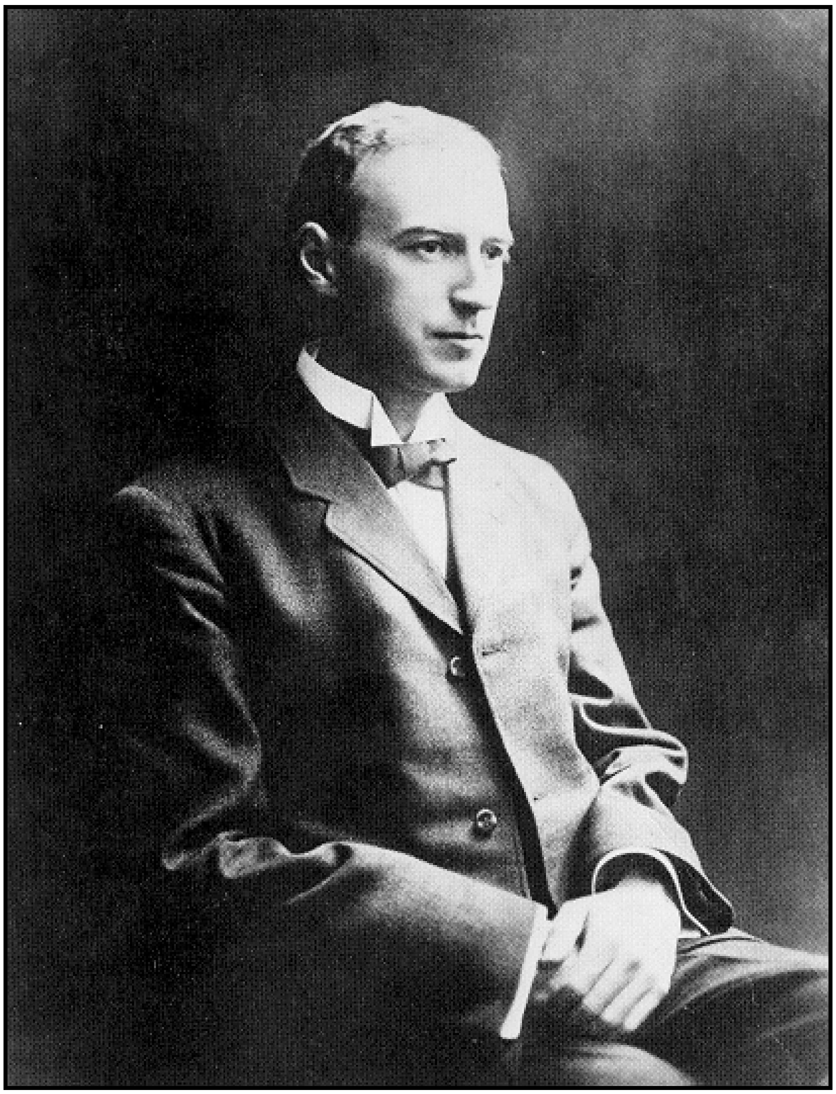
WALLACE CLEMENT WARE SABINE ACOUSTICS PIONEER

by Brian Roberts, CIBSE Heritage Group



Wallace Clement Ware Sabine, 1868-1919

Sabine was born in Richmond, Ohio, on the 13th June, 1868. Little seems to be known about his family or childhood. One report says "according to tradition, four racial strains were joined in him, each of his four names representing some family of his ancestors, one Scotch (sic), one Dutch, one English, one French." The Sabines, possibly of Huguenot stock, came to Ohio from New England in the early 19th century. His father was Hylas Sabine (1829-1910). His mother was Anna Ware (1835-1923).

The Wares, his mother's family, of English Quaker antecedents probably came from New Jersey. It seems Wallace married Jane Downes Kelly (1863-1950) and they had two daughters: Janet Sabine Cummings (1903-46) and Ruth Sabine (1906-22).

