CHAPTER

1

Replacing a Scientific Legend

Winters in Geneva, Illinois, can be bitter and ruthless. Raw, icy winds howl across the snow-covered plains to the north and west, pushing blizzards across the barren farmland as they go, and slam into the wet, heavy air above the Fox River Valley. The cold is bone chilling, paralyzing.

In February 1919, however, the winter was undoubtedly of less concern for Paul Earls Sabine than the opportunity to observe for his first time the Riverbank Acoustical Laboratory, a scientific laboratory that recently became his responsibility.

The only convenient way to reach the laboratory was by automobile. Sabine would have parked in the laboratory parking lot located on the western edge of this privately owned 600-acre estate. When stepping from his car, he would have been standing at the highest point in Kane County. Immediately southward was the acoustical laboratory, a large structure that defied definition. The building seemed to be a composite of architectural styles, owing nothing to anyone.

The main section of this unique structure was (and still is) a four-story conglomerate of masonry topped by — depending on one's aesthetic viewpoint — either a blockhouse, a lookout tower, or a cupola. On the east end of the building stood a ten-foot-square, six-story-tall bell tower. Although the tower was more reminiscent of a college or university, it mysteriously managed to entwine with the academic image auras of medieval nobility, spiritual ecclesiastical order, and American patriotism.

On the roof of the cathedral-windowed belfry perched a full-winged, concrete replica of an American bald eagle. From afar, this powerful-looking portrayal of our national emblem appeared to be soaring above the Riverbank tree tops, the Fox Valley, and all Kane County, ever peering, searching, and protecting — an allegory that Riverbank estate owner, Colonel George

Fabyan, surely intended his personal sculptor, Silvio Silvestri, to convey.

As Paul Sabine approached the laboratory entrance driveway, he passed two Silvestri-sculpted sentry lions bearing shields, each mounted atop an eight-foot brick column that completed a wrought iron fence. When he reached the main entrance, he saw, carved into the cornerstone, the date 1918 and the initials "W. C. S." These same initials and the inscription "The Wallace Clement Sabine Laboratory of Acoustics" were etched in the frosted glass window of the door, reminders that this new acoustical laboratory, the first independent laboratory dedicated to the science of architectural acoustical testing, was specifically designed by, and built for, Wallace Sabine. The unexpected death of Wallace Sabine a month earlier was the immediate reason that his cousin Paul was standing at the door of this strange building on a frigid day in 1919. The other, less clear-cut reasons for Paul's arrival at Riverbank have their roots in the plays of Shakespeare, the pursuit of levitation, and the secrets of the Rosicrucians.

In 1913, Colonel George Fabyan was in dire need of an acoustical consultant to assist with a scientific project being conducted on his estate. This particular Riverbank project dealt with the building and testing of an acoustical levitating device constructed from a seventeenth-century description of a similar machine written in code by Sir Francis Bacon and deciphered by Elizabeth Wells Gallup. Mrs. Gallup had come to Riverbank just after the turn of the century to continue her life-long search for proof that it was actually Bacon who had written the Shakespearean plays. During her research, she discovered that Bacon was a member of the Rosicrucian Society of England, a clandestine organization whose activities included conducting scientific experiments. Because this type of activity was interpreted by some to be witchcraft, the Rosicrucians had to carry out the experiments and divulge their findings in secret.

