who were in all cases most ready to give me every facility in obtaining information.

The data as regards the state of the air in the schools were taken from the following published papers:—

(1) Report to the Aberdeen School Board, by Brazier and Niven, "On the Ventilation in Certain Schools," 1885.

(2) "The Carbonic Acid, Organic Matter, and Micro-organisms in Air, more especially of Dwellings and Schools," by Carnelley, Haldane, and Anderson (Philosophical Transactions of the Royal Society, B4. 1887, Vol. 178, pp. 61—111).

(3) "Report on the Composition of the Air in the Schools under the Edinburgh Board," by Cosmo Burton, B.Sc. 1888.

(4) "Report on the Atmosphere of Twenty-six Buildings in Newcastle-on-Tyne," by Bedson, Lovibond, and Severn (North-Eastern Sanitary Inspection Association), 1888.

The data and information obtained from all the above sources have been very extensive, and the labour required, both for working these up, and for afterwards condensing the results into a practical form, has been very great indeed. The information has likewise come in piecemeal, and at somewhat long intervals; hence the considerable delay which has occurred in the appearance of this Report.

The details for each school are given in a series of MS. Tables, to which reference may be made if necessary; for the sake of convenience, however, the general results only accompany this Report, and are represented in Appendices II. and III.,* and in the Table on page 28.

In Appendix II. the mean results of the various methods of heating and ventilating are given in considerable detail for each town. The object of the Table is to allow the various systems adopted in a given town to be compared with one another without reference to other towns.

* In all cases in which the caretaker of the school is provided with coal free, three tons of coal have been deducted from the total amount consumed annually, in order to make such schools as far as possible uniform with the others. A deduction of three tons is perhaps a little too small, but it is probably near enough for the purpose. Some few schools are used on Sundays. In these cases one-sixth of the coal used has been deducted.

In Appendix III. the mean results for the various towns are classified according to the mode of heating and ventilating. The object of this Table (which is much more condensed than Table I.) is to allow the several towns to be compared with one another, and also to compare the general averages of the different methods of heating and ventilating as derived from the results obtained in all the towns.

In the Table on page 28 are given the results of the measurements which have been made in the mechanically ventilated schools in Dundee, Aberdeen, Govan, and Paisley.

Of the various methods of heating, the one most extensively used is the system of large hot-water pipes (low pressure). Open fires are also a very favourite method; whilst all others are much less common. Thus, of the 311 schools examined in this respect,

147 * are heated by large low pressure hot-water pipes (chiefly in Birmingham, Bradford, Nottingham, Leeds, and Liverpool).
82 † are heated by open fires (more or less common in most towns. The Edinburgh Schools are heated exclusively by open fires).
32 are heated partly by open fires and partly by stoves (22 of these are in Leeds, and 8 in Leicester).
31 are heated by small high pressure hot-water pipes (20 of these are in Sheffield).
9 ‡ have adopted the mechanical system (Dundee and Aberdeen).
5 are heated by hot air (Salford only).
4 are heated by high pressure steam pipes (Sheffield and Newcastle).
1 is heated by low pressure steam pipes (Leicester).

Of the various methods of ventilating, the most common mode of admitting fresh air is by open windows, doors, &c., and also in many cases by Tobin's tubes; whilst the most usual outlet is the chimney of an open fire, or ventilators in the roof.

In some few schools, as in several in Aberdeen, the outlets consist of large wooden shafts running from near the floor up to the ceiling, and opening into roof ventilators, the inlets being Tobin's tubes or Sherringham's valves.

* All the Glasgow Board Schools, some 70 in number, are also heated in this way.

† All the Manchester Board Schools are also heated by open fires.

‡ Schools in various other towns are also ventilated mechanically, but detailed results have not been obtained from these, as they have only been in operation for about a year or under.

~~Report to the School Board of Dundee, 1889.~~
Refers to contemporary study of environmental design and to systems in use.

furnaces within one brickwork building; and the arrangement of heating flues round the coils may be considerably varied from that described.

The air heating arrangements would consist of equivalent constructions of parallel horizontal and longitudinal coils of hot water circulating tubes in sets supported over each other angling upwards at their ends either in bends or by couplings, and built within standards at suitable distances apart, each set resting on cross-stays and inner notched plates bolted to these stays between the standards which would thus bind them vertically and longitudinally in sets, at some little distance apart for the air to pass through them to be heated. And these pipes might extend down to near the floor of the heating chamber, and up to near the roof, or they may be erected over wood partitions with doors, which would regulate the admission of the cold air, or the circulation of the heated air from one division to another when these coils are arranged in vertical sets across the building at distances apart; and similar doors might also be fitted at the top of these coils to open up or fold down in front of the coils to regulate the admission of the air. And doors might be fitted to swivel out on and at right angles to the columns supporting the several coils, so as to swivel on either horizontal or vertical hinges and direct the current of air through any divisions of the different sets of coils over each other as found desirable for the best regulation of the air passing between the coils, the air to be heated being directed through any number of these by and through the said doors. Two, three, four or more sets of these water circulating and air heating coils might be mounted over each other between their supporting standards erected parallel to each other, and any number of the complete coils and standards may be placed in the said chamber or air heating building, the hot water in each set or coil coming from the furnace coils to the upper tube of the set and returning from the lower to their respective furnace heating coils. For the purpose of washing and cleaning the air passing through the heating chamber, a beam would be hung and stretched parallelly and longitudinally at the top preferably in the space between the first and second set of air heating coils, and have hung on this beam a vertical set or screen of cocoa-nut, or other rough surface fibre such as horse-hair and hemp, or it might be yarn or fine thread fabric, such as open gauze, hanging down to the bottom of the coil, and water would regularly and intermittently be automatically let on from time to time from a tank through a rose pipe over the beam supporting the screen, to saturate and wash it, so that it will cleanse the air passing through this fibrous screen which might be of several vertical layers, fine enough to allow the air to pass and yet cleanse it, and also regulate the moistness or dryness of the air being heated. The air would be drawn by fans or air propellers and conveyed from this heating chamber by main ducts and supplied by service branches fitted with valves to each division or apartment of the building or institution for heating or ventilating purposes.