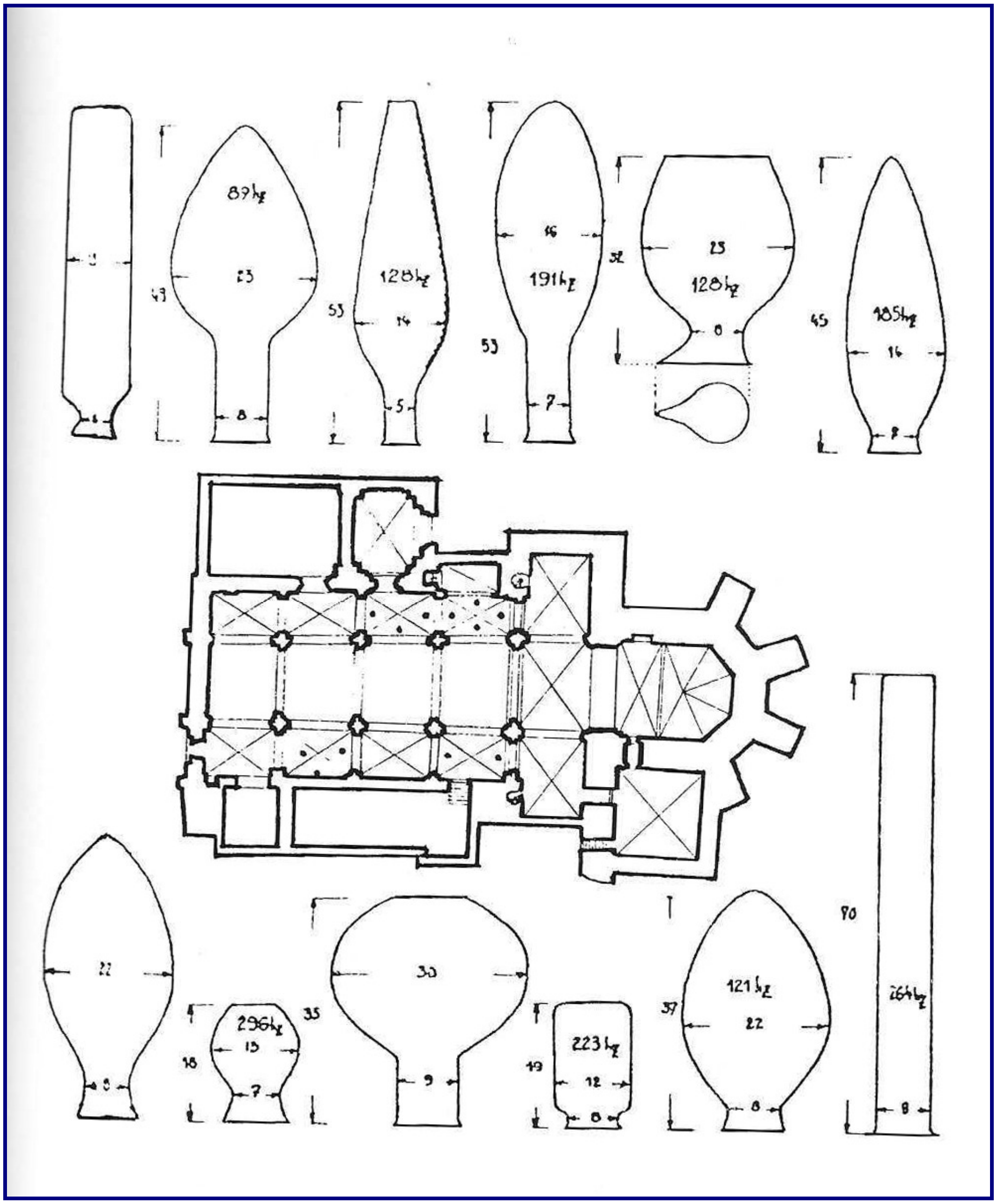
In 1886, at the age of 18, Wallace Sabine graduated from Ohio State University and entered Harvard University. After graduate study, he remained as a faculty member.

Ohio State University, Department of Mathematics, 1880

Harvard University, probably late 19th century

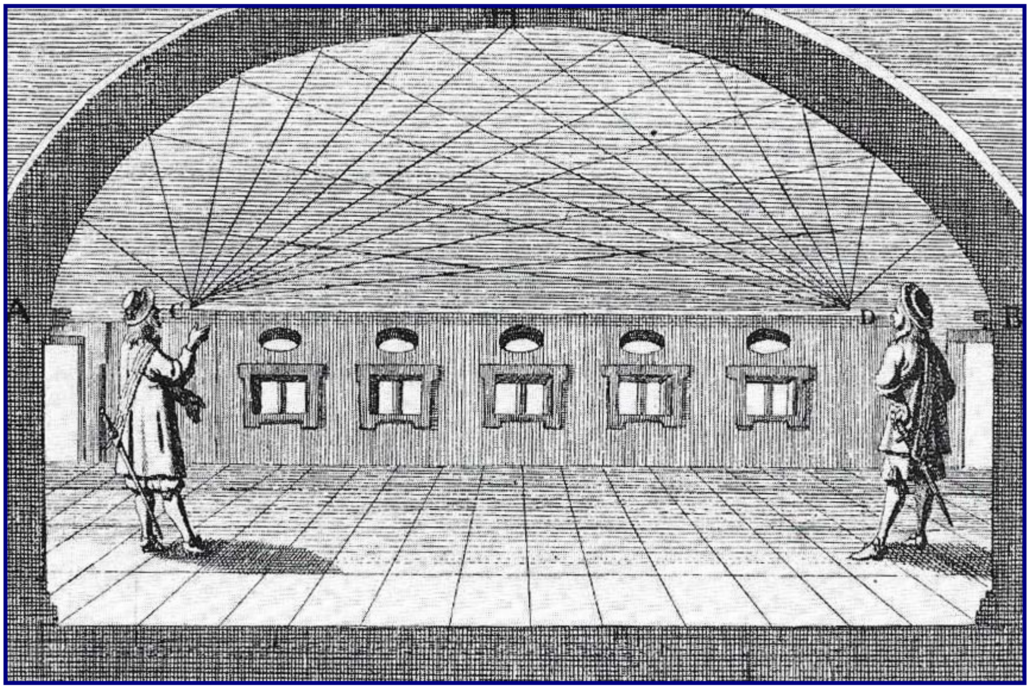
PIONEERS IN ACOUSTICS

In Roman times, Vitruvius described the acoustics of amphitheatres in his *Ten Books of Architecture.* Like Aristotle, he knew that sound was the result of air waves and he described reflection and reverberation. He also employed bronze vessels of various shapes and sizes in predetermined locations as resonant vessels. Later, medieval builders embedded clay pots in the ceiling vaults, and sometimes in walls or floors, of churches and chapels, now believed to effectively absorb sound, smoothing the frequencies and decreasing contrast.