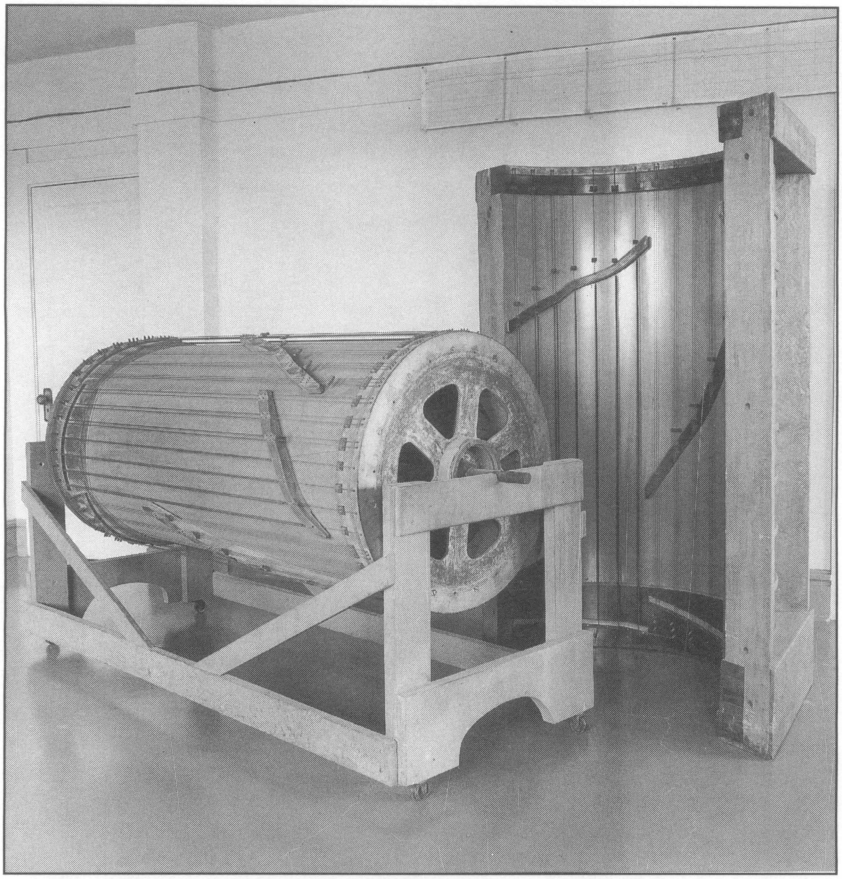
Fortunately for the society, Sir Francis Bacon was in charge of the Queen's royal printing and was able, by virtue of the position, to provide the medium through which other members were informed of experiment results. A biliteral cipher (not unlike the binary code used in computers today), using two different-sized alphabets, allowed Bacon to encode information about recent experiments; this encoded text appeared in printed pamphlets or proclamations. Members of the Rosicrucian Society, who knew how to decipher the code, were thus able to read about the research of others.

According to Mrs. Gallup, Bacon applied the same coding technique in many of his personal writings. This is referenced in the galley proofs of "The Fundamental Principles of the Baconian Ciphers," dated 1916, a document the colonel dedicated to his mother. In this work Mrs. Gallup included various poems, short stories, and nursery rhymes, along with explanations of a variety of the society's experiments — one of which was an experiment with an acoustic levitation device. Immediately after she deciphered the descrip-

Laboratory Entrance and Cornerstone.

tion of this so-called antigravity machine, Mrs. Gallup informed Colonel Fabyan. The colonel responded by hiring Bert Eisenhour, a civil engineer from a woodworking firm in Chicago, to construct the device.

In essence, the Bacon cipher described the principle behind the levitation device in this fashion: If (1) musical strings are incorporated in the proper sequence on a vertically mounted cylinder, (2) the cylinder is rotated inside a peripheral outer shell assembly that contains similarly mounted musical strings, (3) the cylinder is rotated at a high rate of speed, its strings struck and set into vibration, and (4) the strings are in perfect tune with the strings



The Acoustical Levitating Device.

mounted on the shell, then, through sympathetic vibration, the strings on the shell will also vibrate, creating a combined force field within the cavity between the cylinder and the outer shell that results in a lift force strong enough for the outer shell to levitate. Such was the theory, but the device built at Riverbank could not be made to work.

Eisenhour felt certain that the device did not perform as hoped because of improper tuning. He believed that when the cylinder was in rotation, the strings stretched and, therefore, were out of tune with their counterparts mounted on the shell. To resolve the problem, Eisenhour reasoned he needed to find an individual knowledgeable enough in acoustics to calculate the frequency at which the strings should be pretuned to become in tune with the strings on the outer shell when the cylinder rotates at the proper speed.[1] The expert they contacted was Wallace Clement Sabine of the Physics Department at Harvard University. Sabine made his first visit to Riverbank in the same year, 1913, a visit that resulted in the end of the levitation device project but the beginning of a long-term friendship with Colonel George Fabyan.

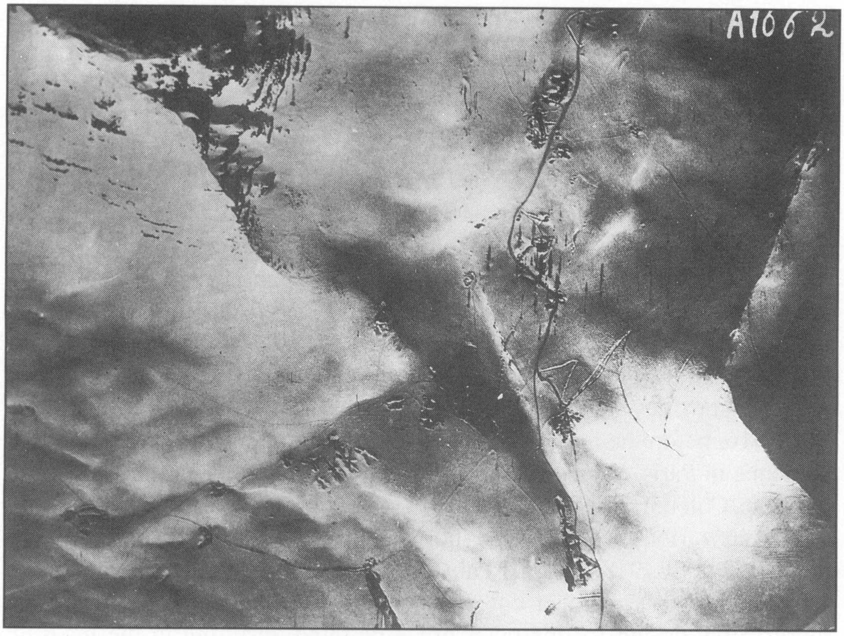
In 1915, during one of his many stays at the estate, Sabine told his host about the technical problems he had encountered in trying to perform experiments in architectural acoustics at Harvard's Jefferson Laboratory. Most of the problems, the professor explained, centered on the unwanted noise and vibrations from the street outside the laboratory that created difficulties in obtaining meaningful data; most of the testing had to be conducted late at night. The colonel proposed that if Wallace Sabine would consider coming to Riverbank, he would pay for the construction of an acoustical laboratory of the professor's design. Naturally, Sabine agreed.