air filters

humidity control

fans & air distribution

Dated the 5th December 1890.

W. R. M. THOMSON & Co.,
96, Buchanan Street, Glasgow, Agents.

COMPLETE SPECIFICATION.

Improvements in and relating to the Heating of Air for Heating and Ventilating School-houses, Churches, and other Buildings, and in the Apparatus therefor.

We, WILLIAM KEY, of Eildon Villas, Mount Florida, Renfrewshire, Gas Engineer, and ROBERT TINDALL, of 79 Loch Street, in the Town and County of Aberdeen, Heating Engineer, do hereby declare the nature of our invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement in writing, reference being had to the accompanying drawings, that is to say:—

This invention has reference to and comprises a new or improved system, and

Key and Tindall's Patent; lodged Oct 1891 and approved in Jan 1892.
Extracts showing reference to control of humidity and temperature.

exit is always open so that the air forced out of the building by the air current propelled into it passes outward uninterruptedly in all states of the weather.

By the arrangements and mechanism described the air is propelled by a fan or air propeller I^2 driven by an engine I^3 or electro motor and an installation of the arrangements with the heating apparatus suitable for the heating and ventilating of one building or suite of appartments, can be made to do duty for a second building of similar cubic air space, such as a church and a school when combined and it is desirable to ventilate and warm two such buildings or distinct sections of one building by the one set of apparatus. As shown in Figures 23 and 24, two main air ducts I^4, I^5, are constructed and led to within a short distance of the air propeller I^2 between these ducts and the point where they terminate and become one near the back of the fan I^2. A swing door or air valve I^{111} is erected by which one building can have the duct leading to it open to the air current, and so ventilate and warm it, while the swing door is closed on the mouth of the duct I^4 or I^5 leading to the second building; and when it is desired to ventilate and heat the second building, the swing door or valve I^{111} is swung round so as to close the mouth of the duct to the first ventilated building and open the mouth of the duct to the second building or section of building, thereby the air current is directed into the main duct leading to the second building. By such an arrangement the expense for a heating furnace and heating coils, washing screen air propeller and engine which would be required for one of these buildings would be saved. Or the valve may be used to freshen the air of both buildings by being fixed so as to allow warmed air to be propelled up both ducts when the valve I^{111} was in its centre position as indicated by dotted lines in Figures 23 and 24. The swing door or valve I^{111}, may be hung on hinges fixed vertically and the door moved to right or left, or the swing door may be hung horizontally on hinges fixed horizontally and the door moved up or down vertically to close over mouth of one or other of the two ducts I^4, I^5, placed the one over the other.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is,—

First. The system or mode of, and arrangement and combination of furnace heating and circulating coils and air heating coils, and purifying and air inlet and distributing appliances and fittings, for the heating and ventilating of school-houses, churches, and other buildings or apartments by pressure air, substantially as herein described, in reference to and by way of application shown in the accompanying drawings.

Second. In a system for the heating and ventilation of buildings or apartments, the construction and use of a furnace with sets of heating and circulating coils in combination with air heating coils, forming separate or any number of circuits, and with air inlet and regulating doors and fittings, substantially as herein described, in reference to and by way of application shown in the accompanying drawings.

Third. In a system for the heating and ventilation of buildings or apartments, the arrangement and use of a vertical screen or screens formed of cocoa-nut, or other fibrous yarns, meshes, cloth, or equivalent material through or over which water or liquid falls or passes, in combination with air heating or cooling pipes or coils placed within a close chamber, substantially as and for the purposes herein described, in reference to and by way of application shown in the accompanying drawings.

Fourth. In a system for the heating and ventilation of buildings or apartments the construction and use of a vertical screen or screens formed of cocoa-nut or other fibrous cords or yarns, jute Hessian cloth, or equivalent material, through or over which water or liquid falls or passes for the purpose of washing or cleaning and purifying currents of air, substantially as herein described in reference to and by way of application shown in the accompanying drawings.

