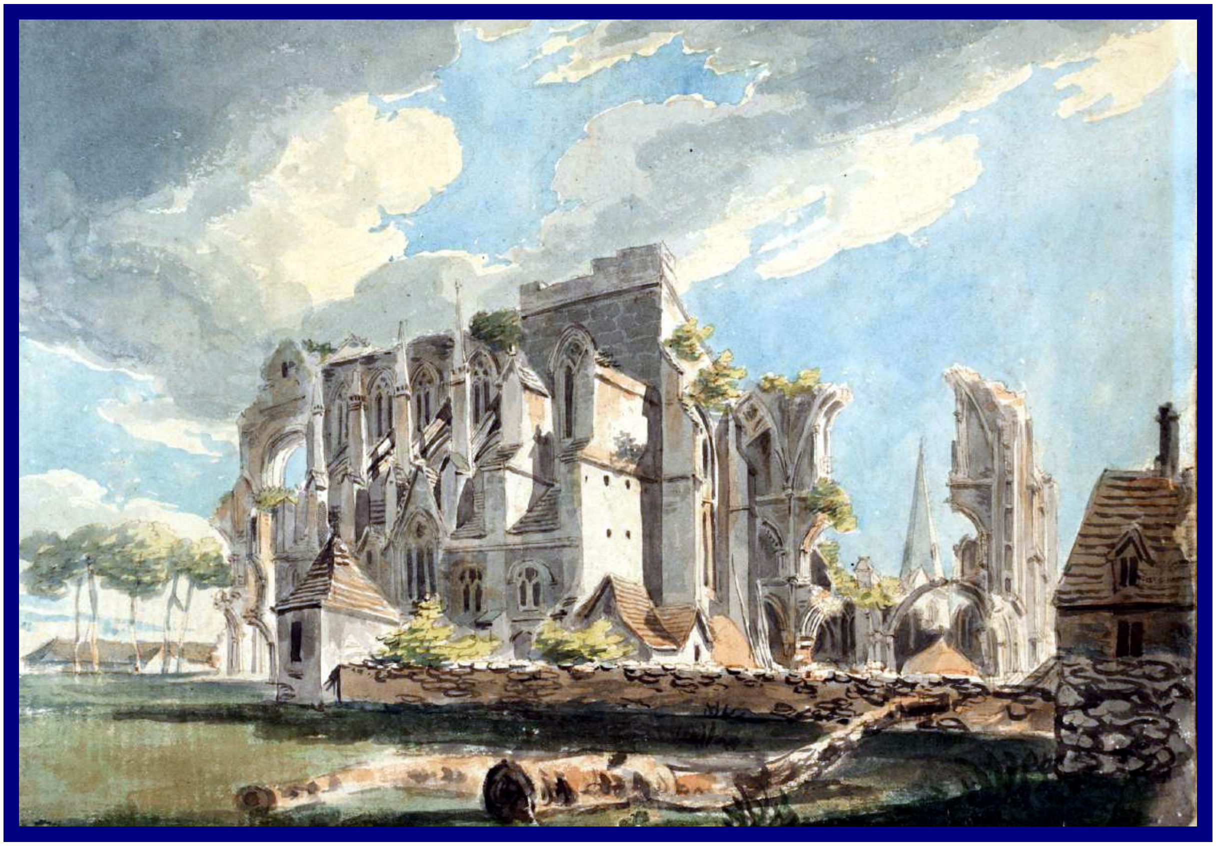


Malmesbury Abbey (Painting by J.M.W. Turner), Heated by Gurney Stoves

ENGLISH CATHEDRALS & CHURCHES

HISTORIC HEATING: PART ONE

BRIAN ROBERTS

BATH ABBEY

LPHW Heating by G N Haden & Son

CONTENTS

Malmesbury Abbey: Heated by Gurney Stoves

A wealth of information and illustrations on heating stoves and manufacturers is available on the Heritage Group website and is now supplemented by the Cathedral plans and photographs in this Part-One, which may be of assistance to future researchers in recording the positions of heating stoves in these historic Cathedrals.

With special acknowledgment to sources listed it may be noted that Paul Yunnie of the Heritage Group has also written in 2020 for the Heritage Revisited series: "The London Warming and Heating Company & The Gurney Stove".

BMR, Budleigh Salterton 2021.

FOREWORD

The WARMING & VENTILATING of VICTORIAN & EDWARDIAN CHURCHES

The Bells of Waiting Advent ring
The Tortoise stove is lit again
And lamp-oil light across the street
Has caught the streaks of winter rain.

John Betjeman

Section-1

FOREWORD

This electronic heritage book is an on-going project. It was commenced in 1999 and because of its subject matter is capable of almost unlimited expansion.

The title refers to Victorian and Edwardian "Churches," but in practice also included are cathedrals, abbeys, chapels and other religious buildings of Church of England, Roman Catholic, Methodist, Baptist and other denominations. Most of the buildings included to date are in England, with just a few in Wales and elsewhere.The "Victorian & Edwardian" in the title refers to the period of the installation of the heating and/or ventilation. The building may have been built, restored or extended in these times, but many, such as the famous cathedrals, were started in Norman times. It is often the case that the original Victorian heating or ventilating systems have been stripped out, sometimes with the merest trace of their existence remaining, with little or no record of the system details, only to be replaced by so-called modern systems. Many of these, particularly the direct gas and electric systems have no regard for aesthetic considerations. Also, depressing is the lack of interest by many church authorities who have allowed valuable items of engineering heritage to be ruthlessly scrapped even after having been advised of their rarity value.

The Heritage Group continues to locate, record and where appropriate save the best examples of the Victorian & Edwardian engineers' heating systems and equipment.

ACKNOWLEDGMENTS

The WARMING & VENTILATING of VICTORIAN & EDWARDIAN CHURCHES

ACKNOWLEDGMENTS

Very many people and organisations have provided assistance, information and pictures for this electronic book. The authors would like to thank the various cathedral and church authorities who have granted access and given permission to survey and photograph their buildings and their engineering services. We must also thank the clergy and lay persons who have given of their time, answered questions and shown us around.

A special thanks goes the various libraries and their staff who have provided much essential background information, including: The Record Offices at Bristol and in Dorset, Gloucestershire, Herefordshire and the Wiltshire Record Office where the Haden Archives are kept. Assistance has also been given by The British Library (Patents Section), the Newspaper Record Office at Collingdale in London and the Library of the Building Research & Information Association (BSRIA) at Bracknell. A special thanks goes to the staff at the Bourne Hall Library in Ewell, Epsom, Surrey who tracked down and made available all the copies in the Buildings of England Series by the architectural historian Nikolaus Pevsner (more than 50 books), as well as other important reference material.

A number of firms and organisations have been of considerable help: English Heritage, the Council for the Care of Churches, Grundy, Haden Young, Skinner Board, The National Trust and the National Association of Decorative & Fine Arts Societies (NADFAS). Assistance from individual engineers and enthusiasts is also acknowledged.

The authors also acknowledge the support and information provided by past and present members of the Heritage Group, including Mike Barber, John Barnes, Geoff Brundrett, Linda Bullock, David Drewe, Geraldine O'Farrell, Richard Forster and Stephen Loyd. A special thanks to former Vice-Chairman Paul Yunnie (now living in Australia) for providing his collection of church documents and papers dating from the 1950s.

BMR, Tadworth, Surrey
FJF, Bristol
2006 Revised 2012

INTRODUCTION: H&V PIONEERS

The WARMING & VENTILATING of VICTORIAN & EDWARDIAN CHURCHES

Section-1

INTRODUCTION

At the beginning of the 19th century, it was recognised there were insufficient churches to serve a population that was not only increasing in numbers but moving from the countryside into the towns. In 1803 there was "An Act to Promote the Building, Repairing or Otherwise Providing of Churches and Chapels." This was amended in 1811, but the key legislation came in 1818 with "An Act for Promoting the Building of Additional Churches in Populous Parishes." This allowed State finance to be available for church building, these being known as Commissioners' Churches, or Waterloo Churches, being built with the approval of The Commissioners for Building New Churches in the years following the Battle of Waterloo (1815). All of this was consolidated in an Act of 1824.

The Victorian Era lasted over sixty years. Queen Victoria came to the throne on the 20th June 1837. She died on the 22nd January 1901. The reign of Edward VII, the Edwardian era, lasted until 1911. Some extent of the work carried out by the growing heating industry may be gauged from the construction rate of new and rebuilt Anglican churches during the years 1835 to 1875 when some 3765 churches were consecrated, of which 1010 were in the peak decade of the 1860's. In addition, numerous Catholic churches and convents were built during the same period.

Pioneers of Warming & Ventilating

Steam heating was an English innovation, first proposed by a Colonel William Cook in 1745. It was not immediately taken up, though James Watt used it to heat his writing room in 1784, and his partner, Matthew Boulton, to warm his living room and bath in 1789. James Hoyle of Halifax took out a patent for steam heating in 1791, while in 1793 Green took out a patent "to heat air in double tubes, through which steam or water can circulate." Most early applications of steam heating were for factories, and later in glasshouses. The first church to have been warmed by steam may be one in Dublin, said to have been arranged by Count Rumford in 1796. But steam heating for English churches was extremely rare.

THOMAS TREDGOLD

The choice of heating for churches lay between warm air and hot water. The English loved their open fires. Heavy masonry stoves were used from around the 11th century in Germany and Switzerland, and then particularly in Scandinavia and Russia, but never caught on in England. Metal stoves were developed in Germany from the early 17th century, but these only really came into use in Great Britain in the second quarter of the 19th century. Many thousands of churches came to be heated by stoves in Victorian times, and a number of specialist manufacturers were predominant in this field, notably Haden, John Grundy and The London Warming and Ventilating Company, manufacturer of the Gurney stove.

Hot water heating dates back to at least 1716, when a greenhouse was heated by Sir Martin Triewald. In spite of this, it was not until 1816 that hot water heating was introduced in England by the Marquis de Chabannes. He believed that there would be more opportunity for central heating in England, where wood was scarce and coal common, that in his native France. The Price Bros of Bristol secured a patent specifically for heating buildings, but the first application of their system in a church appears to be St Mildred, Whippingham on the Isle of Wight, about 1860. Hot water heating was taken up by Haden who used it successfully in many churches in the 19th century. Another firm which carried out the heating of many churches from 1873 was John Metcalf of Preston. These hot water heating systems had to operate by gravity circulation as no suitable pumps were available. Early in the 20th century a number of "accelerators" for promoting rapid circulation of heating water through the system were introduced, the Reck system introduced into Britain from Denmark in 1903, and the Cable system of A H Barker devised in 1904. These required a source of steam but even so a number of churches had accelerators installed.

An alternative system of hot water heating using small-bore tubes was developed by A M Perkins. This system initially used very high temperatures and operating pressures and was considered by many to be dangerous. Later refinements to the system later lowered both temperature and pressure. However, many churches were fitted with the Perkins system and towards the latter part of the 19th century, a number of firms in the north of England were installing these systems, some apparently under licence; others possibly not. These included Lewis Hill, Acme Ventilating and Renton Gibbs, all of Liverpool, and Longbottom of Leeds. Acme and Gibbs developed their own form of high pressure hot water boiler.

Calculating the heat requirements of buildings, particularly churches, was carried out on a very rough rule-of-thumb basis and coupled with such practical experience as was available. The earliest book on heating is generally regarded as "A Treatise on the Economy of Fuel and Management of Heat," by Robertson Buchanan (Glasgow, 1815).