In 1916, before he began preparations for his scheduled lecture tour at the Sorbonne in Paris, Sabine submitted his drawings for an acoustical laboratory to the Colonel. Because both the colonel and the professor became immersed in various war projects shortly thereafter, the laboratory was not completed until 1918. Colonel Fabyan conformed strictly to the professor's design of the test chamber but deviated considerably from Sabine's more conservative design for the outer office building, resulting in the majestic structure that greeted Paul Sabine less than a year later.

Also because of the war, Professor Wallace Sabine was unable to present his Sorbonne lectures on architectural acoustics as a Harvard exchange professor until 1917. These presentations were followed by lectures at the Ecole des Beaux Arts (School of Fine Arts) and before the French Society of Architects in Paris. During this same period, he was a scientific advisor for the United States Navy Department of Information and the French Bureau of Inventions on submarines and airplanes. He later became a staff member of the Bureau of Research for the Air Service of the American Expeditionary Forces and provided services for the British Munitions Inventions Bureau in England, the French fleet at Toulon in the Mediterranean, and Italy on the Italian front.

One of the professor's developments, that involved Riverbank, was the use of cameras in airplanes for aerial reconnaissance. Because of this work, the French awarded him the French Legion of Merit Medal for locating some hidden German airfields. Glass negatives (the photographs were apparently taken by Sabine himself) discovered in one of Riverbank's laboratories in 1980 showed aerial views of sections of actual World War I trenches at the front. The trenches were later duplicated at Riverbank for training purposes. The Riverbank project focused on the effectiveness of new explosives and weapons, including a special type of trench mortar, in and around the artificial ditches.

Professor Sabine participated in various Allied experiments and was at the



Austrian Cannon in the Alps with Path
An Aerial Reconnaissance Photograph of the Italian Front.

English, French, Italian, and American fronts. Although he earned the rank of colonel in the four Allied armies, there are no records or pictures indicating he ever wore a military uniform. If this were the case, had he ever been captured, he would have been regarded as a spy. Reportedly, the Germans tried to capture him three times, and on their third attempt, they missed by only five minutes.

After leaving the western front in the fall of 1917, Wallace Sabine returned to Washington and became director of Technical Information for Bureau of Aircraft Production in the U.S. War Department. In 1918, he was appointed by President Wilson to serve as a member of the National Advisory Committee on Aeronautics. It was during the fall of 1918 that the professor was able to see his new laboratory in Geneva, Illinois, for the first time and take a set of absorption measurements.

On November 11, 1918, the day the armistice was signed, Professor Sabine was finally able to relinquish some of his military obligations and return to Harvard University, where he proceeded with his work in architectural acoustics. These efforts included preparations for experiments at his new laboratory in Geneva. The government, however, continually required his services, and he virtually commuted back and forth between Harvard and Washington. One such project was to set up a plan for study and research in aeronautics. The plan he created was so futuristic in scope that the guidelines, written in 1918, were incorporated into the guidelines established for National Aeronautics and Space Administration decades later.