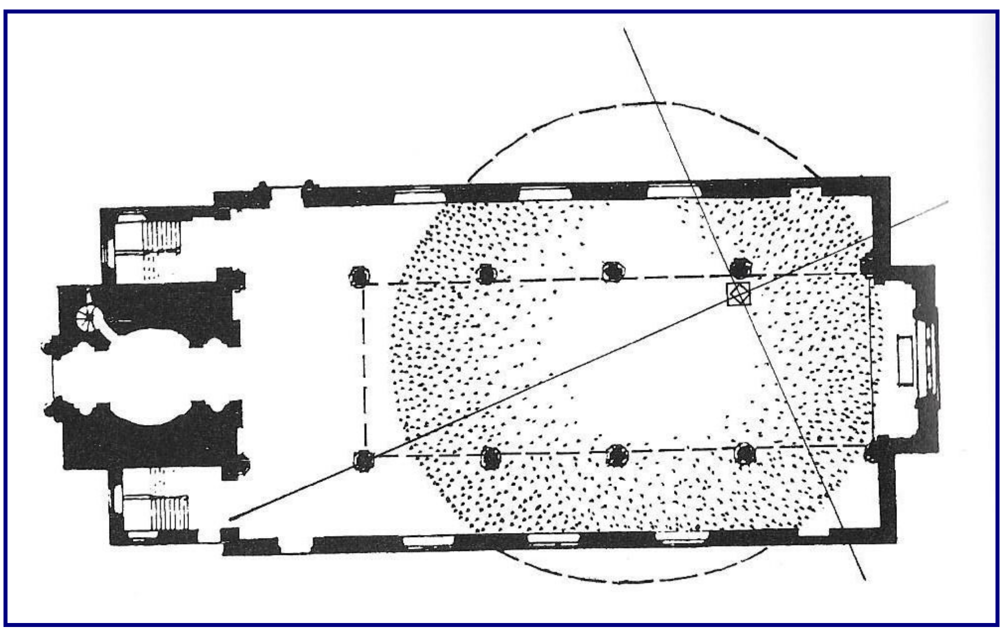


Acoustical vases (black dots on plan) in a French church

By the middle of the 17th century, the geometry of sound reflection was familiar to many scientists, who assumed it behaved in a manner similar to light. Sir Christopher Wren, in his design for churches, set maximum dimensions for the nave and located pulpits to ensure worshippers seated in the pews could clearly hear the sermon.

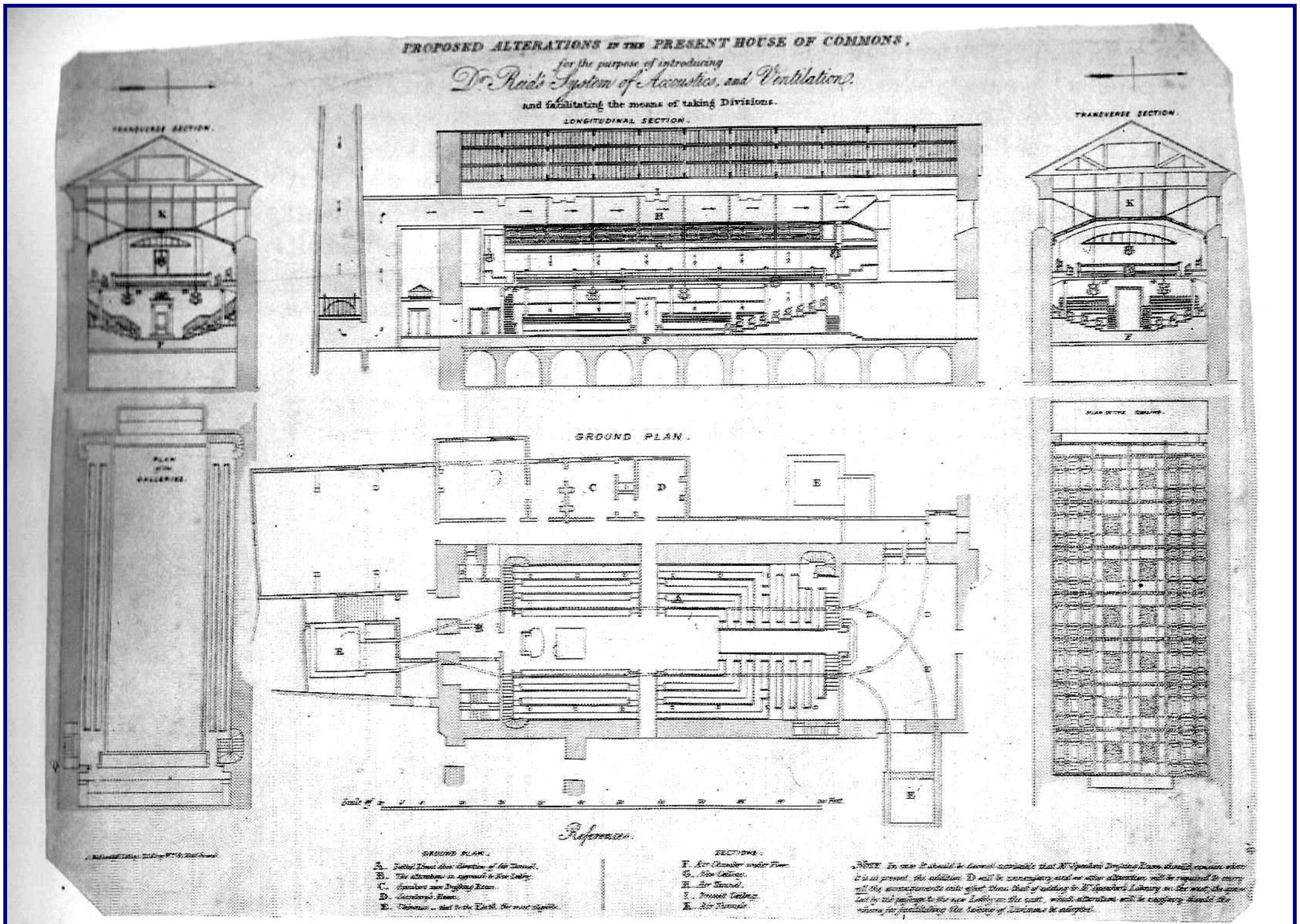


Geometric concentration of sound reflections (17th century drawing)



St Bride's Church, London by Christopher Wren with his speaking range theory and pulpit location superimposed

The U.S Capitol, rebuilt after the War of 1812, was plagued with acoustical problems, but in 1834 Dr David Boswell Reid, appointed to design the ventilation of the temporary House of Commons for the British Parliament, was one of the first to become concerned with building acoustics. As his writings show, he appreciated the significance of reflection and absorption of sound and the effect of building surfaces on reverberation. He made a number of proposals which were largely adopted and said to give excellent results. However, when he presented his designs for the new permanent House to the Select Committee (including adjustable acoustic surfaces to cater for a variable audience) his proposals were turned down. Later, in 1848, the design of Sir Charles Barry was severely criticised.