Thomas Tredgold: 1788-1829

The first classic heating text is "The Principles of Warming and Ventilating Public Buildings, etc.," by Thomas Tredgold (London, 1824). Tredgold determined that the total heat loss from a room was the sum of the necessary ventilation, the infiltration through doors and windows, and the window losses "in air equivalent." No allowance was made for heat losses through the solid building fabric, such as walls and roof. He also devised a formula to work out the area of heating pipe needed, and was able to estimate the hourly and annual fuel consumption on the basis of continuous heating. Churches are notoriously more difficult, being used only intermittently. Tredgold proposed to assume some appropriate preheating period to be added to the duration of occupation to give the daily total hours of use, to which the fuel consumption would be proportional. He gave a set of recommendations for Warming and Ventilating Churches, Chapels, &c:

"Churches and chapels are usually lofty and capacious: so that in winter when heat is required, only a small quantity of ventilation is necessary, on account of the short period the congregation remains in them at any one time. But abundant summer ventilation must be provided for. I shall first consider the means of heating them in winter, and afterwards the ventilation for summer.

Let us suppose a church for 1200 people, to contain 100,000 feet of space, and that the congregation in winter is, at an average, 600, and that there are 28 windows with 1000 feet of surface of glass, and that it is to be kept at 60°, when the external air is at 30°, or 30° above the external air.

Here by the rule, art.68, the loss of heat from the glass will be	1500 cubic feet
Ventilation for 600 people	2400
And the escape of heated air from the windows about	300

Making the total quantity to be heated per minute	4200 cubic feet

The quantity of surface of steam-pipe that will produce this effect is 428 feet. And, since there is 100,000 cubic feet of space in the church, divide 100,000 by the quantity to be warmed per minute, or 4200, and the quotient 24 is the number of minutes the boiler should be in full action in this case to warm the whole of the air in the church (his argument is unsound: Billington)

In order to distribute the heat, simple steam-pipes of cast-iron, of about four inches diameter, will be found most convenient and effectual. These must be placed according to circumstances: they should not be raised much above the floor, and in most cases will pass conveniently under the seats.

If four-inch pipe be used, you will require as many feet as you want feet of surface, because a four-inch pipe girts very little more than a foot (the external surface area of one lineal foot of four-inch cast-iron pipe is approximately one square foot); and, accordingly, the boiler should contain 37 cubic feet of steam, for this will be found to be the quantity that would fill the whole of the pipes."

Tredgold's scheme of heating for the Portland Chapel, Cheltenham (1821) is unusual in using steam. Tredgold also dealt with the ventilation of churches:

"The summer ventilation of a church or chapel is an important subject, were it only in so far as bodily inconvenience renders the mind unfit for the duties of the place; hence, the currents of cold air to which a person of delicate constitution is exposed by an ill-conducted system of ventilation, should be carefully avoided: for it is a hard case, indeed, that such a person should have to encounter, unnecessarily, all the evils of disease, in consequence of attending the public worship of our Creator. I will, therefore, endeavour to point out the causes, and the means of lessening the effects, of bad ventilation."

Tredgold discussed the effects of cold draughts in a warm church from opening windows of varying sizes and locations. He preferred multiple, large openings, close to the floor to prevent high velocity descending draughts. He suggested a rudimentary form of inlet grille

JOSEPH BRAMAH: Dr NEIL ARNOTT

(wire-work with 64 apertures in a square inch) to disperse the air currents or, better still, "tubes under the paving (provided with shutters) to admit cold air in the central parts of the church," and for air outlets:

"The warm air should escape at the ceiling at different places, through air trunks, furnished with registers.....
The air-trunks should be of equal height, and equal exposure to the sun. If the aperture be made through the ceiling into the space in the roof, and from this space an air-tube be taken up within the steeple or bell-turret, an effectual ventilation may be obtained within adding outlets to the roof......All side or end windows should be kept shut, for if the apertures at the ceiling be of proper size, side openings will diminish instead of increase the ventilation." In a footnote Tredgold refers to a little work on Warming and Ventilating Meeting Houses recently acquired (*Observations on the Construction and Fitting up of Meeting Houses, &c.* by William Alexander, York, 1820) which he notes confirms, and predates, his own recommendations.

Tredgold next considers how to provide ventilation in more difficult conditions, which he defines as close, still and gloomy weather. He suggests that in hot weather, the internal church rise in temperature due to body heat should be limited to 5° F which he states requires an escape of air of $2^1/_2$ cubic feet per minute for each person and he provides an example calculation. In practical terms, he suggests five or more extract ventilators in a flat ceiling and at least three in a vaulted or arched roof, with the openings for admitting air about double the area of those at the ceiling.

Joseph Bramah & Sons

The 3rd edition of Tredgold, published in 1834, after his death, contains an Appendix added by Thomas Bramah, also a civil engineer, but one who preferred "heating by means of warm water" rather than the steam systems of Tredgold. Thomas's father, Joseph, was a prominent engineer, the inventor of an early water-closet. After his death in 1814, the company J Bramah and Sons went on to install hot water heating apparatus in the Orangery of the Royal Palace at Windsor in 1829 and for the New Westminster Hospital in 1830. Though no examples of Bramah installing heating in churches have been discovered, his Appendix to Tredgold's book is significant in renouncing the idea of steam heating in favour of hot water:

" .....it has appeared expedient (in this New Edition), in order to render the work more complete, to notice the mode of using water below its evaporating temperature as a vehicle for carrying or disseminating heat as it is now so generally adopted. The ingenious and scientific Author (Tredgold) has given a decided opinion unfavourable to this mode of heating, and has there indeed declared it to be, without the agency of steam, unattainable upon philosophical principles, but he subsequently became a convert to its acknowledged practicability....."

Dr Neil Arnott: 1788-1874

An early, but short reference to church warming is given by Dr Neil Arnott, who was Physician Extraordinary to Queen Victoria, in his book "On Warming and Ventilating" (London, 1838, pp.85-6):

GEORGE & JAMES HADEN: THOM. HOOD

"Churches: The warming of the walls previous to the meeting of the congregation should be continued longer than in other cases, because of the long intervals which the building is unused. The heat should not be great, as people generally go in their walking dress. Four or six large stoves distributed over the floor, and acting for some hours before the meeting, would warm the seats and walls of any ordinary church, so as to give the desirable temperature. Afterwards ventilation would be obtained by openings in the ceiling, and inlets below, for cold air to approach the stoves. The mass of air in a church is generally so great in proportion to the number of people, and the duration of the service is so moderate, that ventilation is there of less importance than in many other cases. The temperature and dryness of the walls, however, should have strict attention."

George Haden: 1788-1856 & James Haden 1790-1871

In 1816, the Haden brothers established the firm of G & J Haden, later (1855) **G N Haden & Son**, at Trowbridge, acting as agents of Boulton & Watt to erect steam engines in the West Country. It was at the instigation of Matthew Boulton that Haden went into the warm air stove business. By 1825, the firm was doing work for a variety of customers, including churches and schools. The Haden Company Archive at the Wiltshire Record Office (WRO.1325) holds nearly 250 sets of documents, including a Record Book (Serial No.42) with copies of letters and estimates sent to various customers, almost entirely for warm air stoves during the period 1824-42. A book celebrating 150 years of the Company records its growth during the 19th century: "The warming of churches.....gained momentum in the '50's and '60's until by the end of the century Haden had heated thousands of them. Most of these churches had a Haden patent warm air ventilating stove (George Haden secured BP9259:1842) installed below ground with air ducts leading to channels covered by gratings down the aisles. Hundreds of these installations are still in use today (written in 1966) with the warm air stoves being repaired or replaced from time to time." A mid-19th century Haden book of testimonials from satisfied customers refers to a letter of 4th February 1840 from the Reverend Peter Balfour of Clackmannan, "...the church is seated to accommodate 1250 persons: yet....it was during a great part of the year, exceedingly damp and cold. When the weather was very inclement, the most robust of my parishioners complained to me of their inability to endure the cold of the Church. We got erected a ventilating warm air stove by Mr George Haden: the consequence is that our church is about as warm as any sitting room...from about 52^{o} to 57^{o} (F)......."

Thomas Hood: 1805-1889

However, after Tredgold, the next major attempt to set out design procedures was "A Practical Treatise on Warming Buildings by Hot Water, Steam, and Hot Air, etc.," written by Charles Hood (London, 1837). Hood's procedure was not dissimilar to that of Tredgold. The idea was to work out the total area of glass and evaluate the volume of air which this glass would cool. To this was added the requirement for ventilation and leakage, allowing the area of heating surface or length of pipe to be calculated. It was fortunate that the losses through glass were over-estimated which afforded some compensation for the neglect of other structural losses. Hood was perhaps the first to attempt a guide to current practice. For churches he recommended maintaining an internal temperature of 55^{o}F which would require 5 ft of 4-inch pipe as heating surface for every 1000 ft^{3} volume of the building. The calculation procedure he gave (Hood, 5th edition, 1879, pp.123-4) stated:

WALTER JONES

"CHURCHES AND LARGE PUBLIC ROOMS.-- To heat these when they have an average number of doors and windows, and only moderate ventilation, divide the cubic measurement of the building by 200, and the quotient will be *the number of feet in length of pipe, four inches diameter*, that will be required to produce a temperature of about 55° in very cold weather. This is equivalent to allowing five feet of four-inch pipe for every thousand cubic feet of space which the building contains. If the apparatus is so contrived that the warming of the air is effected before it actually circulates in the room, and that the same portions of air are not returned to be heated a second time, but fresh portions of external air are brought successively in contact with the heating apparatus, it will require from 50 to 70 per cent more pipe to produce the same effect; but the air will, of course, be more pure and fresh."

Walter Jones: d.1924

However, Hood's rules were based on a water temperature of 200°F and in practice temperatures were usually much lower than this, a fact pointed out in "Heating by Hot Water," by Walter Jones (London, 1st edition, 1890). Jones was the founder of the firm of Jones & Attwood of Stourbridge, both manufacturers and installers of heating apparatus, and he went on to be the second President of The Institution of Heating & Ventilating Engineers in 1899. Jones complains that the quantity of pipes (as heating surface) is frequently under-estimated. He states that the calculation should be based on the cubical capacity of the building and the temperature required. He continues, "The quantity of air to be warmed per minute is 4 cubic feet for each person, adding $1^1/_4$ cubic foot for each square foot of glass in habitable rooms or public buildings."

Jones produced his own recommendations "Table No. 3. Length of 4-inch Pipe *Required for every 1,000 Cubic Feet*." For churches he gives "Temperature Required, 55 degrees: 4-inch Pipes Required, 6 to 7 feet," which in contradiction of his earlier statement ignores both number of persons and area of glass though to be fair he does say the table is for rapid calculations and must be considered as approximate only. He also states:

"The position and aspect of the building should be considered; if it is in an exposed position, or has a north, or north-east aspect, or if has a number of corners or angles, an increased length of pipes will be required, When placed in channels or trenches (a typical method employed in heating churches), from 10 to 20 per cent should be put in to allow for the absorption of heat by the soil and brickwork."

Jones also refers to Hood's later rule for calculating the length in feet of iron pipes required for heating the air in a building:

"Multiply the volume of air in cubic feet to be warmed per minute by the difference in maximum temperature of the room and the external temperature; and multiply by 1.12 for 2-inch pipes, by .75 for 3-inch, and by .56 for 4-inch pipes, and divide the product by the difference of the internal temperature and that of the pipes."

Jones raises a number of objections to this rule and considers the results obtained to be unreliable. He uses the example of a church with lofty interior and a relatively small window surface; 176,000 ft^3, 688 ft^2 of glass; seating for 800 persons, and an average attendance of 400 persons. Jones calculates the heating surface requirement, using his Table 3, as 1,760 feet run of 3-inch pipes. Using Hood's method he calculates either 563 feet or 341 feet of 3-inch

WALTER JONES

pipe according to whether 800 or 400 persons respectively are allowed as being present. Why Jones chooses, after referring to numbers of people and area of glass as being important, to use his simplified Table based on building volume only to criticise Hood's method appears unjustified. But there is no doubt that Jones was an eminently practical and sucessful heating engineer. Perhaps his installations were "over-engineered." It may be noted that all these calculations refer to heating by means of pipes, for which a variety of coil arrangements were developed. These coils were frequently surrounded (for the sake of appearance) with ornamental coil-cases. Gradually, the American practice of using radiators became more common-place, though there seemed to be a traditional British reluctance to this practice. Even Jones, writing of pipe coils, which he apparently preferred, found it necessary to state: "When a large heating-surface is required in a limited space, radiators are often substituted."