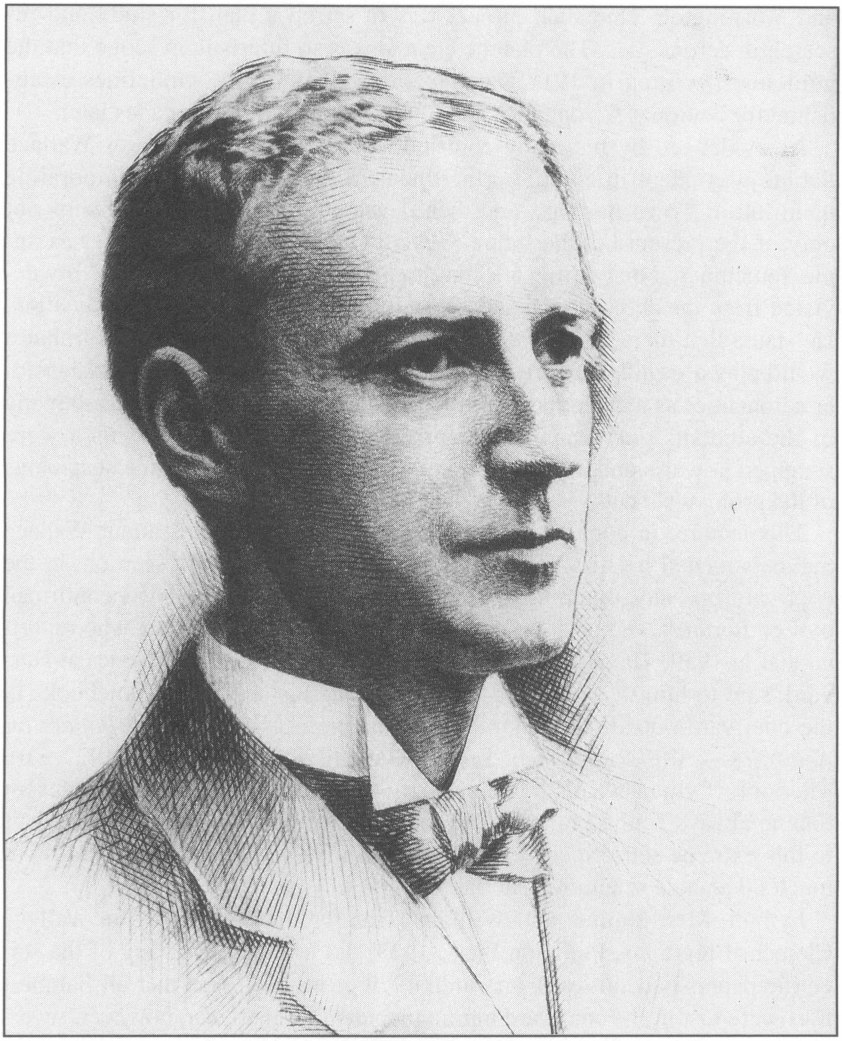
As evidenced by his many contributions to science, Professor Wallace Sabine was adept in compiling pertinent facts and theories, incorporating them into his own findings, and then developing solutions to problems not only of the present but the future as well. One Harvard alumnus, for example, remembered that during a lecture to a physics class, Sabine suddenly deviated from the class subject and began to expound on the future of aviation. He stated that there would most assuredly be another war and that airplanes would play a significant part. He went on to suggest that the students consider aeronautics as a career because the demand would be great. Because many of the students only knew about airplanes of 1918, most of which were scrapped at war's end, it is no wonder that these students became suspicious of the professor's wits.

This lecture, in conjunction with another raised questions about Wallace Sabine's mental health. As the story goes, the professor was seen out in the courtyard one day, dumping and burning his files. The story was confirmed by Leo Beranek, author of several articles about Wallace Sabine, who reported that in 1939, Theodore Lyman, then emeritus professor of physics at Harvard, said to him that he found Sabine burning his papers and notebooks in the courtyard outside the laboratory. In the preface to *Collected Papers on Acoustics — Wallace Clement Sabine* (Harvard University Press, 1922, vii), Theodore Lyman wrote, "The severity of the criticism which Professor Sabine always applied to his own productions increased with time, and it is to this extreme self-criticism and repression that we must ascribe the loss of much invaluable scientific material."

Lyman, Mrs. Sabine, and William Dana Orcutt (author of the Wallace Clement Biography, Plimpton Press, 1933) did not know that any of the scientific papers had survived, and until 1979, it was believed that all Sabine's files were lost in the courtyard burning incident. In that year, however, several Wallace Sabine files were found at Riverbank. How they actually got to Geneva is uncertain, but in any case, valuable and irreplaceable information was found. A copy of their contents is now housed in the Harvard archives.

As it turned out, the files that were burned contained data from his one-, two-, and four-organ pipe configurations, which he used for determining the sound-barrier qualities of a wall. These data had been cited in other file documents as inaccurate.

The retrieved files disclosed a personality and a brilliance so unique that most acousticians read in awe from beginning to end. Today, Professor Sabine's *Collected Papers on Acoustics* (Peninsula Publishing, Los Altos, California, 1994) is regarded as a must for those involved in the science be-



Wallace Sabine.

cause much of what he states remains the state of the art. His formula for sound absorption is still used in many standard acoustical tests, and the unit of absorption now bears his name, minus the *e:* sabin.