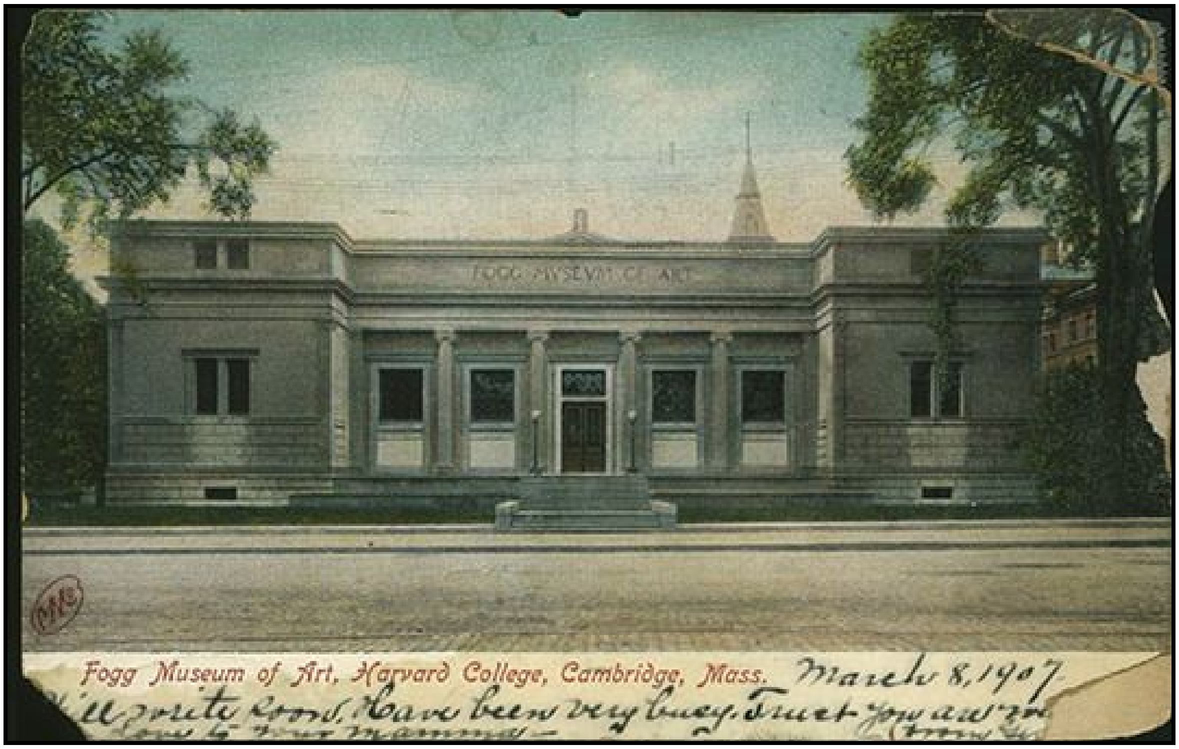


Dr. Reid's system of acoustics and ventilation for the temporary House of Commons (1835).

Proposed Alterations to the Present House of Commons for the purpose of introducing Dr Reid's System of Acoustics and Ventilation

In 1895, the senior staff of the Physics Department at Harvard determined it necessary to improve the acoustics of the Fogg Lecture Theatre, part of the recently constructed Fogg Art Museum. Generally considered an impossible task, the assignment was passed down the line to a young physics professor, Wallace Sabine, who had never received his Ph.D and had no particular knowledge of sound. Sabine set himself the task of determining what made the Fogg Lecture Hall so different from other acoustically acceptable facilities, in particular Harvard's Sanders Theatre.

The Fogg Lecture Hall



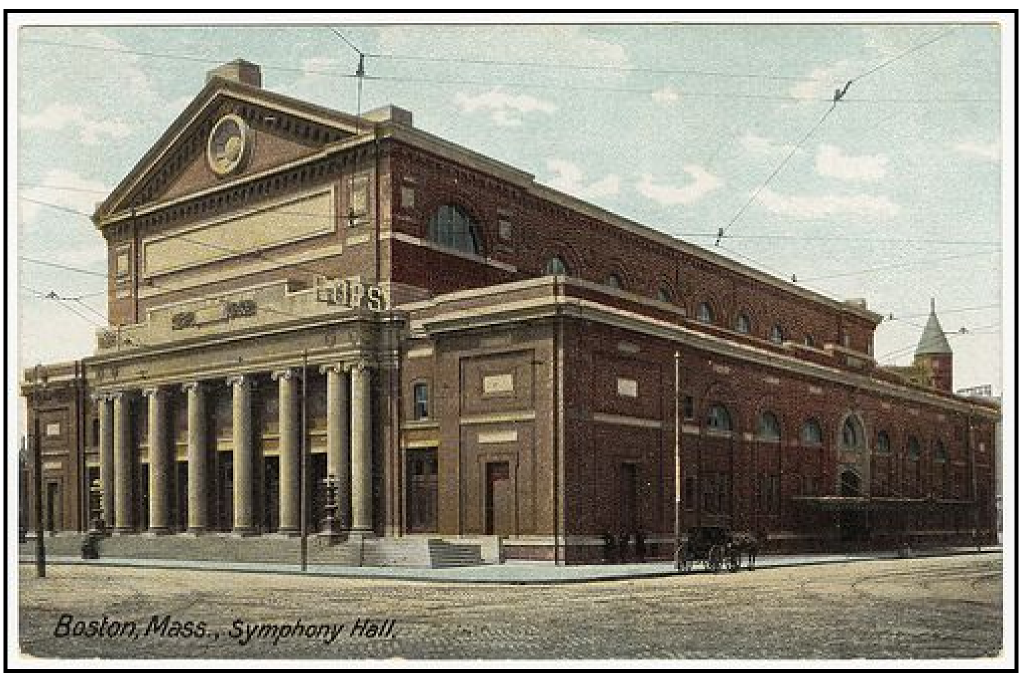
Harvard's Fogg Museum of Art, 1907

The Sanders Theatre is said to have been inspired by Christopher Wren's Sheldonian at Oxford and is famous for its design and acoustics