Fifth. In a system for the heating and ventilation of buildings or apartments, and none of the windows of wards or other apartments or corridors are ever opened. This is what is known as the Plenum system of ventilation by air propulsion. What is of the highest importance, not only for an infirmary, but for all classes of public buildings, is that there is no possibility of any air getting into the building through crevices or from any undesirable quarter, as it can only be admitted by the single fresh air inlet provided for the purpose. The fresh air inlet shaft is open to the sky, and is a capacious chamber, entirely lined with white enamel bricks. The air is drawn down this shaft and passed through an entirely new air-washing arrangement, specially designed for the infirmary by Mr Key, which gives 200 square feet of surface, whereby dust and soot particles are extracted. This, in a city occasionally visited with soot-laden fogs, will be an especial boon to the inmates. After the air is screened it is partly warmed by passing through a gigantic heater formed of steam-heated coils of tubes, and then enters a large and lofty fresh air chamber. From this the air is drawn by two air propellers, each driven by a gas engine, and forced into the two air passages which extend under the buildings, the one supplying the air to the wards and the other to the administrative apartments. Before the air flows into the flues leading into the wards and rooms it is finally heated by passing upwards through secondary steam coils placed in recesses along each side of these passages. The warmed air is blown into each ward through wide, shallow shafts five feet above the floor level. There are two of these on each side wall of each ward, by which the incoming air is directed towards the ceiling. The outlets by which the exhaust air is withdrawn, and passed up to escape by the cupolas on the roof, are four in each ward, two in each gable, and are at the floor level. The whole air is thus diffused throughout the higher levels of the wards, moving steadily down from ceiling to floor, and in this way the warm fresh air is utilised for warming ceilings, walls, and window spaces before passing off by the outlets.

So imperceptible is the movement of this vast volume of air through the wards that, when a velocity has been given to it sufficient to renew the whole air in seven minutes, not the slightest draught is observable, nor does the delicate air-meter show any movement. It is only when a lighted taper is taken towards the outlets that the force is seen, for it is then at once extinguished; and the air-meter, when similarly placed, shows the enormous volume of air passing outwards. The copious volume of air blown into each ward is such that, it may be said, none of the inmates will ever breathe air which had previously passed through the lungs of any of the other occupants. It is thus equal to breathing the fresh air in the open, with the difference that in the infirmary the temperature is uniform and the air purer from being screened and washed before passing into the building. The exhaust air is forced up the two shafts at each end of the wards into a large exhaust air chamber immediately under the roof, and passed along a roomy plastered passage to the louvre-boarded cupolas placed on the ridge of the roof. Within these are placed the valvular

was executed also to the designs and specificat[ions] prepared by Mr Key, the arrangement being placing in the fresh-air ducts copper circula[ting] tanks, containing copper steam tubes. These [heat] up the water in large wrought iron hot-water s[torage] tanks in the basement, another set of hot-w[ater] tanks under the roofs being kept in cons[tant] circulation with those in the basement, wher[eby] an instantaneous supply of hot water is alw[ays] available without waiting until quantities of [cold] water in pipes be drained off.

The system of ventilation thus described is enti[rely] new to Glasgow, and so far as we are aware th[is is] the only infirmary ventilated on this principle. [The] Plenum system has been adopted in the Univer[sity] Buildings, Dundee, and in four Board school[s in] Aberdeen; but there are several features at [the] Victoria Infirmary which are quite new, and [were] devised by Mr Key to suit circumstances. [We] understand that the system has been highly spo[ken] of in Aberdeen, where the scholars and teacher[s in] the schools so ventilated are said to enjoy be[tter] health than those engaged in other schools no[t so] treated.

The laundry, washing-house, and mortu[ary] buildings are erected on the part of the site furt[hest] from Langside Road, and are nearing complet[ion.] The grounds surrounding the main building h[ave] been tastefully laid out in walks and terraces, [and] this part of the work on the lower ground is proceeding.

The infirmary has been erected from design[s by] Messrs Campbell Douglas & Sellars, architects, St Vincent Street, and since the death of [Mr] Sellars the work has been carried out under [the] superintendence of Mr Morrison, who has been assumed as a partner of the firm; and [the] ventilation and heating have been carried out [from] the designs of Mr William Key.

The Glasgow Herald, 15 Feb 1890.
Extract from a lengthy report on the opening of the Victoria Infirmary, Glasgow.
Third paragraph from end refers to adoption of Key's variation of the plenum system.

TABLE 2

Cost of building the Victoria Infirmary

Work	*Cost (£.s.d.)*
Excavation, masonry, brick & iron work	£7,872/15/3d
Carpentry & joinery	£3,813/14/6d
Plumbing	£1,207/10/0d
Plaster work	£749/4/8d
Slater work	£281/10/10½d
Painting	£225/0/0d
Miscellaneous (incl. heating & cooking apparatus, laying out ground, & planting)	£1,200/0/0d
TOTAL	£15,349/15/3½d
Add 10% for professional fees, clerk of work's wages, & contingencies	say £1,530/4/8½d
Grand Total	£16,880/0/0d

It was decided to use the new electric light for most of the hospital, including a small electric lamp above each bed, "movable so that it can be carried round a patient for purposes of examination". Heating and ventilation would be achieved in a novel way, using a design patented by one of the Workmen's Governors, Mr William Key, Manager of the Tradeston Gas Works. Known as the plenum system, this relied upon warmed, filtered, and washed air, driven by fan through ducts to the wards, and removed by means of one-way valved exhaust shafts. Windows had to be kept shut, and so draughts were also avoided. The frequent exchanges of copious volumes of air blown imperceptibly into the wards ensured that ". . . none of the inmates will ever breathe air which had previously passed through the lungs of any of the other occupants". It was also possible to increase the frequency of air exchanged when making beds or when the air needed freshening. A cooling valve was incorporated so that the temperature could also be modified.