Late in the winter of 1918, during the Christmas break, Professor Sabine set about the lengthy process of calibrating organ pipes that were to be used as sound generators for the reverberation test chamber at his newly constructed laboratory. Although already in poor health, the professor insisted on performing this task himself–a decision, it turned out, that proved fatal.

During World War I, Wallace Sabine had been diagnosed with a kidney disorder (later diagnosed as cancer) and was told repeatedly that surgery was necessary. He would reply, "Not while my country is in danger." Sabine believed that because he had survived various illnesses in the past, he surely could brave off any disease to respond to his nation's needs. Not that he was foolhardy, weak of mind, or careless; he was, instead, motivated by a sense of purpose, loyalty, and patriotism.

Many individual recollections of Wallace Sabine describe him as soft spoken, mild mannered, courteous, and even tempered. Those who knew him well considered him extremely alert, astute, caring, and deeply devoted — all in all, an individual not likely to be careless or to seek out dangerous or risky situations. Wallace Sabine demonstrated courage, resolution, and perseverance. Throughout his life — and especially during World War I — Sabine often disregarded problems relating to his own health to complete a myriad of scientific and humanitarian tasks.

In December 1918, however, his health could no longer be disregarded. As the holidays approached, Professor Sabine informed his long-time assistant, John Connors, that because of his lingering illness, it might be best if he took full advantage of the Christmas vacation to allow himself some time "to get patched up." He hoped to be in much better condition by the time the next school session began.

He entered the Peter Bent Bringham Hospital in Boston for a preliminary operation that provided temporary relief. He then returned home to recuperate. During this interim, however, he contracted influenza. Although it was still Christmas break, the fact that Wallace Sabine wasn't able to make his periodic visits to the laboratory created growing concern among the faculty, including his close friend and colleague, Professor Edwin Hall.

In the March 1919 issue of *The Harvard Graduate,* Professor Hall recalled that after reading about the possible seriousness of Sabine's illness, he telephoned his friend. According to Hall, Wallace answered in a voice so cheerful and strong that Professor Hall might have put aside any fears regarding Sabine's health; however, he was well aware of his colleague's penchant for feigning wellness to "censor health bulletins relating to himself." Attuned to this diplomatic subterfuge, Professor Hall called on Wallace Sabine at his home the following day. Although Sabine put up a remarkable front, it was not too difficult for Professor Hall to ascertain that his old friend's illness was serious and that Wallace, too, was aware of his condition. Nevertheless, Sabine ignored the rules of the sick chamber and refused to listen to any advice to the contrary. He was then, as he had been during their entire acquaintance, a defier of precept, a law unto himself. This part of his character is even more evident in Professor Hall's account:

> Any time for the past year or two, looking upon his spiritual, still youthful, face, and noting the smiling obstinacy with which he followed a course of toil that must end his life too soon, one might be tempted to think of him as some elfin being that had taken human form in benevolent caprice, but was now planning departure and adventures new. Not that he ever, save in the very ecstasy of pain and weakness, showed any symptom of world-weariness. He was full of affection, full of the zest of life, full of plans for future years. He has told me that he never enjoyed his work of teaching more than during this past fall, so trying to most of those who remained in academic life, and he had been looking forward joyfully to the prospect of resuming his work of research, especially that part of it which was to be carried on in the special laboratory built for him by his friend Colonel Fabyan at Geneva, Illinois.

On January 5, 1919, Wallace Clement Sabine returned to the Peter Bent Bringham Hospital. Despite desperate efforts to save his life, he died, peacefully, on January 10, at the age of fifty. His whole life a private man who shunned publicity and accolades, Wallace Sabine's death was marked by scientists and academicians the world over. Although never well known beyond those small circles in which he operated, Wallace Sabine's contributions were, without question, appreciated and recognized by his peers, and in years to come, Wallace Sabine would be honored posthumously with two deserving titles: The Father of the Science of Architectural Acoustics and The First Modern Day Acoustical Consultant.

The bestowing of the title Father of the Science of Architectural Acoustics caused some controversy among scientists in the field because acoustical research had been conducted many years before Sabine began his work. Indeed, the early Greeks and the ancient Egyptians accounted for sound in their performance facilities. The names of Lord Rayleigh, Joseph Henry and Floyd R. Watson were mentioned to Beranek as more likely candidates to the title. Leo Beranek concluded, however, these earlier scientists dealt primarily with theories and principles of sound propagation and not with architectural acoustics. Joseph Henry authored *Limit of Perceptibility* circa 1860, Lord Rayleigh authored *Theory of Sound* in 1877, and Professor Floyd R. Watson of the University of Illinois wrote various papers from 1890 to the 1950s. Professor Watson, however, supported Sabine for the title. Although Watson's sound work predated Sabine's by twenty years, in a paper at the World Engineering Congress in Tokyo in 1929 Watson stated:

