A CENTENARY OF ARCHITECTURAL ACOUSTICS: HOPE BAGENAL AND WALLACE CLEMENT SABINE

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1 INTRODUCTION

FIGURE 1: PHILIP HOPE EDWARD BAGENAL

Philip Hope Edward Bagenal (1888-1979) was Britain's first independent acoustic consultant and a significant figure in the twentieth-century development of architectural acoustics [Figure 1].

His legacy can be seen in an extensive portfolio of consultancy work which encompassed every architectural style, and most of the major civic and ecclesiastic buildings built in mid-twentieth-century Britain.

His influence in the field of acoustics also extended into teaching, research and legislation, and the hallmarks of his work can be seen in the first codes of practice for acoustics and sound insulation published by the Department of Scientific and Industrial Research (DSIR). He published prolifically in architecture, music, and scientific periodicals from the outset of his career.

Bagenal was also involved in the instigation of the acoustics research division in Britain's Building Research Station (BRS) and in the foundation of the Acoustics Group of the Physical Society, one of the constituent associations which amalgamated in 1974 to the form the present Institute of Acoustics.

Bagenal's career in acoustics had its origins in a research dissertation, and significantly, in a series of letters which he exchanged in 1914 with Wallace Clement Sabine, Professor of Physics in Harvard University.

Wallace Clement Sabine (1868-1919) and his seminal work in the science of architectural acoustics need little introduction to acousticians. His formula for predicting reverberation time constituted the first mathematical quantification of the behaviour of sound within architectural space, and is generally held to have established the foundation of architectural acoustics as a branch of modern building science. His work on the twin topics of sound absorption and reverberation time was published in the US over a number of years at the turn of the twentieth century. However, it was sometime later before that work was entirely disseminated across the Atlantic.[1] Ultimately, Hope Bagenal - while still a student - was amongst the first in England to encounter Sabine's work, to correspond with him on the topic, and to apply his advances to architecture and construction in Britain.

The letters between Bagenal and Sabine were fundamental to Bagenal's early professional development. Bagenal wrote to Sabine with a series of questions, which had been prompted by research he was undertaking for a dissertation. That dissertation, on the topic of acoustics, was to form part of his final examinations in architecture. Sabine responded to his queries in great detail, providing valuable guidance on the direction of the dissertation.

This paper discusses Bagenal's first encounter with Sabine's published work and the context surrounding their subsequent correspondence. It details the beginning of Bagenal's remarkable career in architectural acoustics as it evolved 100 years ago against the backdrop of WWI.

2 CONTEXT: 'PLANNING AGAINST NOISE' AND 'DESIGNING FOR MUSICAL TONE'

Hope Bagenal's engagement with architectural acoustics can be traced back to the years preceding WWI. In addition to his extant professional correspondence with Sabine from this era, Bagenal also left a legacy of unpublished letters that detail influences and events in his personal life which added to his growing interest in the field of architectural acoustics. Those letters are a rich resource in understanding both Bagenal's personal approach to acoustics, and the nature of the questions he posed to Sabine.

Two themes, which are frequently reflected in Bagenal's later published writings, emerge from his personal letters in the years immediately prior to his correspondence with Sabine. Those two themes are i) 'Planning Against Noise' and ii) 'Designing for Musical Tone'.[2] In respect of the former, Hope Bagenal was an ardent proponent of 'the war against noise.'[3] He was a founding member of the Anti-Noise League, and was responsible for drawing up the first guidelines directed towards architects for sound insulation in domestic construction.[4] He regarded the right to a calm and peaceful home environment as a fundamental right, and campaigned vigorously for the introduction of building standards to ensure minimum levels of sound insulation in mass housing. Ultimately, his work in this vein formed the basis of the current construction standards for sound insulation. [5]

At the time of his correspondence with Sabine, Hope Bagenal was training for a career in architecture. He was articled to a firm of architects in London, and lived in a flat in Chelsea. In preparation for his qualifying examinations, he was also registered as a student at the Architectural Association (AA) School in London. The system of qualifying examinations for architects in Britain at the time was centrally administered by the Royal Institute of British Architects (RIBA). It was predicated upon a three-stage route to completion, which consisted of Preliminary, Intermediate, and Final Examinations. [6] Upon successful completion of the requisite examinations, a student could then be proposed for election to Associateship of the RIBA, and begin to earn a full salary. Hope Bagenal undertook his Preliminary, Intermediate and Final Examinations in the years 1909, 1912, and 1914 respectively.[7] At the time, he would probably have been slightly older than the

average examination candidate, having also completed two years of a university degree in engineering before commencing architectural training in 1909.

