CHAPTER

5

The 1920s
The Paul Sabines Get Involved

While Paul and Hale Sabine made reputations for themselves in acoustics, one other Sabine made a mark of her own during the mid–to–late 1920s. Mabel Sabine, wife of Paul and mother of Hale, was an accomplished organist. She was also instrumental in establishing Geneva's Little School, a private institution where education was based on the philosophy of progressivism, a method of instruction that ran counter to the more common passive learning techniques of most other schools. At the Little School, learning was tied closely to doing, and teachers were encouraged to educate the whole child — to develop all the faculties, not just fill the mind with facts. As a further sign of the newness to this pedagogy, report cards were typed assessments rather than letter grades.

Founded by Mr. and Mrs. William Bangs in 1919 in the Bangs Barn, the school moved to the home of Paul Sabine on Fourth and Hamilton in 1922 where Mabel Sabine became the school's first kindergarten teacher. In 1925, the Little School expanded to offer education from kindergarten through grade eleven, which meant expansion or relocation. A building on Sixth and Fulton St. became part of the Little School scenario. In 1927, a group of citizens obtained the funding for a much-needed larger building. It was constructed on the corner of Western Ave. and South St. by the eminent Chicago architectural firm of Holabird and Roche of Chicago's Soldier Field, Palmer House, Board of Trade, and City Hall fame. In addition to the new building, classes continued at all the previous locations, including the barn. The school was also renamed, known for a while as The Adventure School and eventually, as The Geneva Country Day School.

By the 1930s, reforms in the free public school system and economic difficulties brought on by the Depression forced many parents to abandon private education. Consequently, because of declining enrollment and the corresponding drop in tuition, the Geneva Country Day School was forced to close in 1939. Mabel Sabine, remembered by former students as an outstanding and caring instructor and by Geneva residents as a concerned, involved member of the community, was not alive when the school finally closed. Ten years earlier, on September 29, 1929, she had suffered a stroke during a telephone conversation and died.

Hale Sabine had just started his senior year in the Physics Department at Harvard University when he received the news of his mother's death. A letter written at the end of the school year by Paul Sabine perhaps best sums up the situation: "Hale has done us all proud with his studies, the one regret is that his mother will not be able to attend the commencement ceremonies, although I feel she will in spirit."

Without Mabel, Paul still remained involved in community affairs, which included membership on the library board.[17] Although his personal life took precedence over his work during times of crisis or triumph, Paul Sabine continued with his acoustics research throughout the 1920s, publishing a number of articles about his findings in a wide variety of areas. In 1924, for example, he wrote "Acoustics in Auditorium Design," which appeared in the *American Architect* and the *Architectural Review.*

Interestingly, this article, when compared to contemporary papers on the same subject, lacks only the support of sophisticated instrumentation and intricate drawings and methods of data acquisition; his theories are as sound today as they were when he wrote them. This publication was perhaps one of his first technical articles where he made use of subtle humor while he emphasized what not to do in auditorium acoustics:

> The auditorium architect has two courses, he may either ignore acoustics in his original design whereby if there are any problems after completion then they could be solved by absorptive treatment. The architect's second course is to consider acoustics in the design right from the beginning.

The result of the first course, he goes on to say, can be an acoustic horror, and the second can produce an architectural monstrosity. He adds that, generally speaking, rooms are usually acoustically good, not so much because they possess positive virtues but because they lack defects. The designer's problem then, as far as acoustics is concerned, becomes largely a matter of what to avoid. The aim of this article, as much as anything, was to point out, in as practical a way as possible, these acoustic "thou shalt nots."

What makes Paul Sabine's "Acoustics in Auditorium Design" interesting is his use of photographs of sound waves to demonstrate problems that he classified under two general headings. He defines that on the first page: "those arising from the concentration of sound reflected from extended concave surfaces and those arising from excessive reverberation." Indeed, because of recent acoustical catastrophes in auditoriums, perhaps Paul Sabine's 1924 article on auditoriums should be a reading must. If some consultants were to read Paul's list of "thou shalt nots," fewer acoustically disastrous auditoriums might be constructed in the future.

In May 1926 Sabine wrote an article on architectural acoustics entitled "Sound Insulation by Double Partitions." Once again, he went into detail about sound insulation and the sound-reduction factor referred to today as the sound transmission loss. What makes this paper noteworthy is that the derivation of the formulas is figured in terms of sound intensity, which is considered a new and relevant issue today. The article included the following paragraph on page 131, which refers to a psychological view of sound intensity and sound reduction:

> Investigations by experimental psychologists have shown that the sensation of loudness produced by a sound is roughly proportional to the logarithm of the physical intensity of the sound, so that the average value of the logarithm of the reduction factor makes a very good numerical expression for the sound insulating properties of partitions as judged by the ear.