> It appears appropriate to present a paper on Acoustics of Buildings before the World Engineering Congress because, while the scientific basis of the subject may be said to have been laid in the United States in the brilliant, pioneer work of Wallace C. Sabine, the interest in the subject has extended all over the world.[2]

Also, in "Hearing in Auditoriums Effects of Noise and Reverberation," a reprint from *The Architect and Engineer* September 1926-January 1927, Part 1, Page 2, Vern Knudsen, an acoustician of note, had this to say:

> It is an affront to the monumental contributions of Professor W. C. Sabine of Harvard, whose life's work is not only the real foundation but also largely the superstructure of the science of architectural acoustics. Architects and builders all over the United States know of hundreds of instances in which the application of the "absorption" theory of W. C. Sabine has led to complete acoustic success, both in the correction of existing auditoriums and in the design of new ones.

The death of Wallace Sabine was probably felt no more acutely than by his friend and benefactor, Colonel George Fabyan, who now had on his estate a new and virtually unused acoustics laboratory, with no one to provide direction, scope, or purpose. In addition he could not advertise for a qualified expert in the field because in 1919, except for the late Wallace Sabine, there were extremely few.

Finally, the colonel decided that he would contact his brother Marshall at Harvard because it was he who had arranged the first meeting between the colonel and Wallace in 1913. Marshall was well aware of the tremendous loss to the world of science, and in anticipation of George's obvious need, he already had taken action. When contacted, Marshall explained that he had located a more-than-suitable replacement, a cousin of the recently departed professor — Paul Earls Sabine — who had a Ph.D. in spectroscopy from Harvard. Marshall Fabyan mentioned that given current circumstances, chances were excellent that the younger Sabine would be able to step in for his cousin.

Paul Sabine had just completed his part in a project for the U. S. Navy and was returning to a previously held position at the Case School of Applied Science in Cleveland, Ohio. Colonel Fabyan instructed Marshall to do whatever possible to convince Paul not to go back to Ohio but to consider coming to Riverbank. Marshall contacted Sabine, and they arranged a meeting.

The only written account regarding that meeting in 1919 appears in a short note, apparently addressed to a relative, found in Paul Sabine's files:

> I am in preparation for departure to meet my new employer in Geneva, Illinois. According to his brother, it appears that this Colonel Fabyan is very wealthy, patriotic, and quite involved in various scientific endeavors, and it is I that shall heed the beckoned call to continue our dearly departed cousin's work in a new laboratory constructed for him at Riverbank.

"Beckoned" to carry out the work Wallace Sabine had begun, Paul Sabine arrived at Riverbank Laboratories on that bitterly cold day in February 1919 and saw for the first time the unique surroundings that would be his place of work and his home. From letters and notes found in his files, it is clear that Sabine knew the magnitude of the challenges his cousin had left for him and how much there was to be done. It is clear, too, judging from the article that follows ("The Life Work of the late Wallace C. Sabine, An appreciation", *The American Architect,* Vol CXVI, Number 2271, Wednesday July 2, 1919, Page 1) that he knew when accepting the position with Colonel Fabyan, it meant his whole life was about to change. He was, after all, replacing a scientific legend.

THE LIFE WORK OF THE LATE WALLACE C. SABINE
An Appreciation
by Paul E. Sabine

The name and work of Professor Wallace C. Sabine are familiar to all readers of *The American Architect* who have ever had to deal with the troublesome problems of auditorium acoustics. His death, at the age of fifty, which occurred on January 10, cut short a life of extraordinary activity and usefulness. A recital of the facts of his life and the outline of his work in the field in which he was preeminent will be of interest to that large circle of architects in Europe and America with whom his commanding knowledge of acoustical problems brought him into contact.

He was born in Richwood, Ohio, in 1868. He first went to the Public School at the age of eight. At twelve, he entered the preparatory course of the Ohio State University, graduating at the age of eighteen. After two years of graduate study at Harvard, in Physics and Mathematics, he was made an assistant, and shortly after an instructor in Physics. In 1895, he became Assistant Professor of Physics, and ten years later received the full Professorship. Less than another decade later, he succeeded Professor B. O. Peirce as Hollis Professor of Mathematics and Natural Philosophy, a chair which had been filled by a long line of distinguished scholars. In 1916-17, he went as Exchange Professor to France, lecturing on the subject of Architectural Acoustics at the Sorbonne and the Ecole des Beaux Arts, and before the French Society of Architects.

Brown University conferred on him the honorary Doctorate of Science. He was a member of the National Academy of Sciences, a former Vice-President of the American Association for the Advancement of Science, and at the time of his death, Vice-President of the American Physical Society.