Jones's book also dealt specifically with how to heat churches:
"One of the principal difficulties in heating churches or other lofty buildings is in providing and distributing sufficient radiating surface to heat the building efficiently, and yet interfere as little as possible with the furnishing, and the architectural features of the building.......

1. Ascertain the cubic capacity of the building.
2. Find the total quantity of pipes required, including mains.
3. Select a good boiler of ample power.
4. Distribute the pipes as far as possible over the whole of the building.
5. If sufficient heating-surface cannot otherwise be obtained, coils or stacks of pipes may be used. These should be fixed near the entrances, underneath large windows and in the least conspicuous places.......
6. (Relates to horticultural buildings).
7. For churches or other buildings, where occasional or intermittent work is required 2-inch or 3-inch pipes are preferable (4-inch pipes were considered best for horticultural work or buildings where a regular and uniform temperature has to be maintained). They are neater in appearance, hold less water and the temperature will be raised in a shorter time. In aisles or passages 2-inch wrought-iron pipes give a neater appearance than cast, and are well worth the slight additional cost.
8. Avoid dips under doorways, &c.
9. Avoid channels as far as possible. About 20 to 25 per cent more piping will be required to give equal results. The channels form a receptacle for dirt, the pipes get covered with dust, thus impairing their efficiency, and the channels and gratings add considerably to the first cost.
10. In churches, schools, &c. an apparatus (for the average English climate)

There is little or no difficulty in warming churches or other public buildings, but judgment and discretion are necessary to arrange the pipes so that there will be a free circulation ought to be capable of raising the temperature about 25° or 30° above the outside temperature, say, 55° to 60° inside when the outside temperature is 30°., and so that they shall be effective without being conspicuous."

Jones then refers to the problems of down-draughts of cold air in lofty buildings and suggests the best solution is "a thorough distribution of the pipes" because concentrations of intensely hot pipes promote rapidly rising currents of hot air, which is replaced by falling currents of cold air. He comments these effects may be observed by puffing "a cloud of smoke from a cigar or cigarette again the window-pane."

FREDK DYE: D.B. REID: WM WALKER

He also deals with the consumption of fuel, using as an example a large church of 176,000 ft^3 with about 1900 ft of 3-inch pipes, "the total cost of fuel for the whole of the winter being £5."

Jones concludes by stating that a very important feature with low-pressure hot water heating is the immunity of risk from fire. He makes clear his opposition to the high temperatures of the flues in hot-air apparatus and to the very high temperatures employed in high pressure hot water heating systems. As examples, he refers to fires in St Thomas's Church, Stourbridge (1883), the Prestbyterian Church at Hanley, in Staffordshire (1883), and the Wesleyan Chapel, Old Hill (1886). In a 2nd edition of his book (1894), he adds to his list the fire at St Augustine Church in Edinburgh (1891) and is pleased to comment, "The old hot-air heating arrangement, which was responsible for the fire, has now been replaced by low-pressure hot-water apparatus."

Frederick Dye

Charles Hood died in 1889. His "Practical Treatise" was extensively rewritten by Frederick Dye and the following comments are from Dye's 3rd edition (1897). In the preface, Dye notes that the rules and tables that Hood first laid down in 1837 "when the art of warming by hot water was little known and practised less" should still be universally followed except (and he was trying to put this kindly) "that allowance has to be made to balance his accurate experimental data with the less effective results we get in common practice." For the heating of churches Dye introduced two tables. For "Boilers regularly fired," to maintain an internal temperature of 60°, the "Quantity of 4-inch pipe required for every 1000 feet capacity in a brick-built....building" was now 9 feet, while for churches with "boilers which are charged with fuel to last several hours, and worked with a slow draught" the corresponding value is 11 feet of 4-inch pipe. This compares with Hood's original figure of 5 feet (for 55° inside) and Jones's recommendation of 6 to 7 feet (also for 55° inside).

Dr David Boswell Reid: 1805-1863

Without doubt, the first really important book to be written in Victorian times on ventilation is "Illustrations of Ventilation" by Dr David Boswell Reid (London, 1844). Reid discussed the ventilation of a range of buildings, including churches and even ships, railway coaches and lighthouses. Perhaps the most extraordinary example is the ventilation of grave-yards. A small screw or fanner was placed on the ground and connected to a pipe leading to the bottom of the grave-pit. By this means a supply of fresh air for the sexton was assured. Reid thought that in the large pits used at that time, the bottom of the pits became full of carbon dioxide, in which the workman could not safely dig. (Reid's most famous ventilation scheme is that for the House of Commons, rebuilt after the Great Fire of 1834 and described at some length in his book. It was not a success due to the personality clash between him and the architect, Sir Charles Barry; they even refused to exchange drawings. However, at St George's Hall in Liverpool, Reid's scheme of 1851 for warming and ventilation is generally to be considered the first successful large installation in Great Britain.)

William Walker

Ventilation of churches was a preoccupation of many Victorians. The subject is dealt with by W Walker in his "Useful Hints on Ventilation" (Manchester, 1859, pp.25-36). Walker was an advocate of mechanical ventilation, using archimedean screw fans driven by means of a steam engine, but he recognised this solution to be unsuited to churches. In contrast to Boyle (considered later), Walker believed that air quality was not a problem in conventional churches for he wrote:

"In churches with lofty open roofs, of the medieval or early-English construction, without galleries, the total cubic space bears so large a proportion to that portion of it occupied at floor level by the congregation, that scarcely any injurious vititiation of the entire atmospheric contents can take place during the short period of occupation, provided moderate preparations have been made for ingress and egress. Hence, very sudden and powerful ventilation is scarcely required...................(but) in hot weather, the action of the fresh air flues may be accelerated by the exhausting power of a shaft or trunk of adequate size running up within the tower or steeple..."

Unable to use a fan, Walker suggests using gas burners, taking gas from the gas lighting system, to produce heat-assisted ventilation:

"By simply turning the cock in the gas pipe which supplies the jets, the rarefaction in the shaft, and consequently the velocity and quantity of the air passed through the church, may be controlled with tolerable accuracy, and instantly proportioned to any greater or smaller number of persons assembled."

However, in churches, chapels and meeting-houses, with flat roofs and broad galleries, Walker warns that ventilation and air quality is likely to be a problem, due both to the higher ratio of people to building volume, and the fact that often there is nowhere to construct a ventilating shaft. He pleads for the introduction of a spire, tower or turret into such designs for the "promotion of health and comfort." To warm and ventilate such a low-roofed, galleried, and crowded meeting-house, he recommends:

"(an) abundance of fresh-air openings all round under the windows, communicating by brick flues with the lower part of the spaces under the aisles and seats in which the hot-water pipes that are to warm the air should be fixed. Fresh air flues should be constructed in all the piers between the windows, running as high as the gallery to supply it with fresh warmed air. A vitiated air-flue should also commence in each pier under the gallery.........and pass up into a horizontal trunk, running over the roof, along each side, into the foot of the upright shaft below the gas-jets....... Openings should also be left in the roof, communicating with these horizontal trunks, to carry off the bad and heated air over the galleries. Hot water pipes should be conveyed along the side-walls, under the floor, so as to warm the air that passes up within the piers into the gallery."

Walker gives a number of examples of how to calculate ventilation requirements:

(1) A chapel or meeting house, for 2000 persons, 75 ft square, 25 ft average height, volume about 140,000 ft^3.

From Tredgold and Reid he suggests a fresh air rate of 7 ft^3/min per person x 2000 = 14,000 ft^3/min which gives 6 changes or air within the space every hour. He assumes there are 16 openings around the building, each 18 x 6 inches and deducting one-third of the area "for impediment caused by gratings will allow a clear area of half a superficial foot and the aggregate area of all the openings will be eight feet."

WM WALKER

Walker calculates the required air velocity through the inlet gratings as 1750 ft/min, "or more than twenty miles per hour" and concludes "which it will not do, especially on a calm day in hot weather, *when ventilation is most needed*, without the aid of such powerful stimulus......"

Without a fan, or gas jets, Walker can only suggest that the inlet gratings "be considerably enlarged," but he warns against opening the windows.

(2) A large Gothic church, with galleries, and lofty side aisles and nave (believed in the Warrington area) 1800 persons, 80 x 65 ft in plan, a nearly flat roof of 30 ft average height, volume 156,000 ft^3.

Walker calculates the fresh air ventilation requirement as 12,600 ft3/min, or almost 5 air changes, but his only comment is "large openings will obviously be required to pass the quantity in the time."

His overall conclusion for both examples is a warning: "These figures will suffice to show the necessity for a very much larger provision for ventilation that has been customary in buildings containing galleries; in which the cubic contents bear a small proportion to the numbers assembled."

Walker continues: "The proper warming of the air is an important part of the ventilation of churches and chapels, and requires an adaptation of apparatus to that end, more in accordance with natural laws than has generally obtained in practice. A passing allusion to the tendency of heated air to ascend in a vertical column from the source of heat, will demonstrate the fallacy of expecting a church, or any other large building consisting of only one spacious apartment, to have a good distribution of warmth effected over its whole area, from one stove fixed, as has frequently been done, at or under one end of it. If the air be allowed to escape at once from such stove, it will ascend straight up towards the roof, and the heat be carried off at once through the egress aperture, without affecting the body of the church at all; or, if it be attempted to convey it to the other end by flues laid under the floor, with openings at intervals for escape of heat, one of the following results will occur; either contrary currents will prevent any heat at all from ascending, or it will escape at the first openings, and be expended long before it reaches the end. The stove or heating apparatus is usually fixed at the east end, under the chancel; in which case, the heated air is required to overcome all impediment caused by friction within the flues, and to travel in a westerly *horizontal* direction, (in opposition to its *vertical* tendency) for a distance of sometimes 80 or 100 feet. The most formidable impediment to he success of such an arrangement lies in the fact, that the prevailing winds in this country blow in an exact contrary direction, from west to east; and their force has frequently been known to reverse completely the intended movement, causing air to descend from the church through the stove, and issue heated into the exterior."

Walker then makes the following recommendations:

"The most suitable and successful arrangement for churches, is to conduct hot water pipes all along the church from end to end, under the floor, with gratings over them for escape of warmed air; the air-flues being so arranged as to cause the fresh air to impinge on them before it enters the church through the gratings. This plan, carried out with a due regard to a *sufficiency of heating surface*, (the want of which is a constant source of error) provides a source of heat in every portion of the length of the building; and causes the vertically ascending tendency of the warmed air to act unlike in every part of the building, whereby it

THOM BOX: JOSEPH CONSTANTINE

ensures the general distribution of the heat." (The statement in brackets supports Walter Jones's contention that calculating the amount of heating surface by the methods of Hood inevitably resulted in undersizing.)

Walker concludes with a warning about reheated recirculated air, a theme much echoed in the later writings of the Boyles:

"A church may certainly be warmed sufficiently by a stove, (and it has frequently been done,) by closing all egress openings, and heating the same air over and over again. The same total prevention of all change of air will also cause a very insufficient hot water apparatus, with the aid of the animal heat (now termed metabolic rate) given off the by the breath and bodies of the congregation, to provide sufficient warmth. But it is obviously and radically wrong; inasmuch as it is *warmth without ventilation*; and, if in such case the quantity of air proper for health be admitted, it will be to be *ventilation without warmth.* (Alas, the dilemma facing the Victorian heating engineer.)