The Victoria appears to have been the first hospital to use this system, which dispensed with the usual central ward fireplace, a passing lamented by some. Although it was soon afterwards adopted in the rebuilt Royal Alexandra Infirmary in neighbouring Paisley, Key's brainchild appears never to have been a total success. Other new technology included the installation

The Victorial Infirmary of Glasgow, Slater and Dow (see Bibliography)
Reference to use of electric lighting and to Key's system. Costs are of interest but do not extract system costs.

APPENDIX

THE ARCHITECTS OF THE VICTORIA

UNDER the heading " Origin and Development " the expansion of the Infirmary from the earliest buildings to the size attained in 1948 was reviewed. Little mention has been made of the architects responsible. The account which follows is based on information supplied by the present architect to the Infirmary, John Watson, B.Arch., F.R.I.B.A., F.R.I.A.S.

In 1882 plans for a hospital of 250 beds with 1,500 cubic feet of space per patient were invited in an open competition. The assessors for this competition were John Carrick, Glasgow City Architect, and Dr. J. B. Russell, Medical Officer for the city. Messrs. Campbell Douglas and Sellars of Glasgow submitted the design which received the award and they were commissioned to do the work. Building did not commence until July 1888, but the first portion of the scheme comprising " the administrative block, suitable for the entire Institution when fully completed, one pavilion containing three large and three small wards and necessary adjuncts (the present Wards 1 - 3 with their side rooms), and including washing house and laundry, boiler and engine house, mortuary and entrance lodge with the whole of the grounds laid off and walled in " was completed within eighteen months. James Sellars, the architect intimately concerned with the plans, died at the age of 45 only three months after building commenced, and Campbell Douglas took charge of the architectural affairs of the hospital. A second pavilion was completed in 1893 and a third block was added in 1901. This latter block included the Electrical and Röntgen Ray Department and small isolation wards later allocated to the septic and burns unit.

Campbell Douglas (1828-1910) had a series of partners. Initially he practiced alone but about 1860 he entered partnership. The firm was styled successively Campbell

Douglas and Stevenson, Campbell Douglas and Sellars, an after Sellar's death Campbell Douglas and Morrison. Th latter partnership was dissolved after some ten years. In 190 a new partner joined the firm which became Campbel Douglas and A. N. Paterson, but thereafter the senior partne ceased to take an active interest. Among the works for whicl Campbell Douglas and Sellars were architects are St. Andrews Halls (destroyed by fire in 1962), Kelvinside Academy, the New Club in West George Street (now converted to offices) and Belhaven (now St. Luke's Greek Orthodox) Church.

John Keppie (1862-1945) was the chief draughtsman with Campbell Douglas and Sellars at the time of the latter's death. Keppie left to enter partnership with John Honeyman, taking with him, it is said, many of Seller's former clients (Anderson College was one). It was Keppie, now a member of the firm Honeyman and Keppie, who planned Bellahouston Dispensary (Plate 3) for the Victoria Infirmary. The Dispensary, which opened in 1899, was sold ultimately by the Western Regional Hospital Board to the Scottish Co-operative Wholesale Society who demolished it and erected an extension to their premises on the site. It is of interest to record that Charles Rennie Mackintosh, the architect of international fame, was at that time draughtsman with the firm which he had joined in 1889 at the age of 21. On Dr. Honeyman's retiral in 1904 he was made a partner and the firm became Honeyman, Keppie and Mackintosh. This partnership was dissolved in 1914.

H. E. Clifford (1860-1932) was appointed architect to the Victoria Infirmary in 1902. He designed the fine building for mortuary, chapel and pathological museum which was demolished recently to clear the site for the new Out-patient and Casualty Block. He also designed the building formerly known as the Robertson Block, which contained the Clinical Research Laboratory opened in 1913. The major part of this building was demolished a few years ago to make way for the present block of laboratories and operating-theatre suites. He was engaged on a further pavilion (Wards 12A - 17) in 1925 when on reaching the age of 65 he intimated his desire to retire.

The Victoria Infirmary of Glasgow, I Murray
(see Bibliography)
Appendix on Architects of the Hopspital, throughout its life, refers to Keppie's work for the Infirmary, in partnership with Honeyman

★ THE STVRTEVANT SYSTEM ★

In the new building, the loss immediately dropped to only 10,114 days, a reduction of over 45 per cent. When we consider the conditions of yearly salary under which most of these clerks are paid, the financial return from improved ventilation is emphatically evident.

But these cases do not indicate the relative degree of ventilation under the different circumstances with the resultant corresponding death or sick-rate. From a "Report on the Cost and Efficiency of the Heating and Ventilation of Schools, for the use and by the request of the School Board of Dundee" (Scotland), we are, however, able to draw some valuable deductions. The accompanying table compiled from the data therein given, while somewhat incomplete, presents clearly, not only the relative presence of micro-organisms, but the resulting sick-rates for different proportions of carbonic acid gas; while the Government grants to these schools based on the proficiency of their scholars, as indicated by the proportion of passes, is furthermore the best possible evidence of the financial return due to the increased mental vigor of the pupils wherever better ventilation obtains. Although the best ventilated of these schools are decidedly below the standard of fair ventilation, nevertheless, in their relative value, these data are worthy of the careful study and serious consideration of those who question the necessity and expediency of improved ventilation.

Results of Investigations.