This record of scholarly achievement is matched by one of equal worth as an administrator. That masterly director of men and affairs, President Eliot, early marked him as "able and clear headed." In 1906, President Eliot confirmed this judgment by asking Professor Sabine to become Dean of the New Graduate School of Applied Science, a post demanding not only administrative skill and tact, but also unusual capacity for constructive work. That the foundations for a new and vastly important departure in scientific education were well laid is conceded by all who know the brief history of this department of Harvard University. It was equally this same capacity for broad-minded and far-seeing constructiveness that made him a strong advocate of the movement that ended the existence of the Graduate School of Applied Science in the attempted merger with the Massachusetts Institute of Technology.

The value of his services during the war was recognized by the governments of England, France and America. While in France, he was on the staff of the Bureau of Research of the Air Service of the American Expeditionary Force, a consultant of the French Bureau des Inventions and the British Munition Inventions Bureau. Because of his close acquaintance with the airplane activities of the Allies, after his return to this country in the fall of 1917, his time and services were in constant demand for America's airplane program. After the reorganization of this work in 1918, he became Director of Technical Information of the Board of Aircraft Production. A prominent member of that service remarked regarding him, "he is the one man in the service who claims to know least and who actually knows most about all phases of the aircraft problem."

Writing of his work during these days of the war, Professor T. C. Mendenhall of Ohio State University, his first teacher of physics, says:

"His services proved to be of incalculable value and he was constantly traveling back and forth between Cambridge and the Capital."

During all this time he was suffering from a serious malady which came near ending his life in Paris in 1916, and he knew that it could be remedied only by an operation to which his friends had urged him to submit. With a complete forgetfulness of self which was characteristic, he invariably answered, "Not while the war is on and other lives are in danger."

Only after his country's crisis was past, did he turn to save himself. He never rallied from the operation performed on January 6, 1919, which, had it been performed earlier, might have saved his life.

Viewed both by the scientist, and the practical man, there are certain outstanding features of Professor Sabine's work in Architectural Acoustics that mark it as of a high order. To the scientist it appeals as being constructive in the highest degree. Definiteness of purpose, directness of attack, simplicity of method, and thoroughness and complete reliability of results distinguish it throughout. To the architect, it appeals strongly, because his results were always presented in a form immediately applicable to concrete and very troublesome problems. He never undertook research simply for the fun of finding out something new, but always to find the answer to a problem that people wanted and needed to have solved. Having done this, he was at pains to state his results in terms that the man who needed them would understand.

To appreciate the value of his contribution to knowledge, we may, for a moment, consider the situation confronting him, when the Corporation of Harvard University asked him in 1895 to undertake the correction of the acoustics of the recently completed lecture room of the Fogg Art Museum. None of the standard text books on sound even mentioned the question of why some rooms are acoustically good and others acoustically bad. At that time no investigations had been published on the subject.

Out of the careful study made for the purpose of solving the particular problem, grew several important results. First of all, the acoustically bad auditorium was made fairly good. At the same time a large amount of valuable data was collected, and, more important, there was evolved a theoretical basis upon which any similar problem could be attacked with some hopes of successful solution. When a year or two later, Messrs. McKim, Mead and White, architects of the new Boston Music Hall, chose to stake their chances of an acoustically successful concert hall on something more substantial than mere luck, Professor Sabine's experience and knowledge were called upon and the acoustical design of the building followed his recommendations. So confident was he of the correctness of his method, that in an article in *The American Architect,* published in 1900, before the completion of the hall, he predicted the period of reverberation of sound in it of standard intensity to within one-hundredth of a second.

This confidence was justified in the altogether satisfactory acoustical properties of the finished hall. The publication in 1900 of *Architectural Acoustics, Part I,* was the product of five years of painstaking labor and formed the first real contribution to the subject.

In the introduction to this paper is given a complete outline of the elements of the acoustical problem. One needs to consider Loudness, Interference and Resonance, Reverberation, Echo and Extraneous Noises, to know completely the acoustic properties of a room. Of acoustical defects, the most common is excessive reverberation, and in this first paper the writer outlines the method of experimental study and the elimination of this defect. He goes on to develop an adequate mathematical theory, and gives sufficient generalized data to make his method of remedying the difficulty applicable in any particular case, and finally as an example of the use of the method, he gives the computation for the new Boston Music Hall and a comparison with the acoustical properties of two similar halls, the Leipsic Gewandthaus, and the old Boston Music Hall. The publication of this paper definitely removed the whole subject of auditorium acoustics from the half-world of chance and guess work. It demonstrated that the architect may plan for the acoustics of a structure with the same degree of certainty that he provides for lighting and ventilation. It gave a solution both theoretical and practical of a problem as old as architecture itself.