Thomas Box: c.1821-c.1885

The work of Box, an English hydraulic engineer, was wide ranging. In the heating field, he wrote "Heat as Applied to the Useful Arts" (London, 1868). His writings also dealt with ventilation requirements for life, removal of water vapour, removal of metabolic and other heat, and removal of odours. He was a pioneer of heat loss calculations. In a venture into ways of warming and ventilating chapels, Box proposed a *Chapel System* of ventilation that employed a weight-driven fan, later described as,

"a curious system using a fan driven by a weight, impelling air through underground ducts where it encounters hot-water pipes heated by a boiler. The pipes are on rollers (to take up expansion). His system is for a chapel, the object being to provide each pew with its due proportion of warmed air. The weight he uses is 27 cwt with a 30 ft drop, used only 3 hours during occupation and taking half an hour during the week to raise by a winch."

As yet, no examples have been located.

Joseph Constantine

He was a heating and ventilating engineer, writing "Practical Warming and Ventilation" (1881). He devised a Convoluted stove which was used in churches and schools (the most famous installation being for the Free Trade Hall in Manchester). This was not unlike the Gurney stove, being constructed of ribbed cast-iron sections bolted together and enclosed in a brick setting through which air could pass. The surface of the stove was often enclosed (as shown) to reduce the surface temperature, and to allow of convection heating. A feature was the arch of fireclay slabs over the combustion chamber, presumably to promote efficient and complete combustion. What is unusual is the way in which Constantine rated the heat output of his stoves, based on the weight of metal employed: "The difference in weight gives the difference in heating power. Every pound of metal has a certain capacity for radiating heat and no more, and the heating capacity of an apparatus may be readily ascertained in this way." His book includes the following stove rating table:

ROBERT BOYLE SR

Weight of metal cwt	Area of heating surface ft^2	Volume of space to be heated ft^3	Volume per cwt of metal ft^3/cwt
14	35	26000	1857
22	69	50000	2275
34	119	86000	2529
45	280	140000	3111
56	296	220000	3928

(Note his largest stove contained 2.8 tons of metal)

Robert Boyle, Senior: 1821-1878, & Robert Boyle, Junior

The leading proponents of natural ventilation were Robert Boyle and his son, Robert Boyle Jr, who were vociferous both in their condemnation of lack of ventilation and in all forms of mechanical ventilation. Their Company, Robert Boyle & Son Ltd, Ventilating Engineers of London & Glasgow, published a catalogue (c.1900) "The Boyle System of Ventilation," in which they extolled, at great length, the virtues of "Boyle's Latest Patent 'air-pump' ventilator," as used at Christ Church, Lambeth. They had a great love of quotations, the section on Ventilation of Churches commencing with "Pure air ensures health and happiness; foul air disease and death."

The catalogue text begins:

"The vitiated atmosphere usually found in imperfectly ventilated churches is the principal cause of the drowsiness with which many of the congregation are overcome before the service is over, and the fainting fits which so frequently occur in certain churches. This is due to a deficiency of oxygen in the air and an excess of carbonic acid gas, watery vapour, and foetid organic matter, combined, when the gas is lighted, with the poisonous products of combustion (this is a reference to the perils of illumination by gas). A feeling of oppressive closeness and heat is also generally experienced under such conditions.

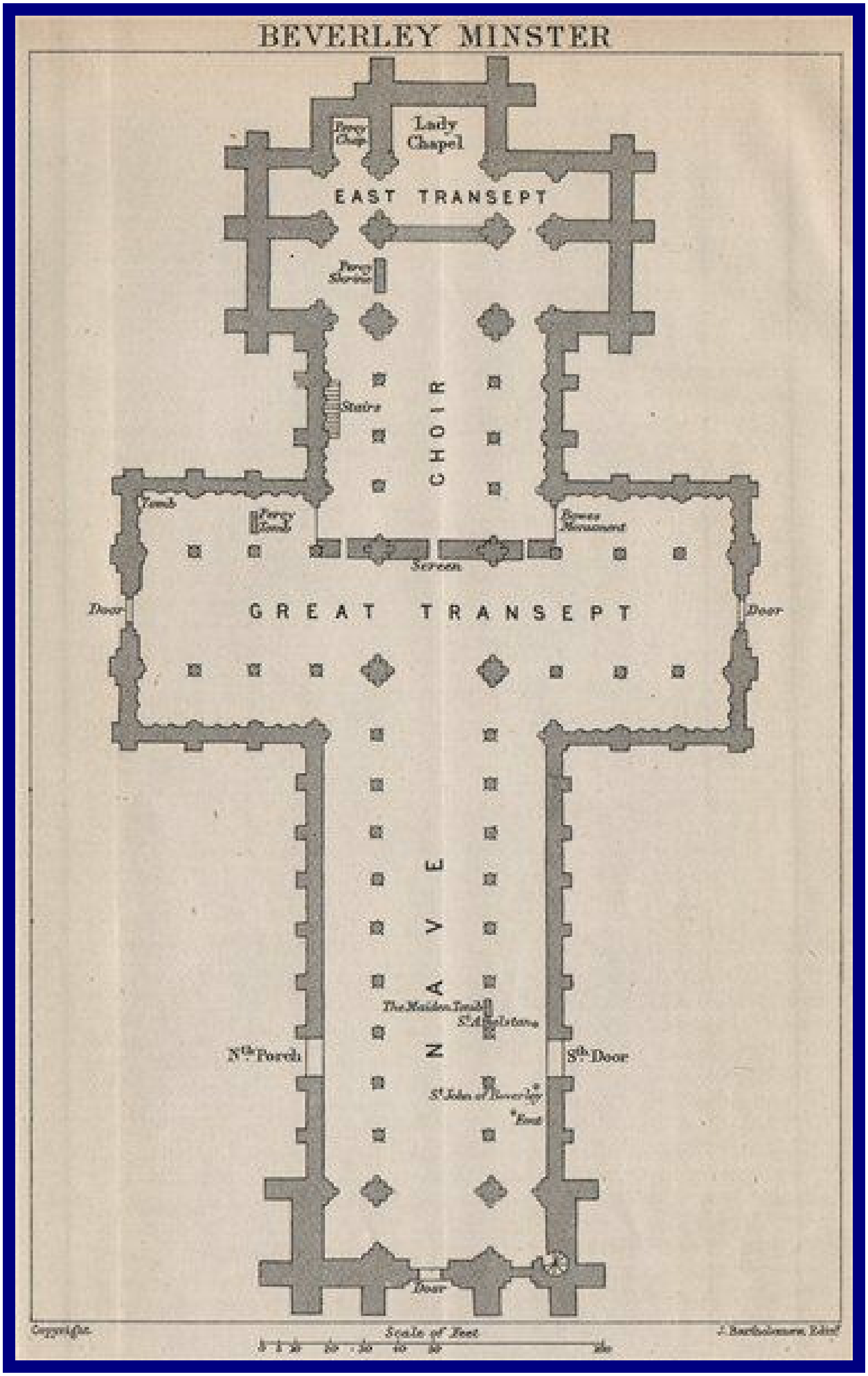
To the deleterious quality of the air found in so many churches is to be ascribed what is known as 'clergyman's headache,' and the feeling of lassitude and nervous irritation so commonly experienced during and after the services.

Badly ventilated churches and halls are, more than any other cause, responsible for the dissemination of disease, and many people abstain from attending on that account alone who would be only too glad to be present if the air was but in a healthy state."

The Boyles continue on for several more paragraphs in similar vein and complete their diatribe with yet another controversial statement: "Hot air should never be employed to heat a church as it is injurious to health owing to the high temperature required for effective heating, and which destroys and deteriorates a part of the oxygen required for the maintenance of health."

The Boyle answer was "Boyle's Patent and Latest Improved Fresh Air Warming and Heating Appliances," in fact their own designs of Ventilating Radiator.