Becker's investigations in European schools show that in a school having

2.0 cubic meters of air-space per pupil, . . 44.6 per cent. of the pupils had habitual headache.
3.5 cubic meters of air-space per pupil, . . 34.0 per cent. of the pupils had habitual headache.
6.8 cubic meters of air-space per pupil, . . 4.7 per cent. of the pupils had habitual headache.

How can a pupil be mentally acute under such conditions as existed in the first two instances?

Sturtevant Company Catalogue, 1895.
Refers to Dundee School-Board report.

THE STVRTEVANT APPARATVS

	Architect.	Designer of Heating and Ventilating System.	Contractor for Heating and Ventilating System.
Wisconsin.			
MILWAUKEE: State Normal Sch.	*W. A. Holbrook.*	*B. F. Sturtevant Co.*	*A. J. Linderman & Hoverson.*
Thirteenth Dist. Primary School.	*H. C. Koch.*	*B. F. Sturtevant Co.*	*H. Mooers Co.*
Seventeenth Dist. Primary School.	*W. A. Holbrook.*	*B. F. Sturtevant Co.*	*H. Mooers Co.*
OSHKOSH: State Normal School.	*William Waters.*	*William Waters.*	*W. H. Crawford.*
England.			
ACCRINGTON: Accrington Technical School.	*Henry Ross.*	*Sturtevant Engineering Co.*	*Sturtevant Engineering Co.*
BLACKBURN: Girls' High School.	*Stones & Gradwell.*	*Sturtevant Engineering Co.*	*Sturtevant Engineering Co.*
MANCHESTER: Municipal Technical School.	*Apalding & Cross.*	*Sturtevant Engineering Co.*	*Sturtevant Engineering Co.*
WIDNES: Library and Technical School.	*Woodhouse & Willoughby.*	*Sturtevant Engineering Co.*	*Sturtevant Engineering Co.*

7.2.96

76

Sturtevant Company Catalogue. 1895.
Lists British installations of the Company's fans by this time.

NOTES ON THE PLENUM SYSTEM OF VENTILATION.

By William Henman [F.].

In the Paper which I read last December on the Royal Victoria Hospital, Belfast,* I particularly stated it was not my desire to raise controversy on the subject of mechanical *versus* natural means for securing ventilation; yet, as members then present expressed the opinion that it might with advantage be further discussed, the Council of the Institute have appointed the 6th of June for that purpose.† If the time then at our disposal is to be well employed, the subject of ventilation generally must be dealt with on practical and scientific lines; and as that was not attempted in the Paper to which I have referred I venture to suggest some reasons which tend to show that plenum ventilation can be beneficially employed in certain buildings, and ought to be more closely studied by members of the architectural profession.

A primary necessity is to arrive at a concisely correct definition of what should be understood by the term "efficient ventilation" when applied to occupied buildings. Apart from outside contaminating influences which would affect ventilation by whatever means obtained, I suggest it is "continuous change of air within a building without causing discomfort or adversely affecting the health of the occupants."

The province of an architect in connection therewith is to dispose buildings on the ground, construct and equip them, so that the available air may be supplied in ample quantities, freed from suspended impurities, tempered and regulated to requirements without deterioration.

Buildings are erected principally to secure greater comfort than can at all times be obtained in the open.

By the erection of buildings, movement of air within them is necessarily less than it would be over the unoccupied site.

Change of air within a building is principally brought about by an ascertainable force—either of propulsion or extraction—although the law of diffusion—*i.e.* the process which brings about intimate mixture of gases without chemical combination—is a serviceable but less powerful agent in connection with ventilation.

If these premises be accepted, the question which has to be discussed is not whether by plenum ventilation a condition within doors can be secured equal to the open air at its best, but whether it can be employed in certain buildings, suitably constructed, so as to obtain at reasonable cost more constant and efficient ventilation than can be secured by other means.

A great hindrance to the proper comprehension of this subject is the employment of unscientific terms such as "artificial ventilation," "automatic ventilation," "natural ventilation," "mechanical ventilation," because they prejudice the mind. Ventilation is a result brought about either by natural or mechanical force. Moved by either, air is the same, just as water is the same, whether allowed to flow naturally or forced on by mechanism. Water may become fouled on its way, so may air, whether it pass in naturally or is propelled in its course from the outside to the inside of a building; but it does not in the least follow that fouling results from the power which caused its movement.

It is scientifically wrong to refer to a fire causing a "suctional" influence in a flue, for it does nothing of the kind. Air when heated expands and is specifically lighter than an equal volume of colder air; it is the latter descending by the force of gravitation which propels the warmer air upwards; consequently an open fire in a room causes change of air by propulsion; moreover, the propelling force of wind is far greater than the suctional influence it exerts upon air within buildings. By realising these facts it is easy to understand that "plenum" ventilation is more in accord with nature's methods than "exhaust" ventilation.

Notwithstanding the acknowledged extravagance of, the dust and dirt resulting from, and the unpleasant draughts at times set up by, the open fire, I for one appreciate its cheerfulness, and believe it will long hold an honoured place in the British home. The mere fact that it necessitates an upcast flue is of the greatest service in connection with ventilation; but as the area of an ordinary smoke flue at the chimney-pot end does not greatly exceed half a superficial foot, the volume of air which can pass through it in a given time is limited, as is also the heating power of a single fire-grate. Consequently, for larger apartments two or more fires are required, and it is well known that unless an adequate supply of air be otherwise provided, smoke will at times be drawn down one or other of the flues. For this and other reasons hot water, steam, air heated by stoves or electricity, are used, none of which demand an upcast flue or flues from the apartment to be warmed thereby. Yet for the health

* Journal R.I.B.A., 19 Dec. 1903.