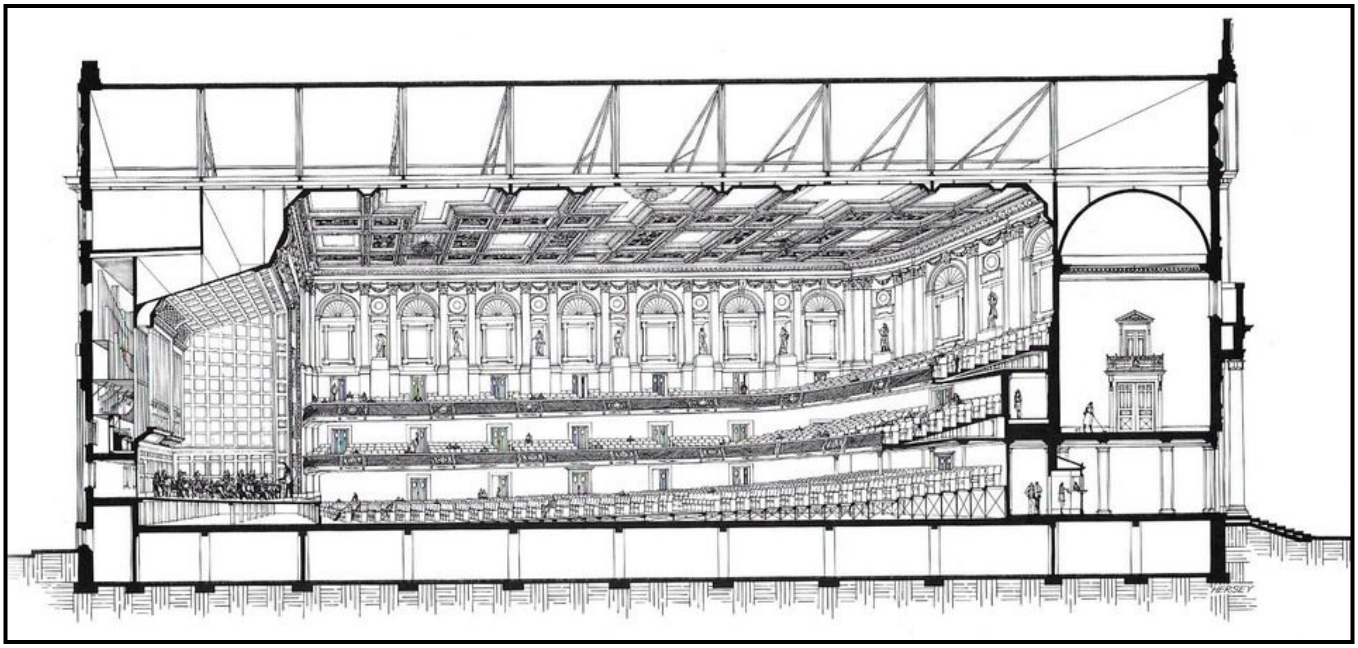
Sabine and his assistants spent many nights, over a three year period, moving materials between the Sanders Theatre and the Fogg Lecture Hall and testing the acoustics. They borrowed hundreds of seat cushions from the Sanders, and using an organ pipe and a stopwatch, Sabine performed thousands of measurements. He noted the time for different frequencies of sounds to decay to inaudibility in the presence of different materials. He tested reverberation time with different type of rugs, with varying number and locations of cushions, around the Fogg Hall and with varying numbers of seated people (he noted that the body of an average person decreased reverberation time about the same as six seat cushions). After each test, everything in both buildings had to be replaced, ready for classes the next day.

Sabine found a relationship between acoustic quality, room size, and the amount of absorption surface. He defined the reverberation time "as the number of seconds required for the intensity of sound to drop from its starting level by 60 dB (decibels)." This became the Sabine Formula, widely used in architectural acoustics throughout the 20^{th} century.

He decided, in his opinion, the best Concert Halls had reverberation times of 2.0 to 2.5 seconds, but that about 1.0 second was preferable for Lecture Halls. In the case of the Fogg Museum Lecture Room he discovered that the reverberation time was too much (about 5.5 seconds) causing excessive resonance and echoes. Sabine then outfitted the hall with absorbent materials, reducing the echo effect. This was a great success and he was appointed for the design of Boston's Symphony Hall, favouring the European "shoebox" configuration rather than the wider "fan shape" then typically used in America. Symphony Hall is still considered one of the best concert halls in the world in terms of sound quality.



Boston Symphony Hall



Architectural cross-section of the Boston Symphony Hall

A modern performance at Boston Symphony Hall

Wallace Clement Sabine

Sabine became Dean of Harvard's Graduate School of Applied Science from 1906 until 1915.