In current parlance, this statement means that sound intensity is roughly proportional to the sound pressure squared, or more precisely, sound intensity is equal to the square of the sound pressure divided by the product of the density of the material (in this case, air) times the velocity of sound (in air).

Other topics covered in the 1926 paper were acoustic insulation by solid partitions, bridged and unbridged double partitions, the effect of filling the airspace, and a comparison of double-wall and single-wall partitions. An interesting side issue about this particular article was that Sabine wrote it for *The Armour Engineer,* which indicates that he was in contact with someone associated with the Armour Institute of Technology, now the Illinois Institute of Technology (IIT). Of course, the IIT Research Institute (IITRI) predecessor, the Armour Research Foundation (ARF), was not established until 1936. The article indicates a relationship between Paul Sabine and IIT that can be traced back to the 1920s.

The article on single- and double-partition walls was followed by "Transmission and Absorption of Sound by Wood Stud Partitions," which appeared in the August 5, 1926, issue of the *American Architect.* In this piece, Sabine writes:

> An examination of the literature of the subject of the transmission of sound by walls of different types and materials discloses a wide divergence in the findings of different investigators working in this field. These differences may be ascribed in the main,
>
> 1. to the intrinsic difficulties of sound intensity measurements,
> 2. to failure on the part of investigators to recognize all the factors that enter into the transmission of acoustic energy and a consequent failure to control all of these factors, and
> 3. to important differences in test conditions and methods of measurement.

> In the seven years that have been devoted to this problem at Riverbank Laboratories, the plan has been to carry on a systematic and ordered program of research to determine the factors that really control the transmission of sound from room to room by way of partition walls, rather than to investigate the sound insulating merits of the many possible constructions and materials that can be used. It is hoped that by employing a single method under conditions that are maintained constant throughout the entire program, the whole series of investigations will in the end present a consistent picture of the essential facts, from which conclusions of general significance may be drawn.

The results of Paul Sabine's early work at Riverbank Acoustical Laboratories were far more accurate than those of a similar investigation conducted at the National Bureau of Standards (NBS). By comparing technique, methodology, and overall conclusions, Paul essentially tore apart the bureau's findings. Despite the disagreement in the years that followed, Riverbank and the NBS worked together on many acoustical investigations, and the rapport between the two organizations was and is good. In 1988, the NBS name was changed to the National Institute of Standards and Technology (NIST). Today, Riverbank falls under the auspices of the NIST National Voluntary Laboratory Accreditation Program (NVLAP) of the U.S. Department of Commerce. Undoubtedly, the early cooperation between Riverbank and the NBS was a shining example in establishing a standard method of sound measurements for laboratories. In 1929, documented acoustic results initiated by Paul Sabine and V. L. Chrisler of NBS were most likely the first such reference to acoustical standards.

Perhaps one of the more controversial issues involving sound absorption which still exists today is how can you have absorption coefficients, or noise-reduction coefficient (NRC) values greater than 1.0 or, as some would say, coefficients greater than 100 percent.

The confusion started when certain writers, in trying to explain absorption, modified the definition of the sabin unit. The original definition was that a sabin is equal to 1 ft^2 of an open window. Later, because of arguments associated with possible reflections off the inside window frame (depth) portion, "open window" was replaced with "perfect absorber." Then, in some writings, the phrase "perfect absorber" was erroneously replaced with "100 percent absorption." Often, these writers used examples such as an NRC of 0.65 means 65 percent absorption. Unfortunately, this example is incorrect. Neither the absorption coefficients or the NRC are percentages.

From the American Society for Testing and Materials (ASTM) standard, the unit of absorption, sabin, (A), is derived as follows:

$$A = 0.9210\,(V)(d)/(c)\ , \tag{1}$$

where

A = absorption, measured in units of sabin.

0.9210 = room decay constant.

V = room volume (ft^3).
d = N/T.
N = decibel (dB) decay measured.
T = the time in seconds, accurate to hundreths of a second it takes the sound to decay N dB.
c = speed of sound = $[49.022(459.67 + \text{temperature F})^{1/2}]$ (ft/sec).

Because the reverberation time is defined as the time it takes sound to decay 60 dB, N becomes 60, and T is rewritten as T_{60}.

Thus, equation (1) becomes

$$A = 0.9210\,(V)(60)/(c)(T_{60})\ . \tag{2}$$

Then, after the temperature is recorded, four quantities (0.9210, V, 60, and c) are entered as constants and designated in the next ASTM formula as (K). Thus, the only variable is the time in seconds it takes for the sound to decay 60 dB. The ASTM C423 shows the formula as follows:

$$\mathrm{A} = \mathrm{K}/\mathrm{T}_{60}\ . \tag{3}$$

where

$$K = .9210\,(\mathrm{V})\,(60)/c\ . \tag{4}$$

At Riverbank, $V = 10311$ ft^3, and the room temperature is held at 72 degrees; so $c = 1130$ ft/sec.