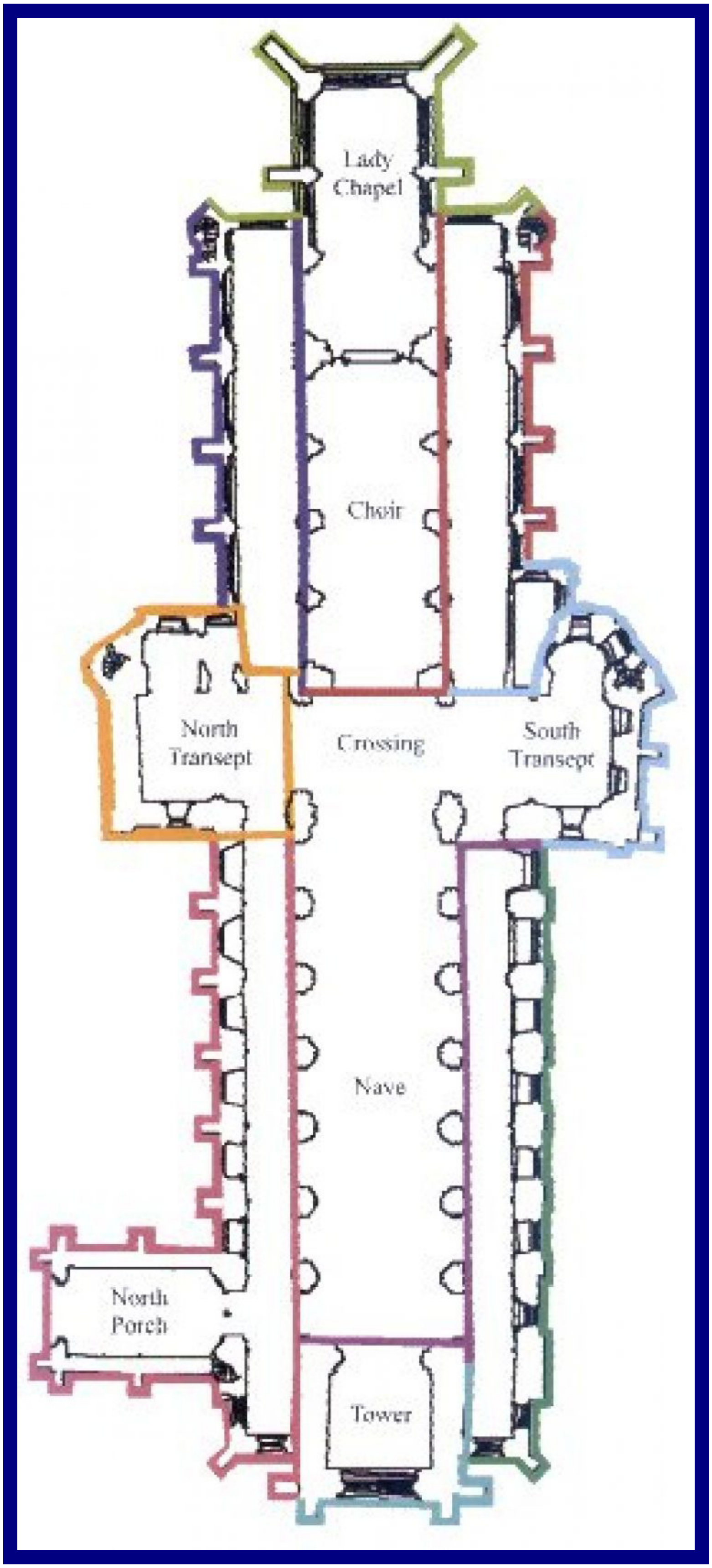
BEVERLEY MINSTER PLAN



BEVERLEY MINSTER

Heating by Gurney stoves: London Warming & Ventilating Company

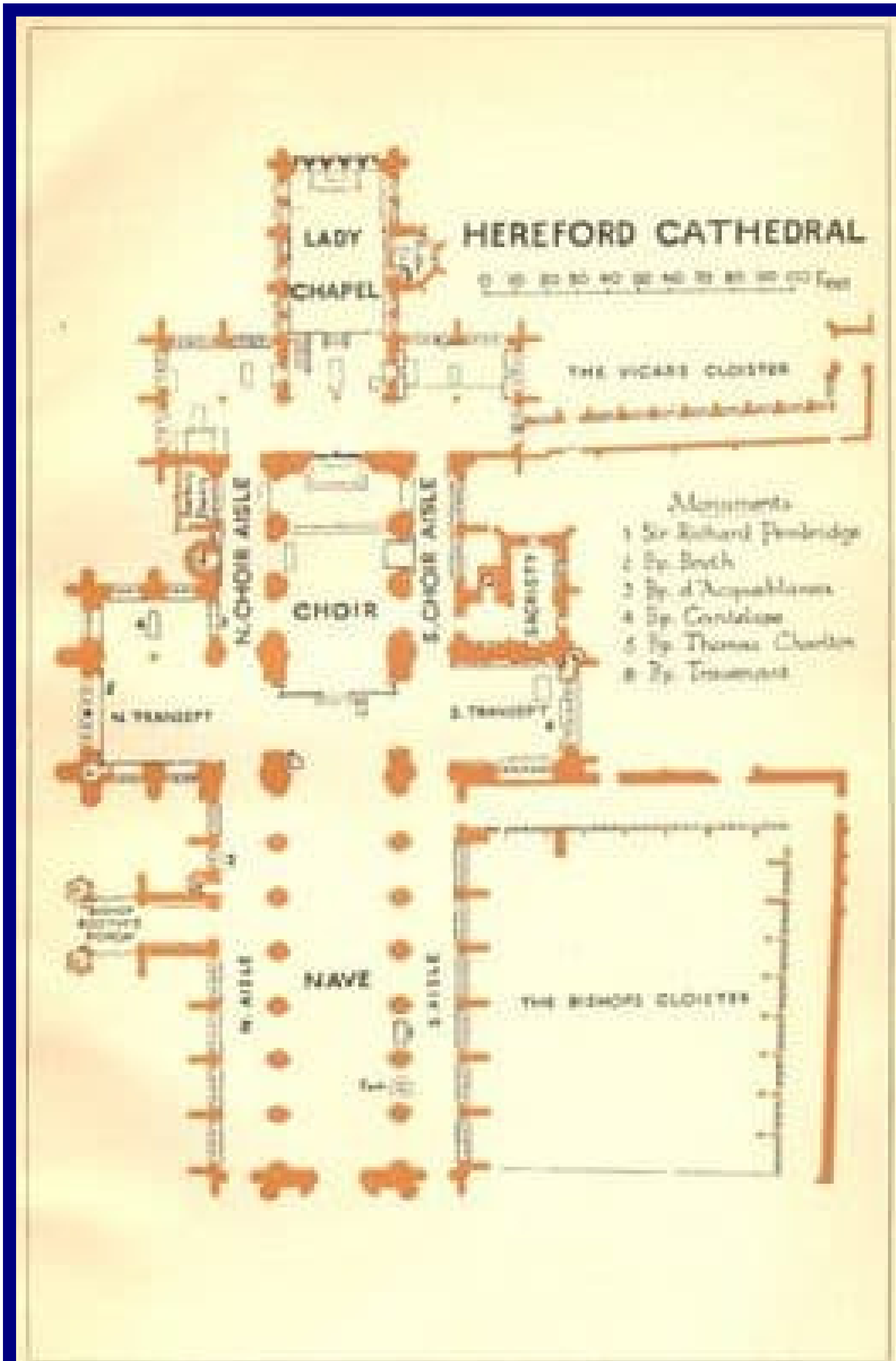
CHESTER CATHEDRAL PLAN



CHESTER CATHEDRAL

1890s: Heating by Gurney stoves: London Warming & Ventilating Company

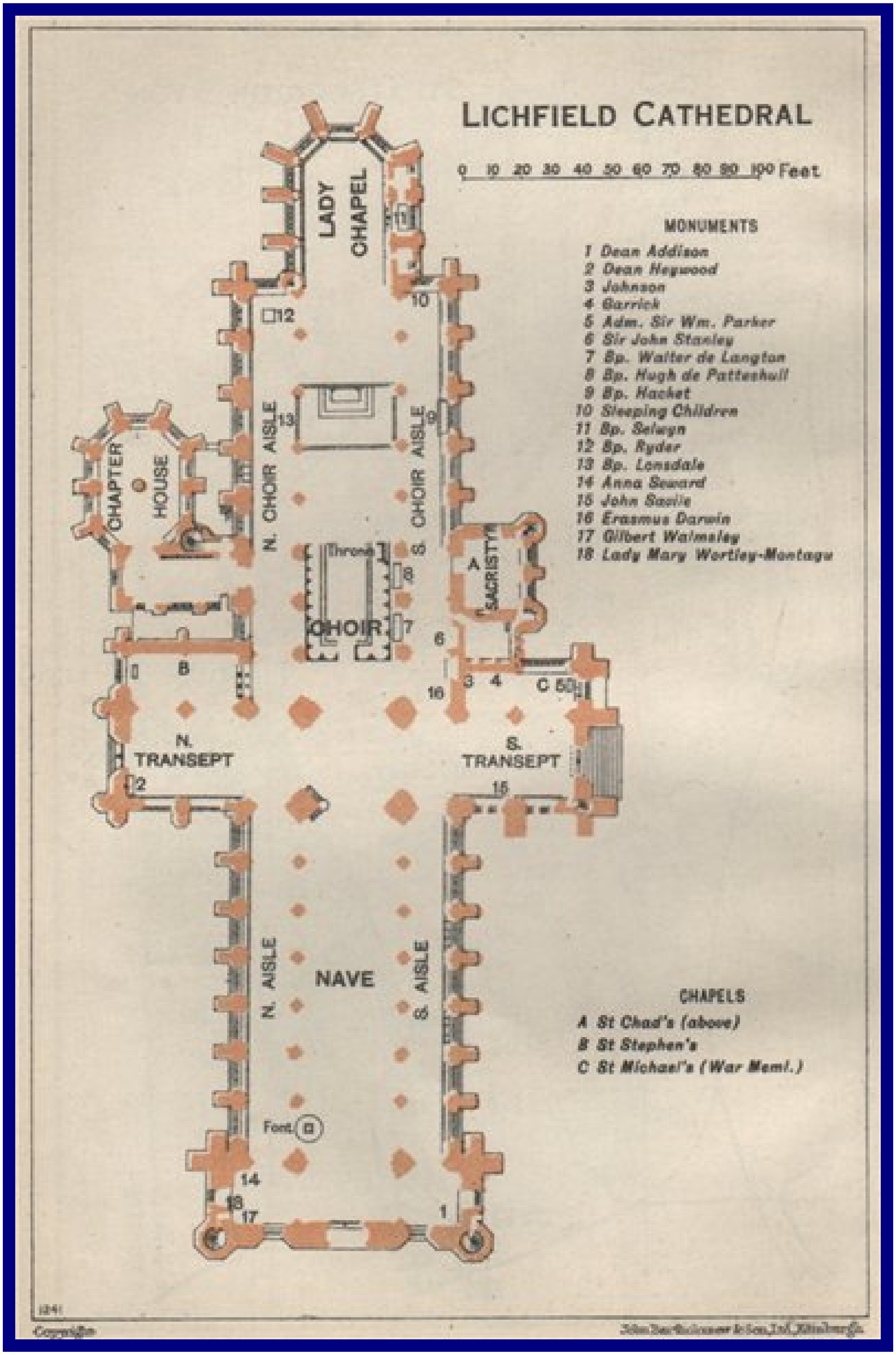
HEREFORD CATHEDRAL PLAN



HEREFORD CATHEDRAL

1867: Heating by four Gurney stoves: London Warming & Ventilating Company

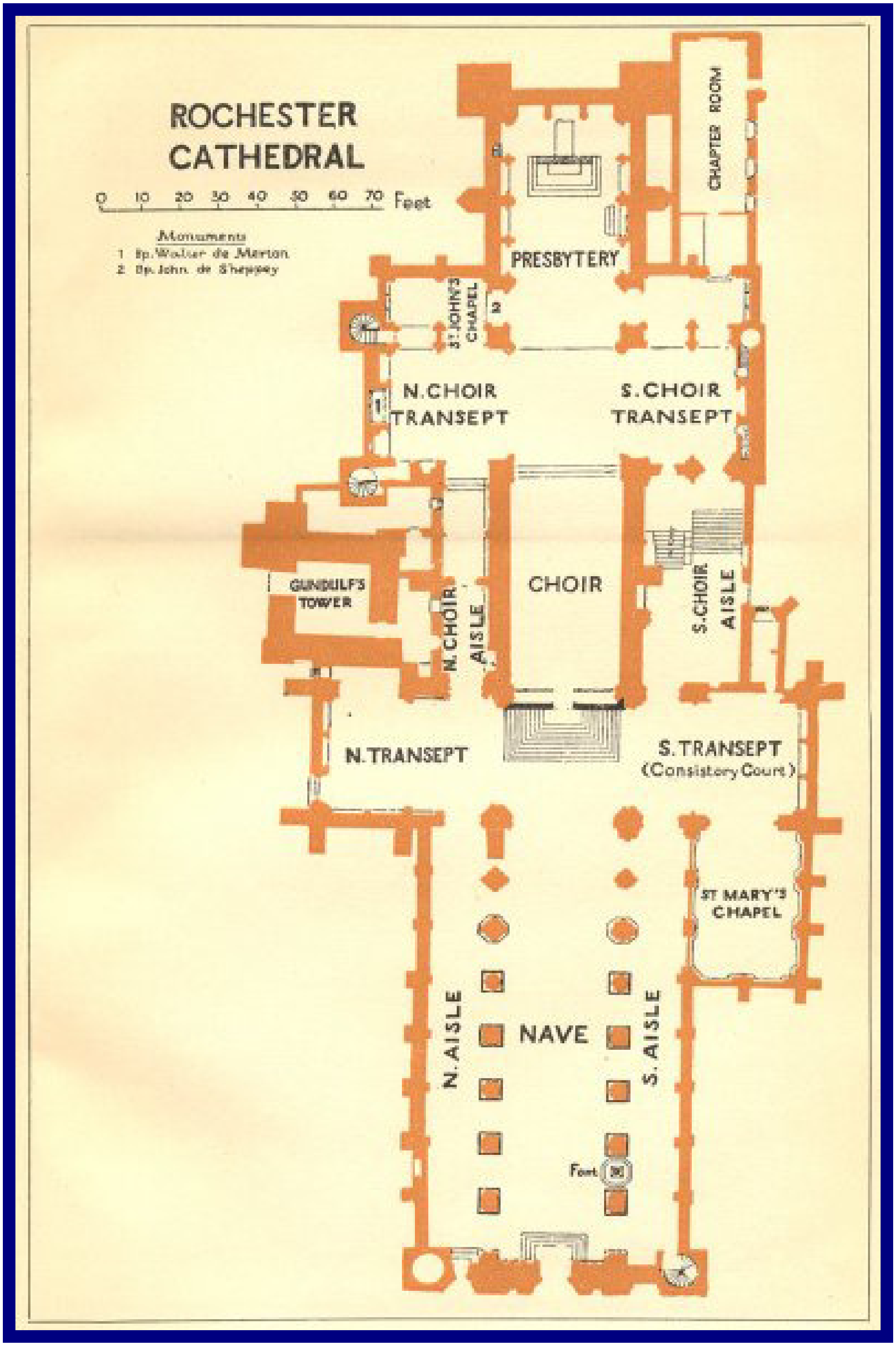
LICHFIELD CATHEDRAL PLAN



LICHFIELD CATHEDRAL

Original heating by Haden & Son. Replaced in 1930s, LPHW heating by Rosser & Russell