APPENDIX I: THE SABINE EQUATION

A simple example of Sabine's equation is shown in the below extract from Parkin & Humphreys' book of 1958:

The second factor will depend on the size or volume of the room because sound travels at a fixed speed, and the greater the volume the less often will waves meet absorbing surfaces and the more will be the decay time. This basic relationship was first put into a quantitative form by W. C. Sabine towards the end of the nineteenth century. The now well-known Sabine formula states that the time required for the sound to decay by 60 decibels (that is, the REVERBERATION TIME) is found from the equation

$$\text{R.T.} = \frac{0{\cdot}049V}{A} \quad . \quad . \quad . \quad . \quad (1)$$

where R.T. is the reverberation time in seconds,

0·049 is a constant (0·05 is often used as an approximation),
V is the volume of the room (in cubic feet),
A is the total absorption in sabins.*

The total absorption (A) is found by multiplying each individual area by its absorption coefficient and adding the whole together—mathematically expressed thus:

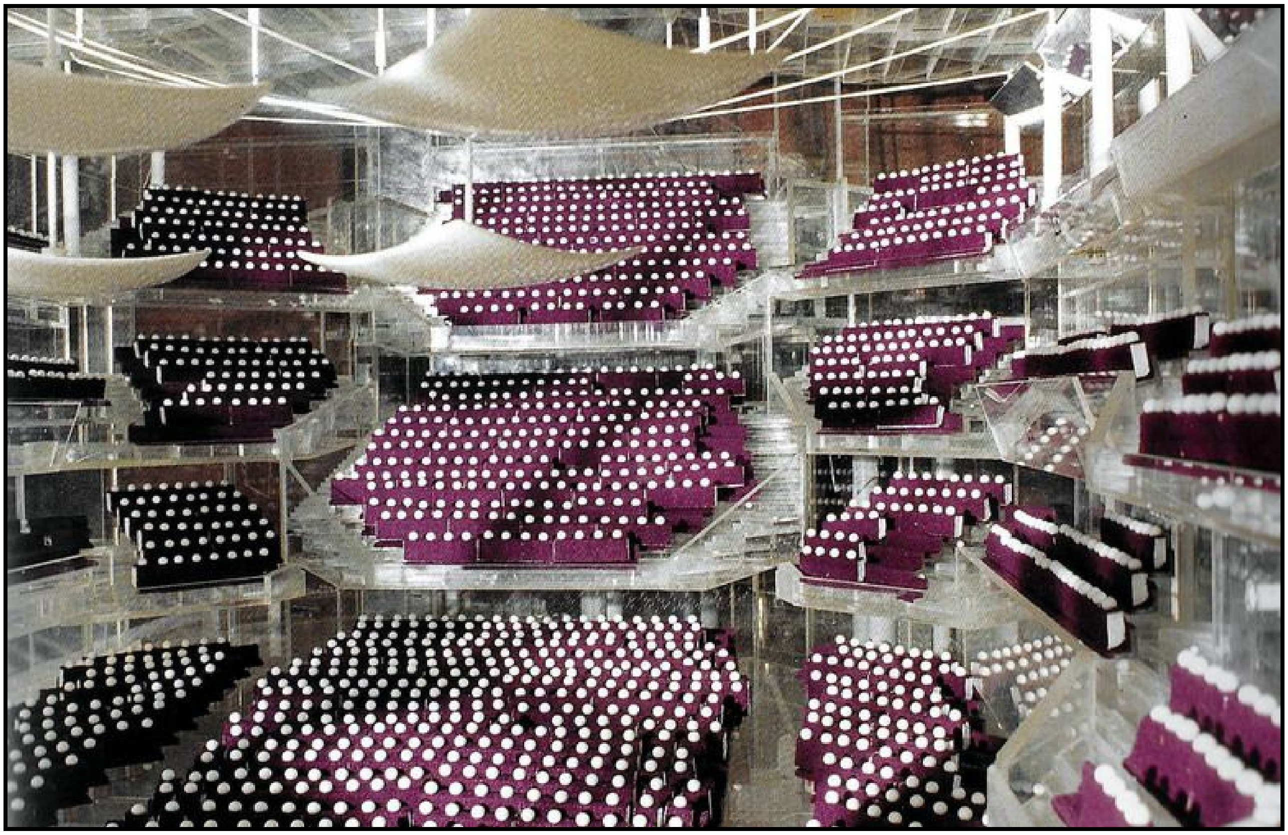
$$A = \sum s_1\alpha_1,\ s_2\alpha_2 \ldots s_n\alpha_n$$

where $s_1 \ldots s_n$ are the areas in sq. ft,
$\alpha_1 \ldots \alpha_n$ are the absorption coefficients.

The reason for the specification of the reverberation time as being the time required for the sound to decay by the particular amount of 60 dB (or to one-millionth of its initial intensity) is merely to regularise the quantity for reference purposes. The only significance in the choice of this particular amount of sound

* W. C. Sabine called the units "open window units" because they are the equivalent in absorption to a similar area of open window, from which of course no reflection can occur and hence has a coefficient of 1·0. They have since been renamed "sabins" to commemorate his name.