Thus

$$K = .9210\,(10311)\,(60)/1130 = 504.2\ . \tag{5}$$

$$A = 504.2/\,\mathrm{T}_{60}\ . \tag{6}$$

The latter formula is then used to determine the absorption at each of the 1/3-octave band test frequencies.

The *absorption coefficient* is defined as the difference between the room absorption with and without a specimen divided by the area of the specimen. The ASTM formula is as follows:

$$\text{Absorption coefficient} = \mathrm{A2} - \mathrm{A1} / \mathrm{S}\ . \tag{7}$$

where

A is the unit of absorption, measured in sabins, derived from equation (3).
A_2 = room absorption in sabins with the specimen in the room.
A_1 = room absorption in sabins without the specimen in the room.
S = the area of the specimen (ft^2).

The noise reduction coefficient (NRC) is calculated as follows: Sum the absorption coefficients obtained at 250, 500, 1000, and 2000 Hertz (Hz) and divide by 4 (average). That's it.

Nowhere in any of these formulas are there any percentage terms or units. Both the NRC and absorption coefficients are not percentages, and values greater than one are possible.

Factors that come into play when an absorption coefficient or NRC of greater than 1.0 is obtained are: shape, size, and edge effects.

Specimen Shape: Odd-shaped specimens create additional absorption as a result of interactions between them. For example, absorption coefficients are meaningless when testing theater seats. The absorption of theater seats or hanging absorbers is expressed as sabins per unit rather than sabins per area.

Large Specimen Size: If a specimen is large relative to the test room, increased absorption can be observed. If the specimen takes up too much space, diffusivity is decreased, and depending on the location or the closeness of the microphone to the absorption material, higher absorption can occur.

Diffraction-bending Wave Dffects: Certain-sized or certain-shaped specimens can cause the sound waves to bend. The energy in the sound wave expended in diffraction is measured as increased absorption.

Edge Effects: Edges can induce bending wave effects if the edges represent a relatively wide absorptive surface in relationship to the total absorptive surface of the specimen.

Additional Explanations: The one explanation regarding NRCs greater than one that appears to achieve the highest degree of comprehension among clients is when the relationship of thickness is projected into the following question: What would you expect to see if originally you tested a 4-inch-thick layer of absorptive material and achieved an NRC of 1.0 and then added another layer of 4-inch-thick material? Surely you would expect to achieve more absorption rather than limiting the NRC to 1.0.

Paul Sabine and V. L. Chrisler had to come up with a test procedure that would give both laboratories similar results. At the time, the only absorptive material readily available was one-inch thick John's Manville hair felt. Both labs had similarly sized rooms and both scientists came up with comparable results. Although Paul Sabine originally stated that a specimen eight feet by eight feet (64 ft^2) would be sufficient, both scientists later agreed to change the size to eight feet by nine feet (72 ft^2) because the size of 1-inch-thick hair felt yielded a coefficient of 0.50, which would normalize on a graph perfectly. Accordingly, they sized the specimen to provide data that would center on a graph from 0 to 100. Neither scientist anticipated that in the future, 4- to 6-inch-thick material would be common and that, on occasion, specimens as large as 18-inches-thick or more would be tested. Thus, about twenty years later, when thicker materials were introduced, the normalized graph was breached, and the problem of coefficients greater than unity surfaced. Nonetheless, all coefficients are technically acceptable as long as you do not think in percentage terms.

As a famous radio commentator says, "Now you know the rest of the story!"

In 1926, Paul Sabine became the acoustical consultant for the Fox-Case Corporation, assigned to work on the design of the first sound motion picture studios in New York and the first Hollywood sound stage. In 1928, he presented to the Society of Motion Picture Engineers a paper entitled "The Acoustics of Sound Recording Rooms." He discussed the idea of making sound recordings in a studio and then synchronizing them with the visual images later rather than relying on the quality of an on-location recording. After explaining how much easier it is to produce quality sound recordings in a studio under controlled conditions, Sabine went on to say,

> In listening to a stage production, the audience hears the voices of the actors as they are modified by the acoustic conditions of an actual stage. What is the best means of securing this illusion in the case of the talking moving picture? Is it to make a record that is entirely free from "room effects," and then put in the room effects by reproduction upon a stage that will introduce them, or will it be better practice to record under conditions that will include the "room effects" in the sound record? Only trial can answer this question, but once answered, I think it is safe to say that our knowledge of acoustics is at a point where the desired conditions for recording, whatever they may be, can be secured without further experimentation.