† For the purposes of the discussion reported *infra*, the author's unrevised draft of this Paper was issued to members with the last number of the Journal.

Journal of the RIBA, 11 June 1904 (see Bibliography)
William Henman is, by this time, fully supportive of the plenum system but makes not mention of his introduction to it by Key.

HOSPITAL DESIGN

John Tovey

Ventilating the Royal Victoria Hospital

THERE are certain buildings which after due passage of time are upon re-evaluation seen to have set a precedent in design concept or method of construction. Such a building is the Royal Victoria Hospital at Belfast, provided originally from funds raised to mark the Diamond Jubilee of Queen Victoria and opened by King Edward VII in 1903. As an innovatory building this hospital has its place in the history of architecture being placed there some ten years ago through the detailed examination of its design and its interior by Professor Reyner Banham in *The architecture of the well-tempered environment.* In this book, Professor Banham raises doubts about the true authorship of this departure in hospital design and ventilation and it is the purpose of this note to clarify the issue.

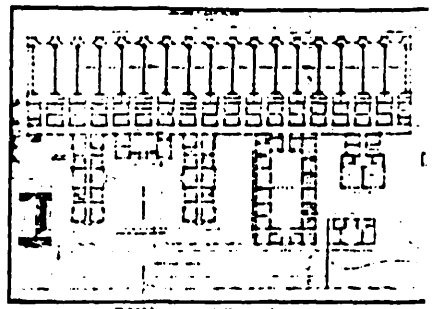
Professor Banham takes as the theme of his book the influence of mechanical services on the development of architectural design, and singles out the Royal Victoria Hospital as a hospital "extremely 'modern' and ahead of its time and its environmental controls", claiming that "it must have been the first major building to be air-conditioned for human comfort". In a previous talk published in *The Listener* in February 1967 he adds, "and very likely the first in the world".[1] This assertion rests on two assumptions: first that the Royal Victoria Hospital was completed three years before Frank Lloyd Wright's "air-conditioned" Larkin Office Building, New York (1906); and second, on the precise meaning of the term "air-conditioning" as understood by Stuart Cramer and Willis Carrier, being the inclusion of controlled humidification of air cleaned and "tempered" for ventilation purposes. The arrangement at Belfast was crude in this respect but satisfied the principles. Moreover, the important factor stressed by Professor Banham was that at a time when it was customary to design hospitals with wards in widely-spread pavilion blocks, the wards of the Belfast hospital were placed deliberately side by side in one long single-storey block lit from above by sealed clerestory windows to fulfil as efficiently as possible the requirements of the Plenum System — then still in its early stages of development.

Before discussing new evidence concerning the authorship of the design of the ventilation system, a brief reference to the underlying engineering principles is necessary. "Fresh air" in hospitals was acknowledged to be an important curative factor, and long "Nightingale" wards, widely spaced, with windows on opposite sides to encourage cross-ventilation were considered to be the most effective solution, though clearly on hot, windless summer days or nights no such change of the air could take place. To remedy this, a Glasgow engineer, William Key, in 1889 sealed all windows at the Glasgow Royal Infirmary thus forming a "Plenum" or closed system supplied by fan-propelled air previously cleansed by passage through screens kept moist by water sprinklers, then ducted to the wards. This system was adopted in 1892 by the Building Committee of the new General Hospital in course of erection at Birmingham, where the architect, William Henman collaborated with William Key in the difficult task of sealing and ducting wards spread over an extended sequence of pavilion blocks. Henman's design for the Belfast Royal Victoria Hospital in 1899 took account of the many obstacles encountered at Birmingham, and with its more compact lay-out it set a precedent for subsequent hospital design. The team at Belfast consisted of the Birmingham partnership of William Henman and Thomas Cooper, with Henry Lea as consulting engineer. They arranged for air entering the hospital first to be warmed by a series of vertical steam pipes, then drawn through vertical cleaning screens curtained with coconut fibre strands down which water from sprinkler pipes poured from above to remove dust and manufacturing smuts. At a later date, hygrometer tests taken twice daily in the hospital wards indicated the changing conditions of humidity and thus the intake air could be adjusted for moisture content by regulating the sprinkler taps. In this way, the hospital received the extra dimension to become "air-conditioned".[2] After further heating, as required by daily conditions, the air was then propelled at low pressure, along the main ventilation duct which extended for 450 feet beneath the entire length of the hospital ward block. The duct measured 20 feet high and nine feet wide at the intake end. "The giant duct", wrote Professor Banham, "is one of the most monumental in the history of environmental engineering".

The propelling fans, fully nine feet in diameter, were provided in duplicate from Samuel Cleland Davidson's "Sirocco" Fan Company in Belfast, a firm greatly experienced in the provision of fan ventilation for ships' engine rooms and cargo holds.

Because of the presence in the locality of this technological expertise, Professor

A ward in the Royal Victoria Hospital, Belfast, c. 1903.