APPENDIX II: SIMULATING THE ACOUSTIC ENVIRONMENT



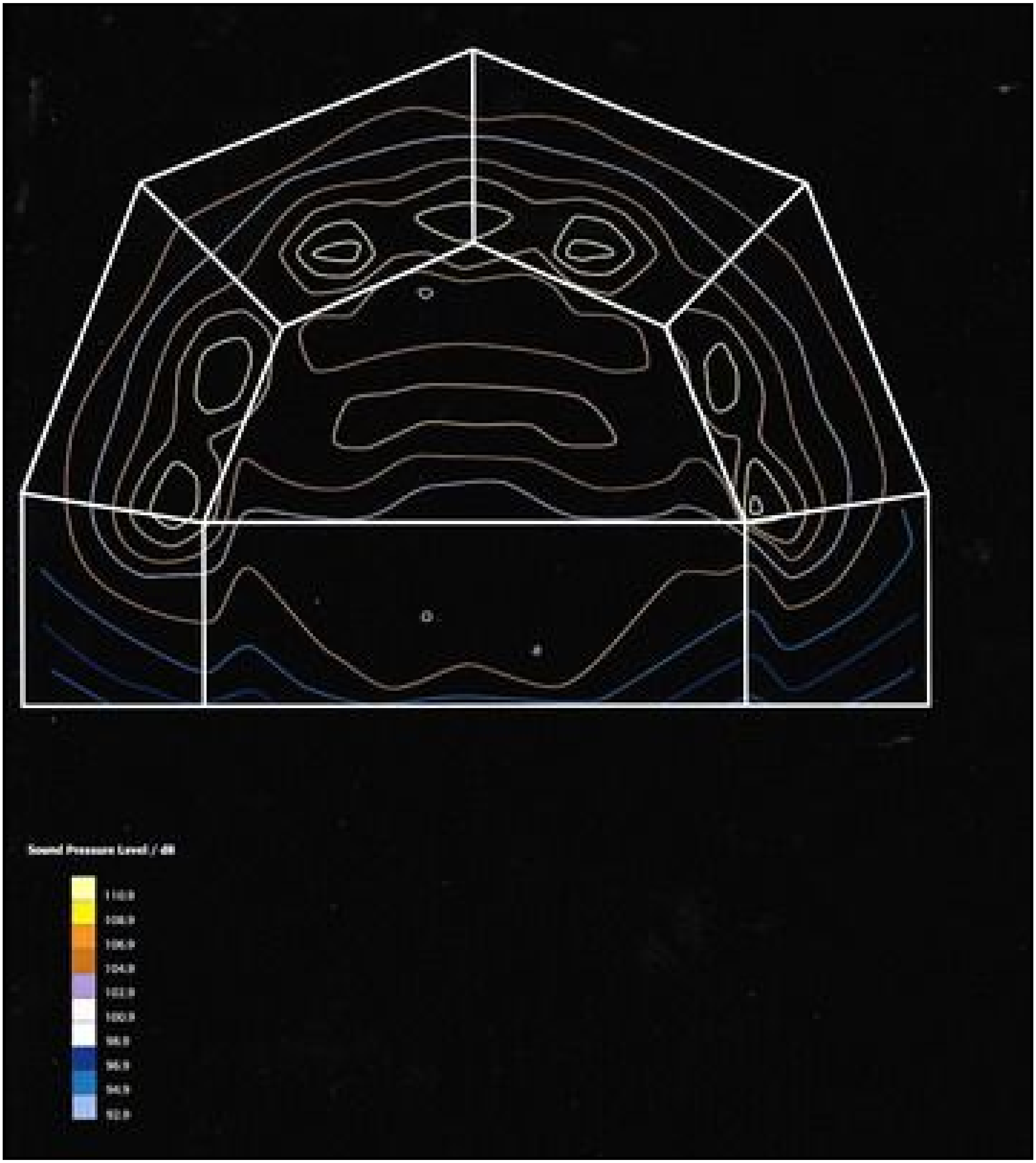
Scale acoustic model of Manchester Concert Hall, Arup Associates

A modern innovation in acoustic design and control was the development of the artificial reverberation system which made use of microphones set in tuned resonators with an array of ceiling loudspeakers.

The next step was the use of acoustic scale models. These enabled analysis of various designs by adding or removing absorptive materials, to check long path reflections and focusing effects, and to improve mid- and high-frequency sound.

Then advances in computer software gave scope for aural simulation, allowing "rooms to be built within computers and simulation of sound to be fed into them. The response of the room can then be assessed, assuming the appropriate source, boundary, and receiver positions are identified."

Acoustic design has come a long way since Sabine and his cushions.



Computer simulation of soundscape by sound reinforcement system, Arup Associates

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REFERENCES FOR ACOUSTICS IN BUILDING ENGINEERING SERVICES

Acoustic design and control in buildings is of vital importance to architects and engineers, and of special concern in the design of air conditioning systems and equipment. The Archives of the CIBSE Heritage Group contain a number of specialist publications:

1952 *Woods Practical Guide to Fan Engineering; Section 15 Noise in Fan Systems*, W C Osborne & C G Turner, Woods of Colchester Ltd

1959 *Modern Air Conditioning, Heating and Ventilating; Chapter 25 Noise & Vibration Control*, Carrier, Cherne, Grant & Roberts, Pitman Press, New York

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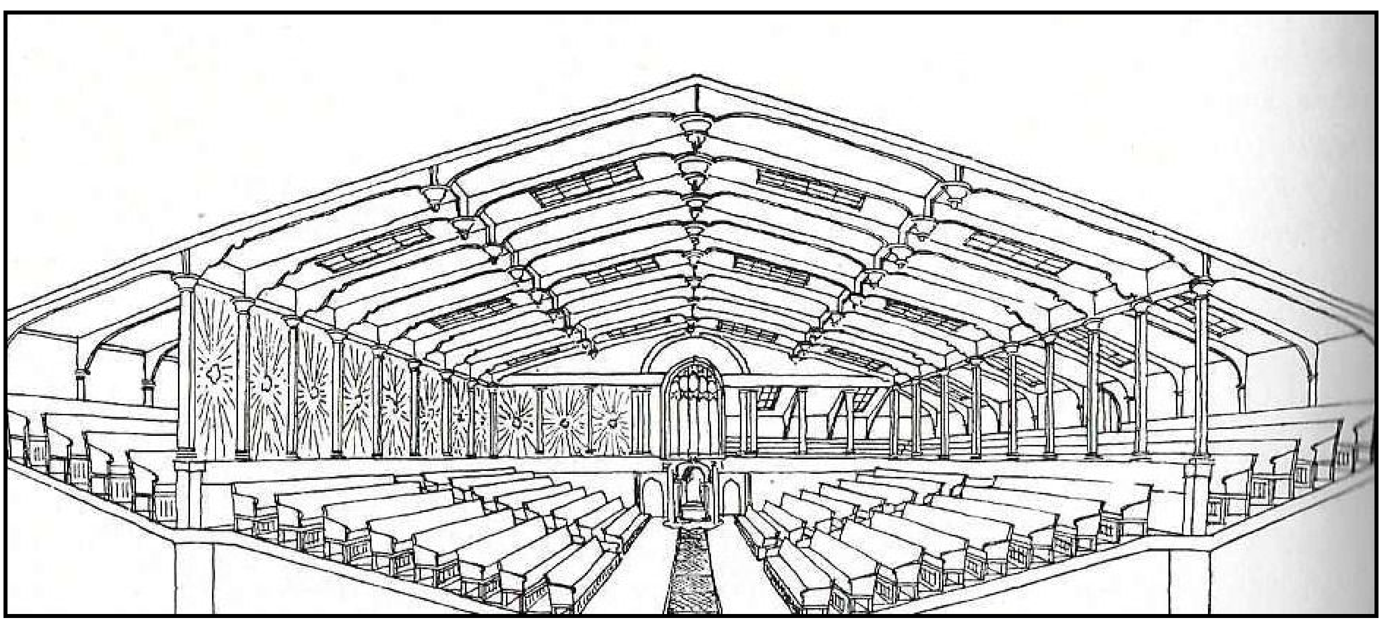
1970 *Sound Control,* IHVE Guide, Book B: Section B12, London