As is also clear from the letters he wrote at the time of his Intermediate and Final Examinations, the achievement of his formal qualifications in architecture was tied up with a personal aspiration. He was engaged to be married and it was intended that the wedding would take place once he had reached the status of a fully qualified professional.[8]

In furtherance of this goal, he took on an architectural position working for the Port of London Authority during the day, while undertaking lectures in the evenings, and a near constant timetable of examinations throughout 1912, 1913 and 1914. The pace must have been exhausting, and many of his letters express his appreciation for a calm and peaceful environment. One in particular, written in the summer of 1912 in the midst of studying for his Intermediate Examinations, describes his frustration at how first his study, and then his sleep were disrupted by external noise perceptible within his flat. The former was rendered impossible by the unwelcome strains of a gramophone emanating from a nearby flat late at night. The latter was disrupted some hours later by a neighbour and returning reveler at 4.30 am, who proceeded to express his high spirits, or as Bagenal described it, 'work the echoes'.[9] Frustration at the issues caused by noise infiltration on that occasion was reinforced the following Monday by what he perceived as a subsequent below-par examination performance.[10]

More significant to his decision to study acoustics however, was the consideration of 'musical tone' in acoustics. Although Anglican by denomination, Bagenal had begun to attend the Catholic Westminster Cathedral in 1911 as a respite from his studies and lectures. Initially, it was in appreciation of the peaceful and contemplative environment of the cathedral, which provided a welcome counterpoint to the busy schedule of work, study, and examination.[11] Westminster Cathedral had officially opened its doors in 1903, and was noted for the high calibre of music which formed part of the services in the cathedral. The director of music, Richard Terry was renowned both for revivalist work in pre-Reformation music – which formed a regular part of the Cathedral choir's repertoire - and for tempering music to particular acoustic conditions.[12] Terry was also noted for having organised a large-scale acoustic experiment in Westminster in 1902 (before the Cathedral had officially opened) to try out different styles of music and determine precisely what sounded best in that Cathedral's acoustic. According to his letters, Bagenal soon became engaged in discussions on the music, acoustics, and architecture of the cathedral and became familiar with the finer points of medieval music theory. He began to write informally on the topic of coincident developments in architecture and music, and in the spring/summer of 1913, formally, began preparation of an article on medieval music and acoustics.[13] His correspondence with Sabine followed shortly thereafter.

3 'SOMETHING OF A REVELATION': BAGENAL- SABINE CORRESPONDENCE.

1912 marked the first year of implementation of a revised architectural examination syllabus introduced by the RIBA. The revisions were an attempt to modernise the examination system, and to allow students to develop an area of specialisation.[14] In light of this, the new syllabus, incorporated for the first time, a research dissertation as a core component of the final examinations. Notably, in addition to the more traditional subjects of history and design, the subject list for the dissertation extended to include 'Science as Applied to Building'. The syllabus stipulated that 'by this is intended a special study of an application of science to definite problems of building.' [15]

Based largely upon his studies of music and acoustics in Westminster Cathedral, Bagenal determined to write his dissertation on the topic of acoustics under the umbrella of 'science as applied to building.'

At the time of the change in syllabus in 1912, there was no reading list for studies in acoustics. The recommended reading for students in respect of architectural science related primarily to sanitation, heating, lighting and ventilation.[16] In terms of its acquisitions on acoustics, the architectural library of the RIBA held the usual historical texts on the work of Vitruvius and Pythagoras and one (relatively) recent book entitled *Acoustics in Relation to Architecture and Building: The Laws of Sound as Applied to the Arrangement of Buildings*. [17] However by 1912, even the latter book, by T. Roger Smith, was outdated in terms of scientific advances in acoustics. It preceded Sabine's research by some three years. The findings were largely based on observation, and the author was quite frank as to the book's shortcomings in terms of both scientific data and procedure. The text described acoustics as 'confessedly obscure' and acknowledged quite openly that it was an unpredictable aspect of design and construction.[18]