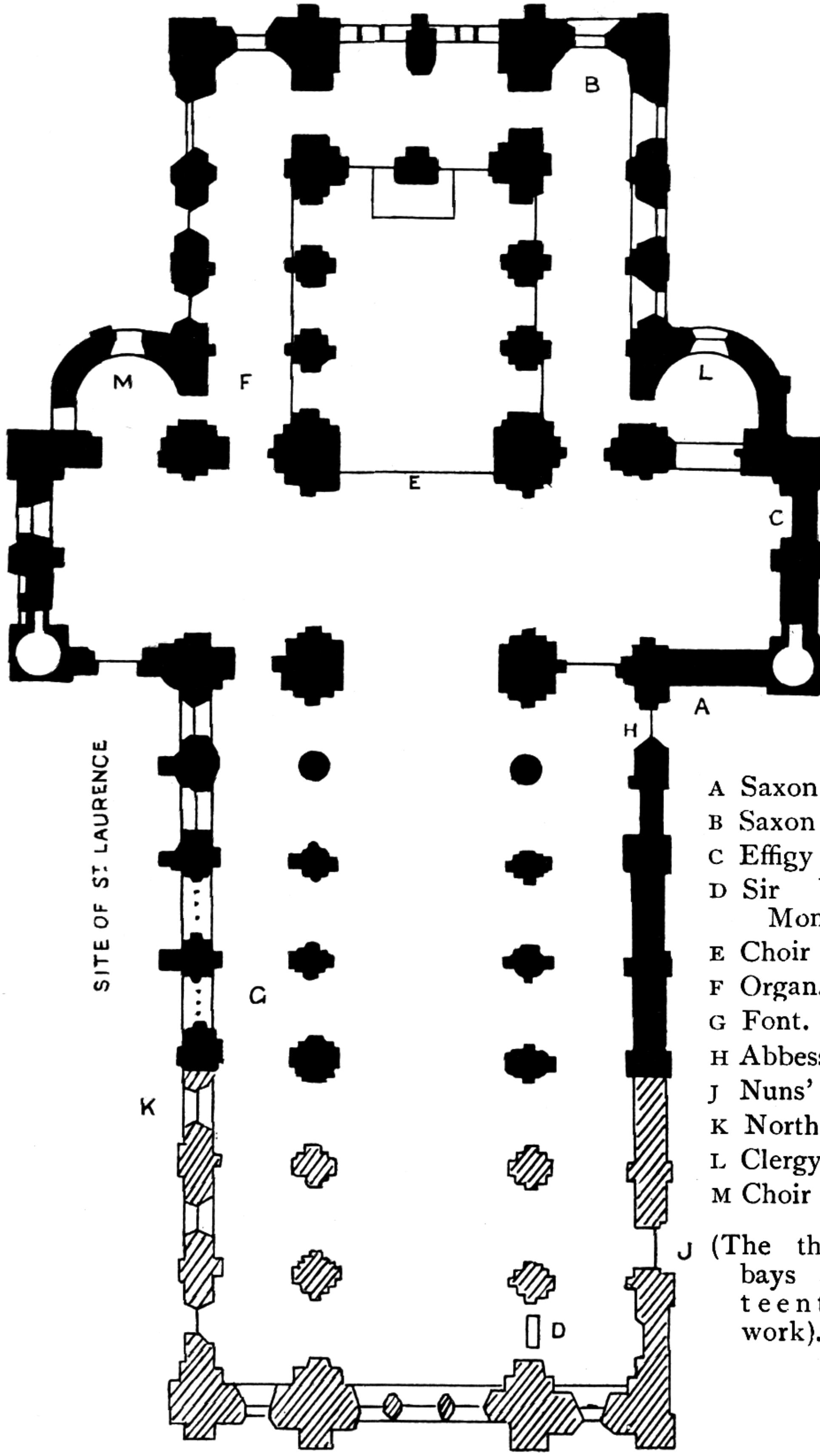
ROCHESTER CATHEDRAL PLAN



ROCHESTER CATHEDRAL

Heating by Gurney stoves: London Warming & Ventilating Company

ROMSEY ABBEY PLAN



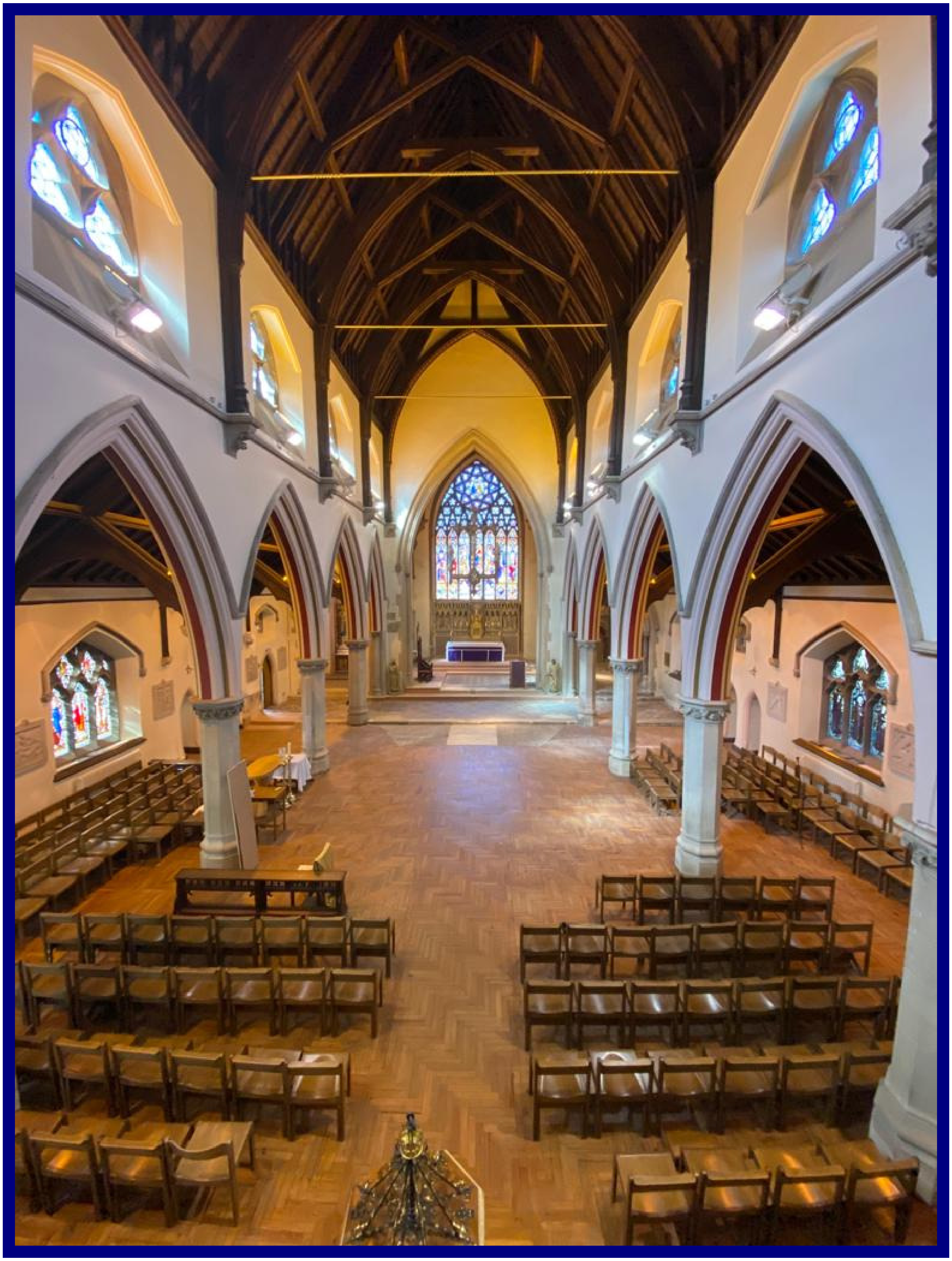
A Saxon Rood.
B Saxon Reredos.
C Effigy of Lady.
D Sir W. Petty's Monument.
E Choir Screen.
F Organ.
G Font.
H Abbess's Door.
J Nuns' Door.
K North Door.
L Clergy Vestry.
M Choir Vestry.

(The three western bays are of thirteenth-century work).

ROMSEY ABBEY

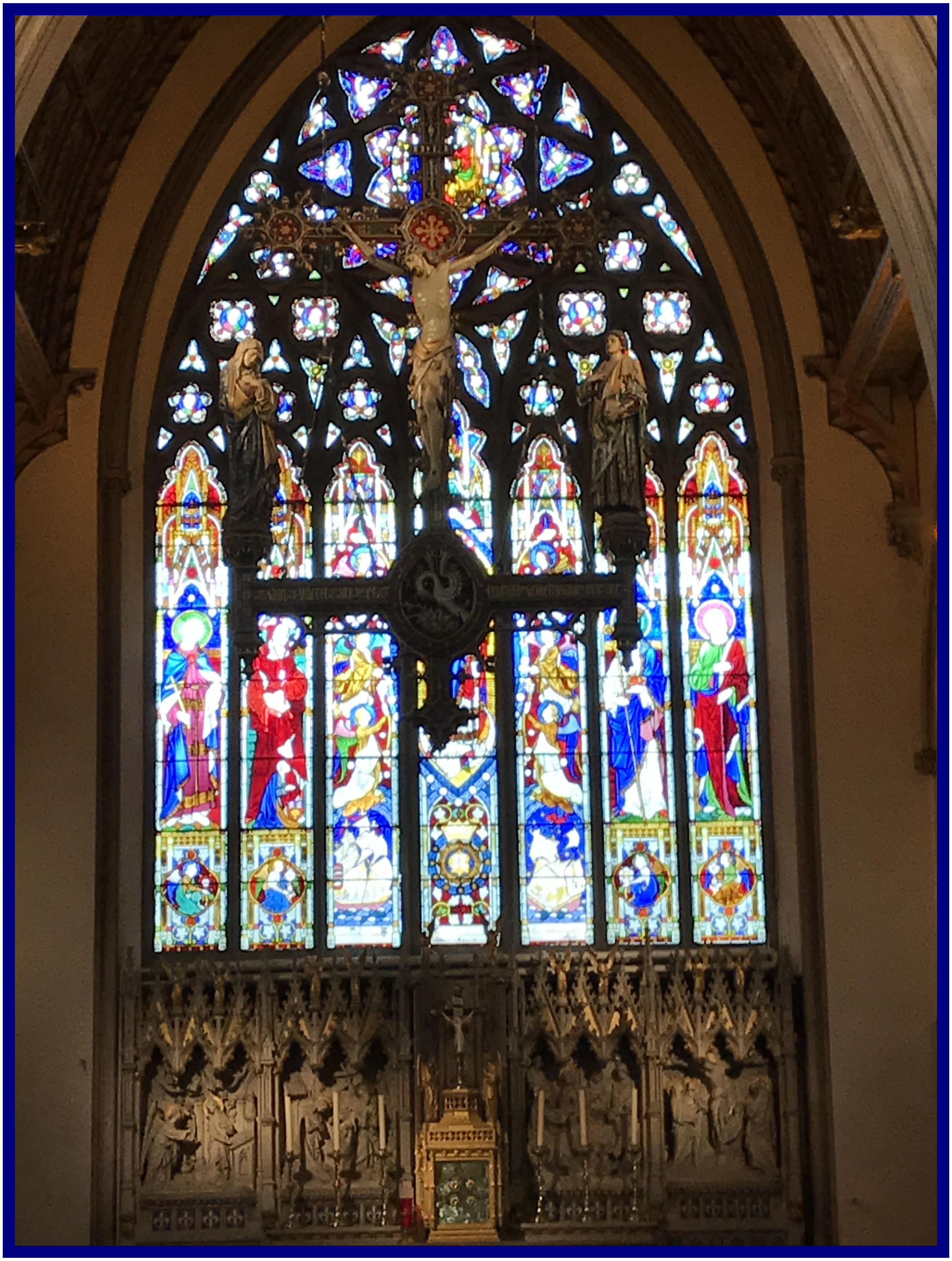
Heating by Gurney stoves: London Warming & Ventilating Company