1970 *Boiler Room Sound Levels*, Hoval Boilers (U.K.) Ltd, May

1971 *Fans and their Application in Air Conditioning*, Trane Company, La Crosse, Wisconsin, USA

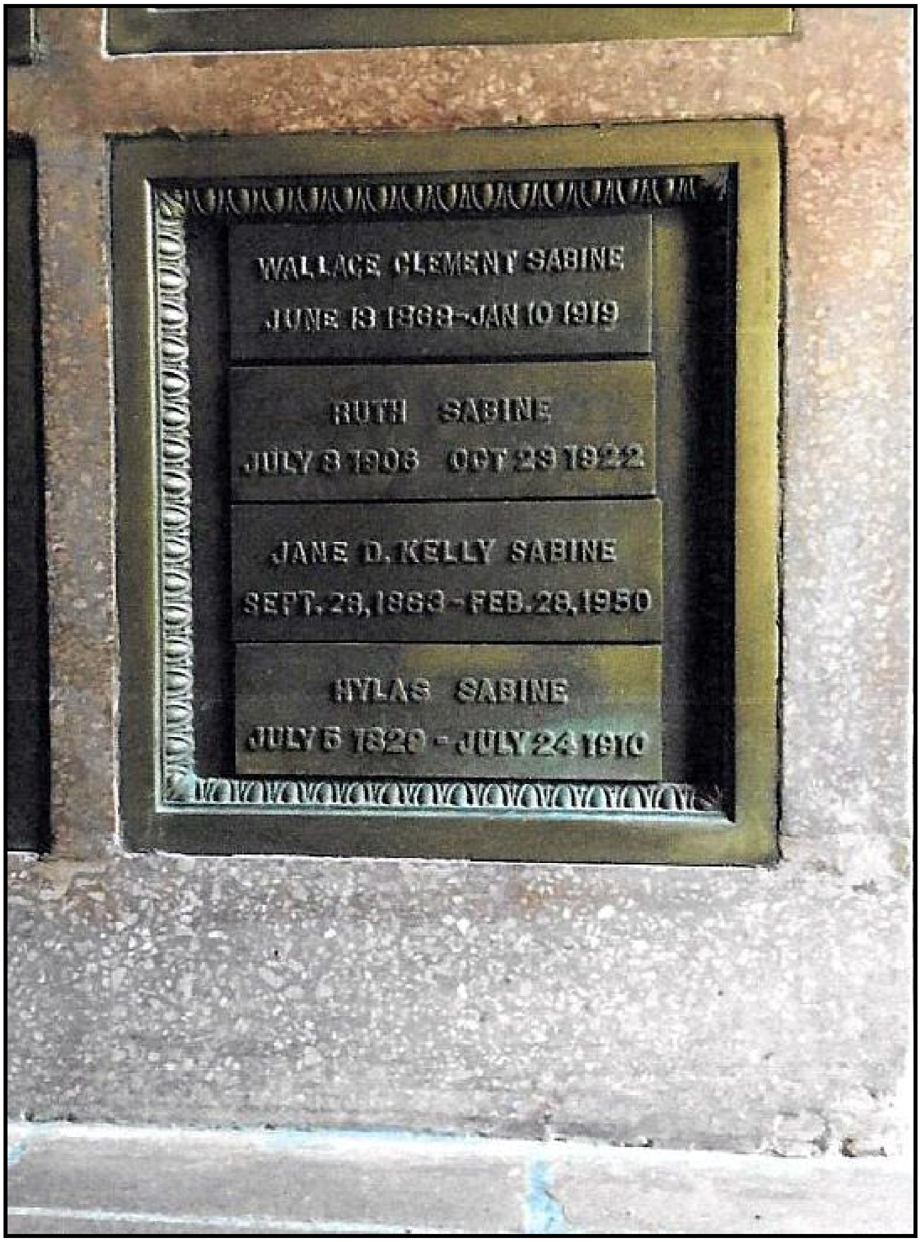
2016 *Noise and Vibration Control*, ASHRAE Handbook, HVAC Applications (CD-ROM), USA



Dr D B Reid's design for a Legislative Chamber with Adjustable Sound Absorbents

EPILOGUE

During World War I, Sabine served on the Rockefeller War Relief Commission and was a member of the National Advisory Committee for Aeronautics. It is said that the strain of all these wartime activities took a toll on his already fragile health, and he died on 10th January, 1919, from complications following surgery for a kidney infection.



Resting place of Wallace Clement Sabine and family members

Sabine was buried at Mount Ashburn Cemetery, Cambridge, Middlesex County, Massachusetts in the Bigelow Chapel Columbian niche 296.