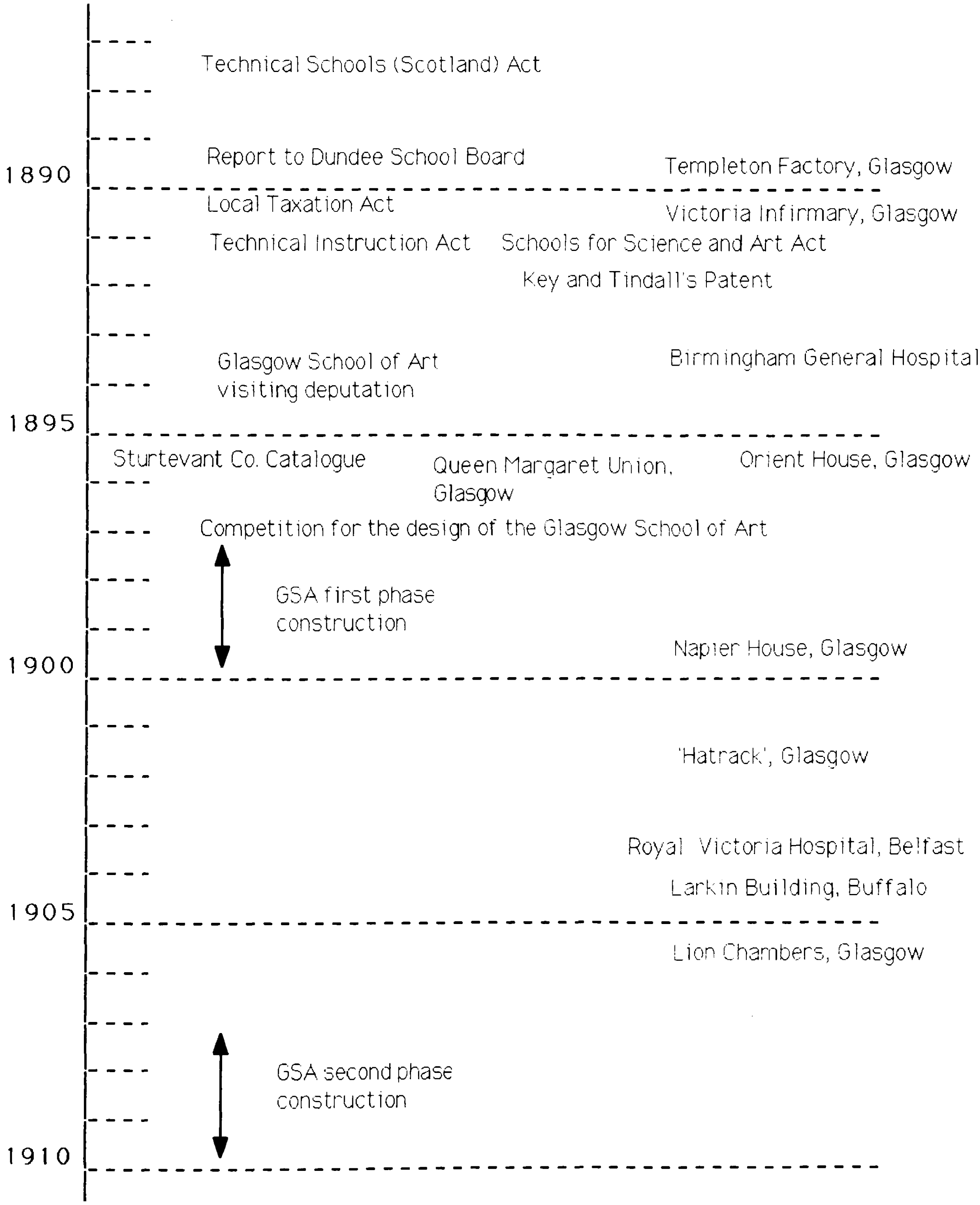
RVH: ground-floor plan.

Banham is inclined to give all the credit for the innovatory design and ventilation of the hospital to the influence of ship-building magnates serving on the Hospital Committee, and in particular to attribute the inspiration for the air supply system solely to the fan manufacturer, even to the extent of stating that: "From the beginning Davidson had intended some form of humidity control", adding, "the degree of control *designed by Davidson* (my italics) into the air supply system was rigorous by the standards of the time and made ingenious use of the comparatively crude technology available." Local Belfast pride naturally supported this idea. Both William Henman and Henry Lea read papers at the RIBA under the presidency of Sir Aston Webb in 1908,[3] explaining their reasoning for the architectural lay-out, detailing its accompanying Plenum installation. There followed two sessions of discussion on June 6 and 25, 1904, since the project was sufficiently revolutionary to have attracted opposition from both architectural and medical opinion. In his radio talk, Professor Banham suggests that "something nasty seems to have happened to the discussion after the papers". He gains the impression from subsequent news-paragraphs and letters "that the discussion was either rigged or filibustered out of time, to prevent something discreditable coming to light" and that "covertly it seems to have been

RIBA Journal, October 1981, (see Bibliography)