SHREWSBURY RC CATHEDRAL



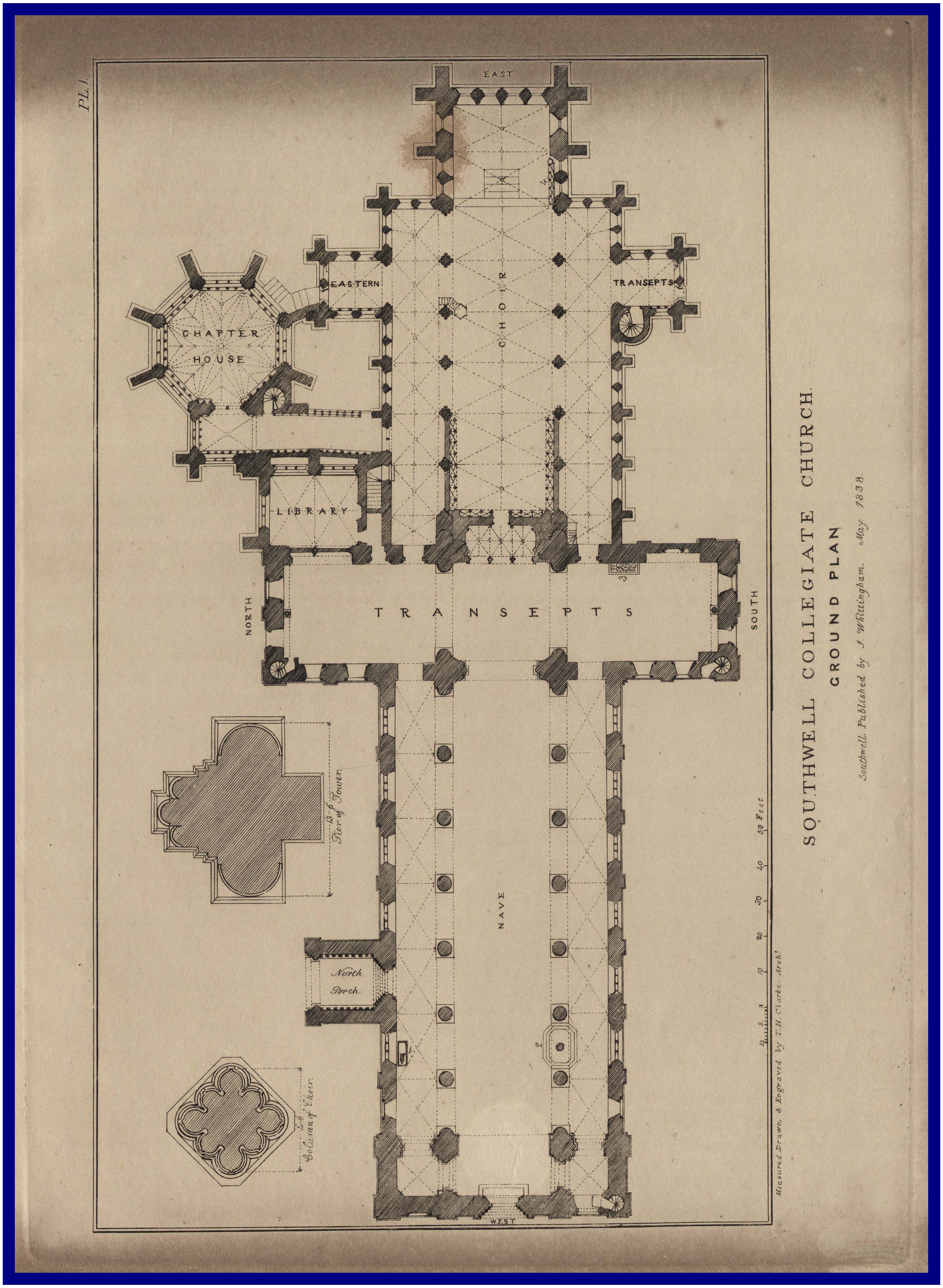
Heating by G N Haden & Sons, in their 1908 listing of installations

SHREWSBURY RC CATHEDRAL



Heating by G N Haden & Sons

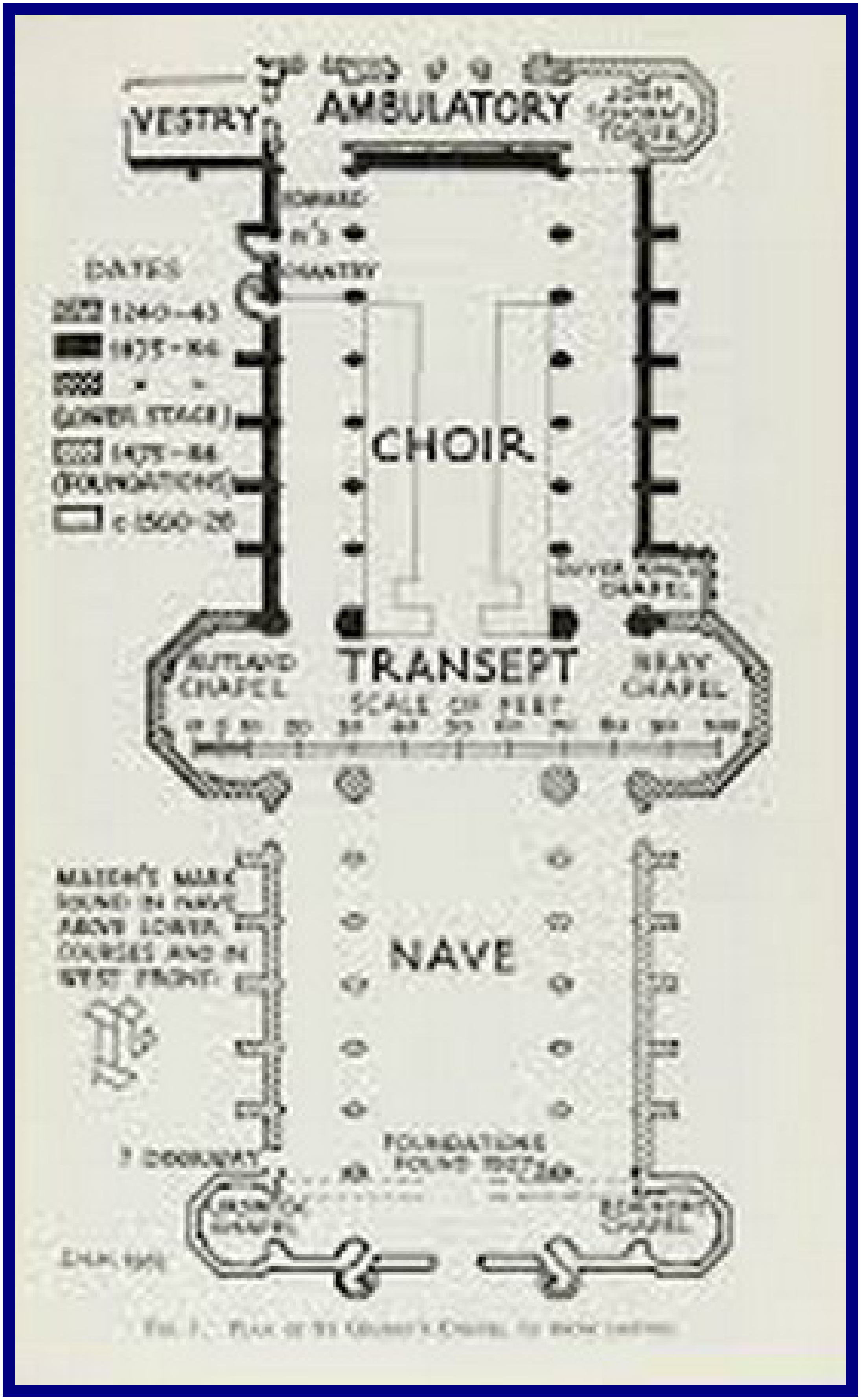
SOUTHWELL MINSTER PLAN



SOUTHWELL MINSTER

Heating by Gurney stoves: London Warming & Ventilating Company

ST GEORGES CHAPEL, WINDSOR PLAN



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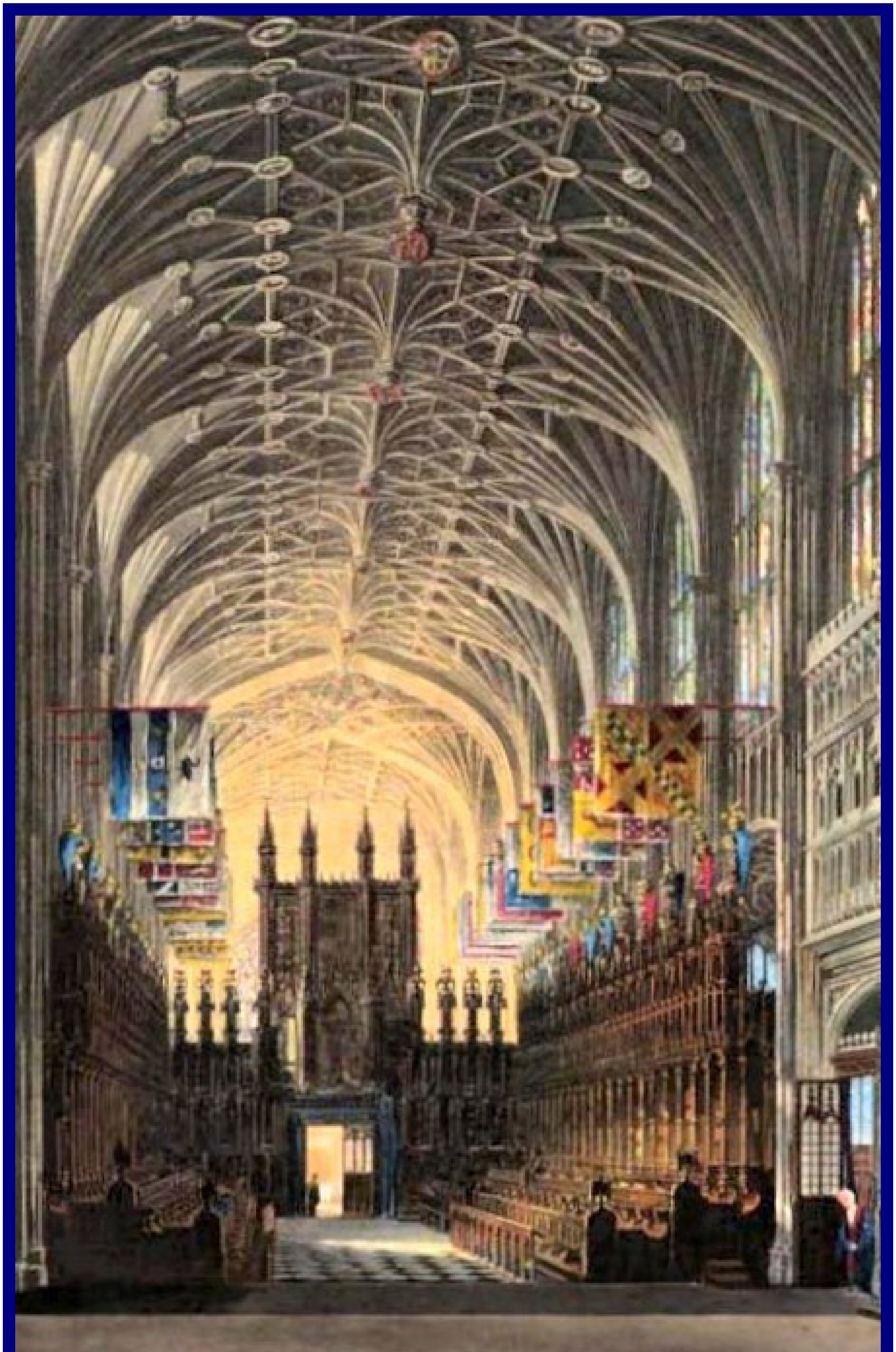
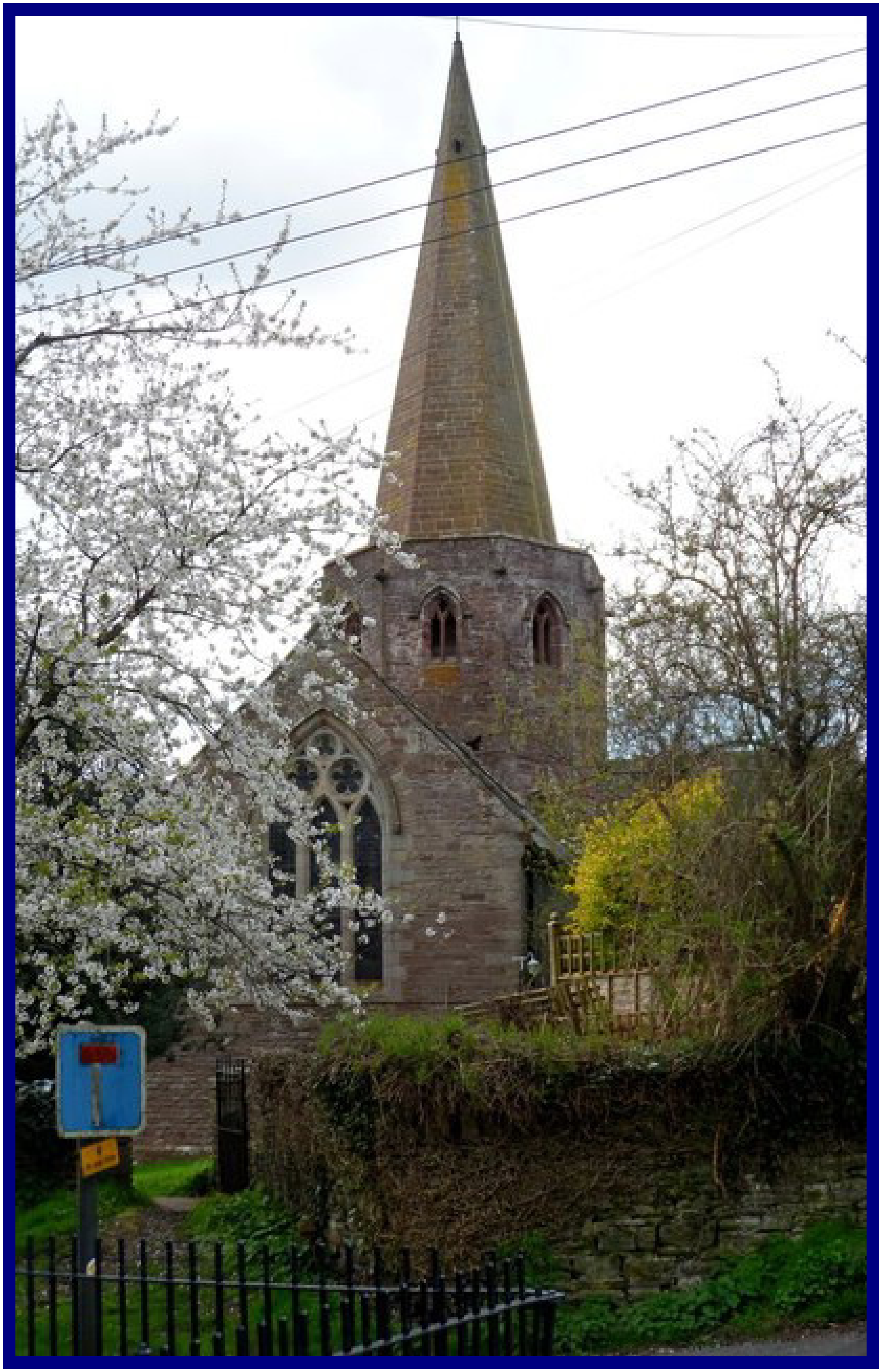