The lack of predictability in architectural acoustics was a topic that had received an intermittent airing in the press since the opening of Westminster Cathedral in 1903. The 'perfection' and 'remarkable acoustic properties'[19] of the cathedral were generally deemed to be the result of a happy accident as much as the outcome of deliberate planning. As expressed in an article in *The Tablet*, the weekly Catholic Newspaper published in London and then owned by the Archbishop of Westminster,

> *The science of architectural acoustics appears still to be in an extremely backward condition, for no architect seems to know what his church will do with the sounds of the human voice produced in it.*[20]

Westminster Cathedral and its music were central to contemporary discussions on acoustics, but researching the topic was not straightforward. Accessible resources on the topic were limited. Bagenal did however manage to locate one short piece of writing by Sabine in the form of an encyclopedia entry on the topic of 'Acoustics'. In later correspondence with Sabine, Bagenal was to describe encountering the article as 'something of a revelation.'[21]

In contrast to the previously available texts, Sabine's article was very precise with respect to the behaviour of sound within an enclosed space. The phenomena of standing waves, interference, diffraction and the isacoustic curve were clearly explained, as was the strategic use of absorbent materials and reflecting surfaces. Sabine's own acoustic data for particular wall and surface linings was presented. Musical notes were discussed in terms of wavelengths: presented in feet and inches. Acoustic distortion was exemplified in terms of its effect on musical chords. Furthermore, Sabine outlined the premise of his work on reverberation time and detailed how the formula was to utilised.

In its precise definition of materials characteristics, the effect on musical notes and the possibilities for quantifying spatial behaviour in terms of reverberation time, Sabine's article opened up the potential to quantify the observations made by Bagenal in respect of Westminster Cathedral. In addition to Bagenal's determination to address the void in the available architectural literature,[22] the article provided reassurance that acoustics was a topic which could be scientifically addressed.

From first encountering that article, it took two further years of trawling different libraries in London before Bagenal managed to locate any further writing by Sabine. [23] The second article, 'Building Material and Musical Pitch' was finally uncovered in 1914: not in an architectural library, but in the library of the London Patents Office.[24]

Subsequent to his discovery, Bagenal wrote to Sabine. His interest had been piqued primarily by Sabine's diagrams on absorptive co-efficient and the manner in which the data had been plotted relative to octaves of the musical scale. He queried the physicist on it at length, specifically in respect of the application of absorptive coefficients – in the both the metric and imperial system - to the calculation of 'residual sound' (reverberation time).[25]

Concurrently in his personal letters, Bagenal wrote of his re-awakened interest in a scientific approach to acoustics.[26]

Sabine responded promptly and clarified the issues that Bagenal had raised. Their correspondence touched on the possibility of calculating reverberation time for individual notes (as opposed to octaves) of the musical scale. Sabine discussed his plans to visit London that summer, and his 'quest for interesting data'.[27] In his response, Bagenal recommended both Westminster Cathedral and Terry's music to Sabine as worthy of further acoustic study.[28]

Bagenal completed his dissertation in the following weeks and submitted it for examination.[29]

4 THE OUTBREAK OF WAR.

Hope Bagenal defended his dissertation on acoustics during the summer of 1914, in the same week that Arch-duke Franz Ferdinand of Austria was assassinated in Sarajevo.[30] He met with some opposition from his examiners at the defence, but had little time to dwell on the outcome. Within a week of the published examination results,[31] England had declared war on Germany. On Thursday 6th of August, Hope Bagenal enlisted with the RAMC.[32] He was given a train ticket and ordered to report for training at Aldershot the following Monday. [33]

It seems unlikely that his plans to meet with Sabine in London came to fruition. Sabine, whose itinerary for the summer of 1914 had included a visit to Berlin, had been temporarily detained in Germany at the outbreak of war.[34] He arrived in London as Bagenal left to begin his RAMC training at Aldershot.

The outbreak of war also delayed Bagenal's opportunity to counter the negative reaction of the RIBA examiners to his dissertation on acoustics.[35] Despite the seeming stalemate facing his professional career however, Bagenal's wartime involvement did push his work on acoustics forward in two unexpected ways.