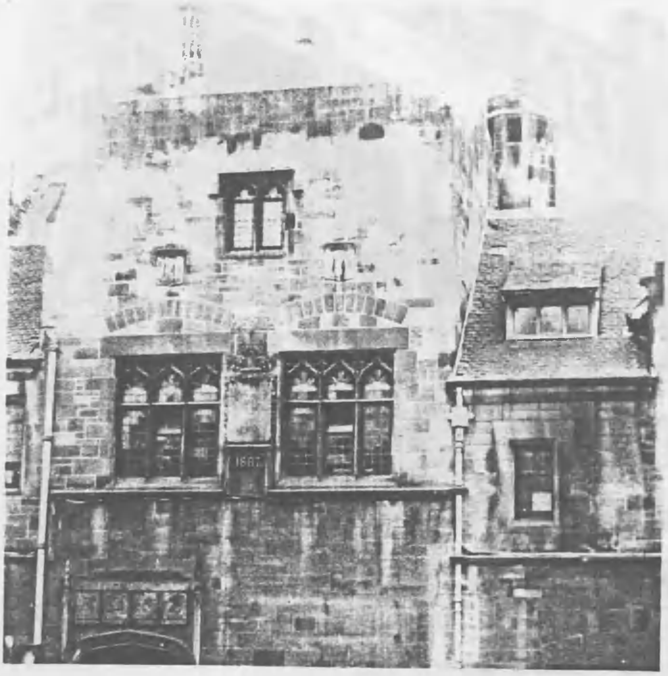
John Tovey writes in support of the Royal Victoria Infirmary, Belfast as the world's first air-conditioned building. Key's work at the Glasgow Royal Infirmary (sic) is mentioned, but without reference to his Patent.

Appendix V
Chronology


Technical Schools (Scotland) Act
Report to Dundee School Board
Templeton Factory, Glasgow
1890
Local Taxation Act
Victoria Infirmary, Glasgow
Technical Instruction Act
Schools for Science and Art Act
Key and Tindall's Patent
Birmingham General Hospital
Glasgow School of Art
visiting deputation
1895
Sturtevant Co. Catalogue
Queen Margaret Union,
Glasgow
Orient House, Glasgow
Competition for the design of the Glasgow School of Art
GSA first phase
construction
Napier House, Glasgow
1900
'Hatrack', Glasgow
Royal Victoria Hospital, Belfast
Larkin Building, Buffalo
1905
Lion Chambers, Glasgow
GSA second phase
construction
1910

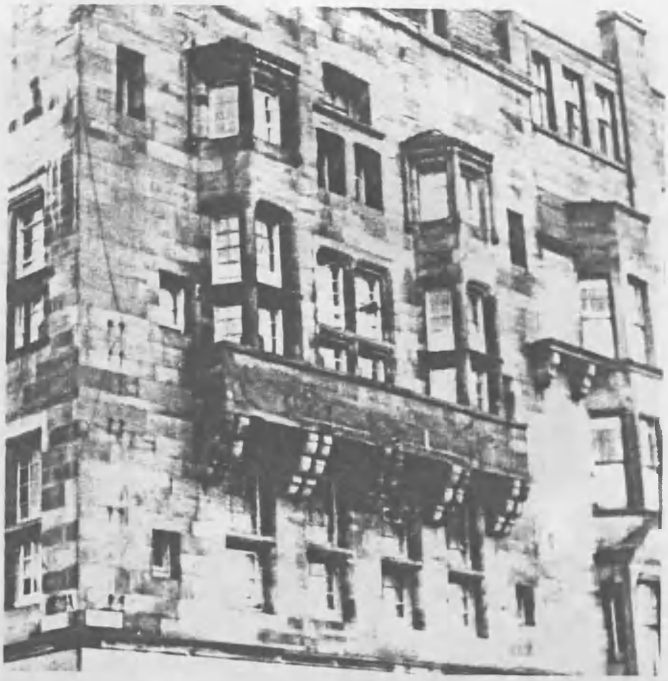
Appendix VI
Additional Photographic References

The following pages show photographs of contemporary developments and of Scottish domestic architecture, referred to within the text of this Thesis.



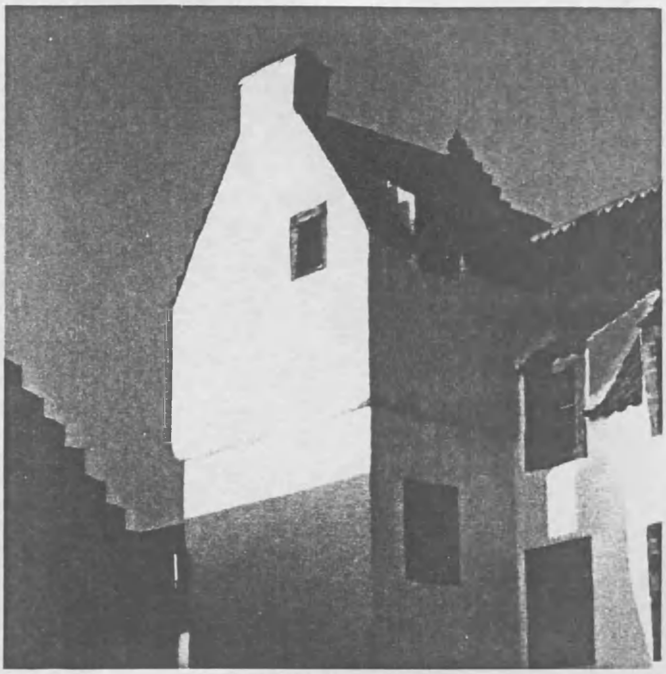
Queen Margaret Union, Glasgow
1895
J J Burnet

Templeton Factory, Glasgow
1889
William Leiper



Napier House, Glasgow
1899
W J Anderson

'Hatrack', Glasgow
1902
James Salmon Jnr



Culross,
Fife