It is to be said that in the eighteen years since the publication of his first paper, Professor Sabine followed consistently the program of investigations there outlined. The order in which they were taken up was determined by the demands of the subject itself, and by the actual needs of architects who consulted him.

A word as to the conditions under which all these investigations were performed may be of interest. In its early stage, the method was largely observational. That is to say, it called for the determination of the acoustical properties of rooms already constructed. In certain experiments these properties were altered by the introduction of large quantities of absorbing material, for example, seat cushions in great numbers. Observations had to be taken when complete silence was possible. To appreciate how rare this condition is, one needs only to undertake to secure it. Necessarily the work was done at night and most of it between the hours of one and five in the morning. Buildings presenting the properties desired for study seldom had the additional advantage of being isolated and free from noise. The notes of this first five years contain data taken in some forty different rooms, ranging in size from small vestibules to large auditoriums and in locations from Bangor to Minneapolis.

In the years immediately following the work on reverberation, the research was extended to include the whole range of musical tones. This, of course, increased many fold the amount of data to be collected. The results of the work of this period were published in part by The American Academy of Arts and Sciences in 1906. In these papers, is described a series of experiments conducted with the aid of some of the faculty of the New England Conservatory, which established the fact that there is a very sharp optimum value of the period of reverberation in a room used for piano music.

The experiments to determine the absorbing power of an audience, and of various wall surfaces, and materials for tones of pitches covering the entire musical range are also described, thus completing the experimental study of Reverberation.

Following the year 1906, the new duties of Dean of the Graduate School of Applied Science would have effectively stopped the research activities of most men. However, Professor Sabine found time, while others slept, to determine the sound-absorbing properties of a great number of materials, for the whole musical range. He also developed a tile whose sound-absorbing properties compare very favorably with those of felt. He gave much time to consultation in this country and in England, both as to buildings in construction and as to methods of improving faulty acoustics. During this period he began the experimental study of the phenomenon of sound interference as applied to interior acoustics. The variation in intensity of sound at points in a room containing a constant source of sound was carefully studied and photographically recorded by means of a telephone receiver and string galvanometer. Thus study afforded much information on the so-called "deaf spots" in auditoriums and demonstrated fully the inadequacy of the "sound ray" method of studying acoustical problems. There was also developed in this period the modification of the Toeppler-Boys-Foley method of sound photography, which was applied so successfully to the study of the problems of echo and loudness in large auditoriums. An account of the application of the method appeared in an article on "Theater Acoustics," in *The American Architect* for December, 1913, with photographs showing the progress of an actual sound wave, in a small model of the auditorium being studied.

In 1914, Professor Sabine began the last of the problems outlined in his first paper, namely, that of elimination of extraneous noise. This, of course, is the difficult problem of sound insulation which had been brought to his attention by inquiries from many architects. The results of a preliminary study were published in February, 1915. The method there outlined is an adaptation of that developed for the study of reverberation and sound absorption, to the study of sound transmission. The results, though admittedly incomplete, serve to indicate the limitation upon the efficiency of so-called "sound-deadening" material as ordinarily applied. It is shown that for complete insulation the thickness of deadening material is prohibitive, although relatively thin layers produce an appreciable reduction in the intensity of sound transmitted. It is further shown that for complex walls, let us say alternate layers of iron and felt, the simple law that succeeding layers absorb the same proportion of the sound transmitted to them, does not hold and that the transmission of such a complex wall bears no simple relation to that of its separate constituents.

Finally, as in a number of other instances, the preliminary study of the problem revealed that the complete solution demanded a great deal more than its original scope had anticipated. At the end of the paper, the author characteristically says, "At this point, the apparatus was improved, the method recast and the investigation begun anew."

The war prevented the immediate accomplishment of this purpose and not until the autumn of 1918 was it possible to attempt again its realization. In the interval, the new laboratory, to be fully described in a succeeding article, had been built at Riverbank, Geneva, Illinois. Within a month of the signing of the armistice, which freed him in a measure from the press of duty to his country, although mortally ill, he had begun the heavy task of calibrating instruments for the new laboratory.

Without this latest work, done within a month of the time of his death, the continuation of his work by others would have been almost impossible.

This sketch of his scientific work can not be closed more fittingly than by quoting from the records of the Faculty of Harvard University:

"He attacked a problem as old as the institution of public buildings. It had never been solved before in any thorough going manner. He did solve it, and he did this not by virtue of any extraordinary resources of modern science. He did it in such a way as to show that it might have been done by a man like him centuries before.

Was it then so easy and simple a thing to do? Did he merely happen to find the solution of a difficulty thousands of years old? No, he succeeded by reason of a combination of qualities among which were unending patience and untiring energy."[3]