The first was that he began to write prolifically. The majority of his writing from this period is on his experiences in the trenches, and many of the articles were published subsequent to the war. In 1915, he took heart and revisited some of his earlier writing on acoustics and music in Westminster Cathedral. This latter work was submitted to a prominent British architecture journal, possibly while Bagenal was on leave in November 1915.[36] The article – a comparative analysis of the acoustics of Westminster Cathedral, Westminster Abbey and St Paul's Cathedral – was accepted. It came into circulation in late December 1915 while Bagenal was on active duty in Flanders.[37] It was the first paper on architectural acoustics to have been published in a British architectural journal in the twentieth century. Within six months of its publication, Bagenal had encountered a fellow country-man who was also familiar with the work of Sabine.

Alex Wood was a Professor of Physics in Cambridge University. He first encountered the work of Wallace Clement Sabine in 1916.[38] Collaborative work with Wood was the second unexpected means by which Bagenal's career in acoustics moved began to move past the seeming impasse presented by the events of the summer of 1914.

Bagenal first met Wood in 1916 in Cambridge. Wood was a commanding officer with the Red Cross, in charge of the convalescent wing of the Eastern General Hospital (EGH) in Cambridge. Bagenal had been injured on the Somme and transferred back to England and the EGH for medical treatment. In 1916, Wood had just encountered the work of Sabine, and was intrigued by Bagenal's dissertation. A research collaboration was instigated. That collaboration led to a contract with Cambridge University Press in 1917 to expand the earlier dissertation into a book.[39]

Subsequent to the book contract and the endorsement of his work by the physics department in Cambridge, the initially-spurned thesis was accepted by the RIBA – some four years after its submission for examination.

Hope Bagenal returned to work as an architect, accepting a position which allowed him 'a certain freedom for work on acoustics '.[40]

The following year, he accepted a position at the AA School, which also allowed him to begin a private acoustic consultancy. Over the succeeding years, he began to build up a lecture course for architects on acoustics. The lecture course became part of the curriculum c. 1922.

5 IMPLICATIONS

Wallace Clement Sabine died in 1919. It seems unlikely that he and Hope Bagenal ever had the opportunity to meet during the time of their correspondence. However Bagenal remained in correspondence both with Sabine's protégé Clifford Melville Swann and with Sabine's cousin Paul for some decades thereafter. Swann ensured that Bagenal received a copy of Sabine's collected papers when they were post-humously published in 1922. In his review of this collection for the RIBA Journal, Bagenal began with the statement that 'It is rare that any branch of accurate knowledge owes so much to a single mind as architectural acoustics owes to Sabine.'

As his own career progressed throughout the twentieth century, Bagenal's aspiration to fill the void in available literature on architectural acoustics was more than fulfilled. In addition to the textbooks which he published, the middle decades of the twentieth-century saw a veritable glut of articles on acoustics published in journals of architecture. The majority were either authored or inspired by Hope Bagenal. The RIBA Journal has never – before nor since – published the same volume of articles on architectural acoustics as it did when Hope Bagenal was a contributing author.

Hope Bagenal's last recorded job was in Ireland, the country of his birth, in the 1970s. He was in his 84th year. Two years later, he was awarded honorary fellowship of the newly-formed Institute of Acoustics.

Alongside a brief resume of his work, his Institute of Acoustics citation described him as

> *'… the most distinguished practitioner of the art and science of architectural acoustics of our age… It is not merely his consulting work which merits the honour we now do him; it is above all, his concern for the beauty of sounds with which he invested the attitude of architectural acousticians in Britain.'*

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[20] The Tablet, 7 June, p. 34. (1902)..

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[26] Letter of H. Bagenal to A. Hogg, 1 April 1914, Hertfordshire County Archive.

[27] Letter of W.C. Sabine to H. Bagenal, 13 April 1914, Royal Institute of British Architects Archives.

[28] Letter of H. Bagenal to W.C. Sabine, 24 April, 1914. Extracts of this letter can be viewed in W. Orcutt, Wallace Clement Sabine: A Study in Achievement, Massachusetts: Plimpton Press (1933).

[29] According to the RIBA Kalendar for that year, the submission date fell at the end of May.

[30] The Austrian assassination took place on June 28th 1914. According to the RIBA Kalendar for that year, the RIBA exams were held during 25th June - 3rd July, with viva dates scheduled for 2nd and 3rd July (RIBA Kalendar for 1914

[31] Journal of the Royal Institute of British Architects. 22, 615. (July 1914).

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