Heating by Gurney stoves: London Warming & Ventilating Company

ST JAMES THE GREAT, WIGMORE

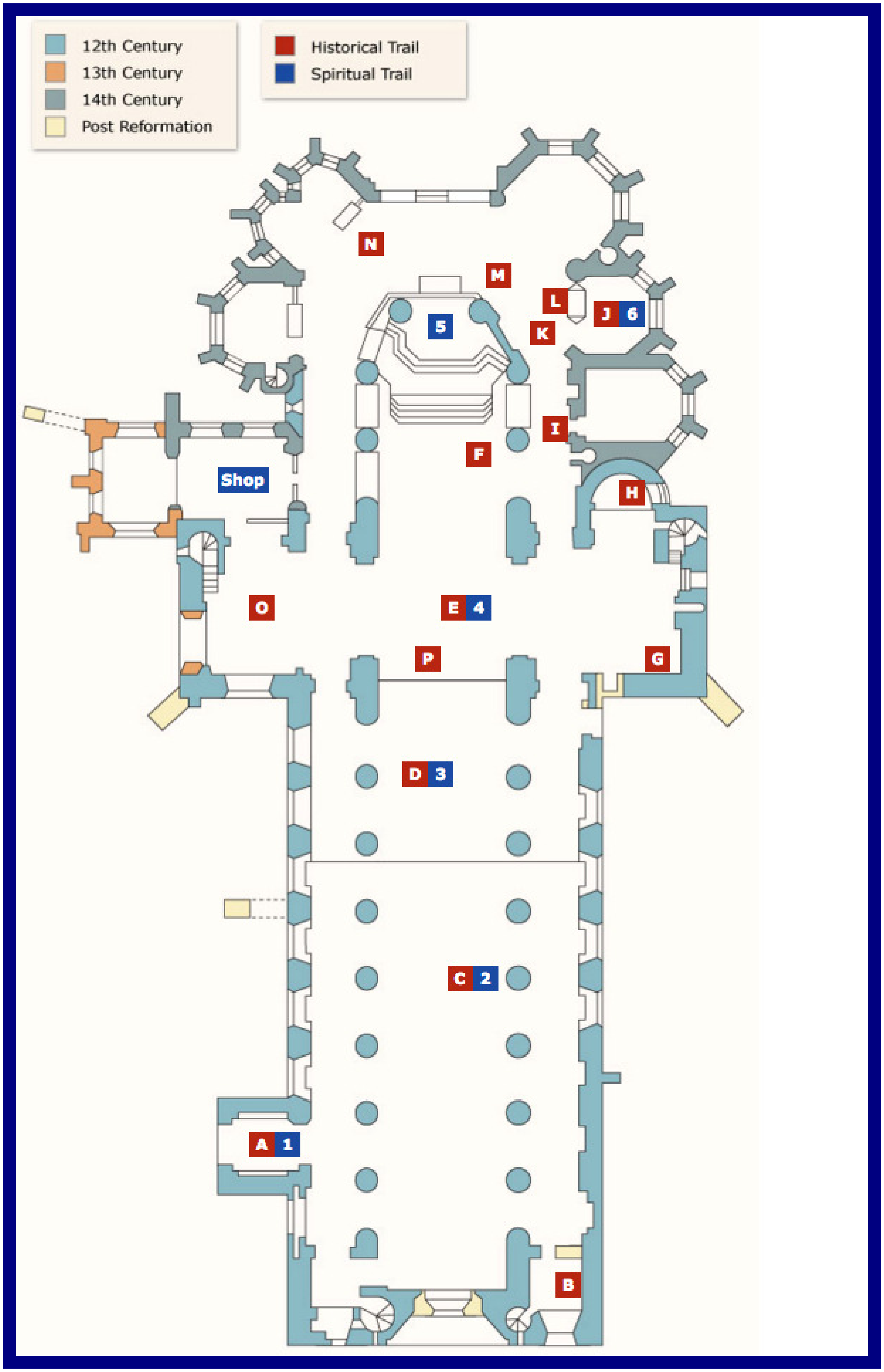
Heating by Gurney stoves: London Warming & Ventilating Company

ST NICHOLAS, GROSMONT



Heating by Gurney stoves: London Warming & Ventilating Company

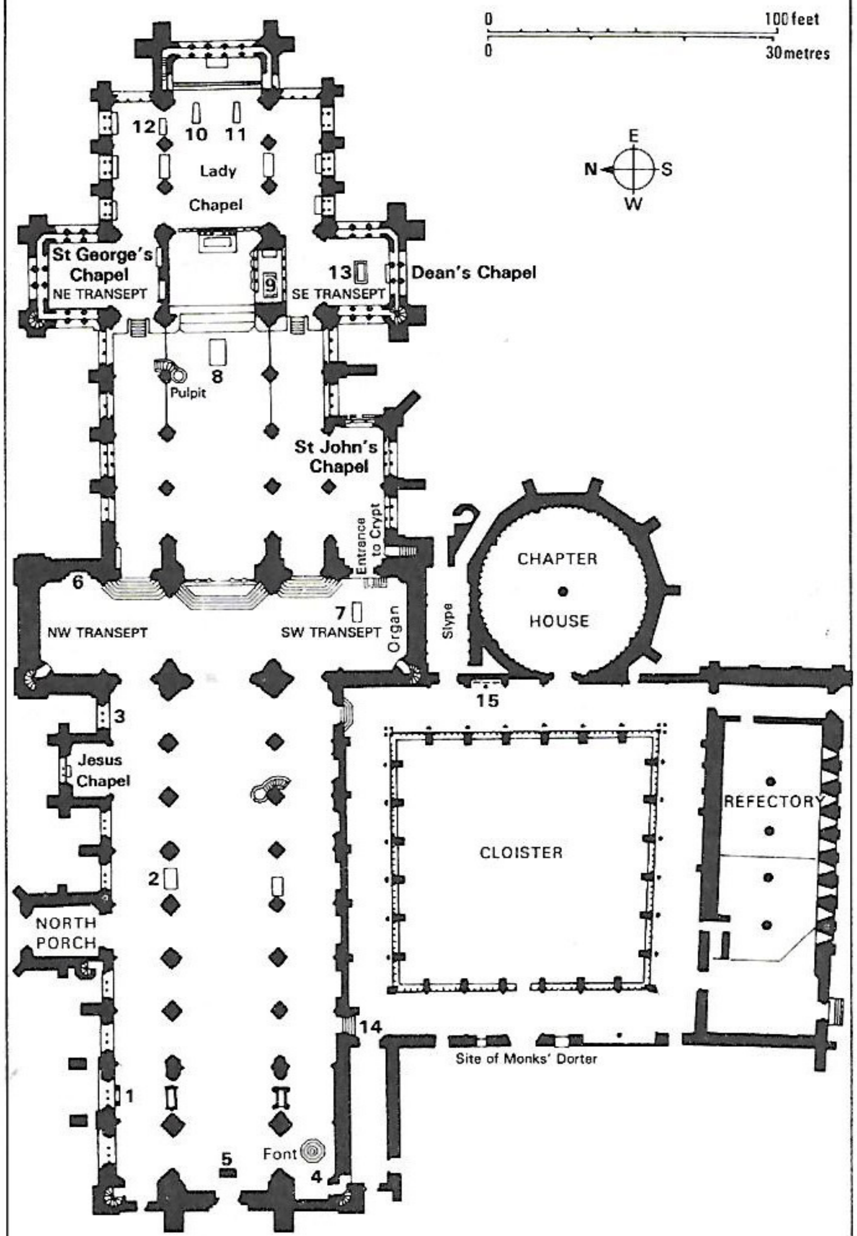
TEWKESBURY ABBEY PLAN



TEWKESBURY ABBEY

Heating by Gurney stoves: London Warming & Ventilating Company

WORCESTER CATHEDRAL PLAN



1 Elgar Meml. Window
2 Sir John Beauchamp
3 Bp Bullingham
4 Bp Johnson
5 Stanley Baldwin
6 Bp Hough
7 Bp Philpott
8 King John
9 Prince Arthur's Chantry
10 Bp Cantelupe
11 Bp Blois
12 Charlotte Digby
13 Sir Griffith Rice
14 'Miserrimus' Stone
15 Medieval Bells

WORCESTER CATHEDRAL

WORCESTER CATHEDRAL

Heating by Gurney stoves: London Warming & Ventilating Company