In 1929, Paul wrote three articles: "The Measurement of Sound Absorption Coefficients," which appeared in the March 1929 issue of the *Journal of the Franklin Institute;* "Architectural Acoustics — Sound Absorption Coefficients of Materials," which appeared in the *American Architect,* June 5, 1929; and "Transmission, Reflection, Reverberation, and Absorption of Sound," printed in the *International Critical Tables,* Volume VI, 1929. These articles indicate that the state-of-the-art acoustic absorptive testing and documentation of manufacturers' products data were advanced in 1929, and the Acoustical Materials Association,[18] helped publicize the existence of absorptive data.

These three articles alluded to absorption data of thirty-nine specimens, listed as follows:

1. Acousti-Celotex type A, a 13/16-inch-thick perforated fiberboard, plain side exposed
2. Acousti-Celotex type B, same as Type A but perforations exposed
3. Acousti-Celotex type BB, 1-15/16-inch-thick
4. Acousti-Celotex, originally tested 1924, 1-inch-thick
5. Akoustolith tile, 7/8-inch-thick fine texture cemented to clay tile
6. Balsam wool, 1-inch-thick soft wool fiber, paper backing, scrim facing
7. Balsam wool, same as #6 but with a perforated metal cover
8. Standard Celotex, 7/16-inch-thick on wood furring
9. Standard Celotex, same as #8 but on 2 x 4 studs
10. Draperies, 10 ounce per square yard, cotton fabric, in contact with wall
11. Draperies, 14 ounce per square yard, cotton fabric, in contact with wall
12. Draperies, 18 ounce per square yard, velour fabric, in contact with wall
13. Draperies, same as #12 but hung 4 inches from wall
14. Draperies, same as #12 but hung eighteen inches from wall
15. Cotton fabric, 14 ounce per square yard draped to 7/8 of its area
16. Cotton fabric, same as #15 but draped to 3/4 of its area

17. Cotton fabric, same as #15 but draped to 1/2 of its area
18. Felt, standard, 1-inch-thick all hair
19. Felt, Asbestos-Akoustikos (hair and asbestos fiber), 1/2-inch-thick
20. Felt, same as #19 but 3/4-inch-thick
21. Felt, same as #19 but 1-inch-thick
22. Felt, same as #19 but 1-1/2-inch-thick
23. Felt, same as #19 but 2-inch-thick
24. Felt, same as #19 but 3-inch-thick
25. Flax-Linum semistiff flax fiberboard, 1/2-inch-thick
26. Masonite Standard 1/2" board (pressed wood fiber) on 1-inch furring
27. Masonite, same as #26 but nailed to 2 x 4 studs
28. Masonite, same as #26 but nailed to 1 x 2 furring
29. Nashkote AAX 1-inch felt with cotton fabric, two coats of paint
30. Nashkote B-332 1-inch felt with perforated oil cloth
31. Plaster gypsum on wood lath on wood studs, rough finish
32. Plaster, same as #31 but lime putty and smooth finish
33. Plaster, lime on wood lath on wood studs, rough finish
34. Plaster, same as #33 but smooth finish
35. Plaster "Calacoustic" 1/2-inch-thick
36. Plaster Sabinite, 1/2-inch-thick
37. Stockade slab, 1-inch-thick wood fiber cemented with magnesite
38. Stockade slab, same as #37 but 2-inch-thick
39. Plaster Sabinite (1929 version)

Realizing the significance of two of his three papers, Paul Sabine applied for copyrights in 1929 through the law firm of Parkinson & Lane. Perhaps it was the copyrights themselves that restricted the circulation of these articles and limited Paul Sabine's opportunities for widespread national recognition.

In almost all the articles written by Paul Sabine, especially those published in the 1920s, the work of Wallace Clement Sabine was invariably cited, as was that of the professor's Harvard associate, John Connors. This generous attribution, although noble and notable, might have worked against Paul Sabine in achieving national recognition for the research he conducted. In essence, he presented most of his own contributions as follow-up or as secondary to what had been achieved earlier by Wallace Sabine.

Both Sabines — Wallace and Paul — shunned publicity and, in certain cases, avoided opportunities that might have brought them fame. For example, Paul Sabine's work in the motion picture industry, had he continued, would certainly have kept him in a position of high visibility and earned him accolades. One reason for his abandoning efforts in the field might have been his religious convictions and their bearing on his life. Because the motion picture industry at the time was not a regulated industry — the Hays office and the strict rules it imposed regarding the morality of films were still in the future — Paul Sabine, given his beliefs, might have chosen to separate himself from it. In addition Paul Sabine was an academician, a scientist whose research was meant to advance science itself and not the scientist.

In December 1928, approximately forty individuals, invited by letter, gathered at the Bell Laboratories in New York with the hopes of forming an acoustical society. Although he was sent an invitation, Paul Sabine did not attend the conference. At this meeting, a decision was made to form the Acoustical Society of America. A temporary set of four officers was nominated, which, as it turned out, were the same individuals officially nominated in May 1929: H. Fletcher, V. O. Knudsen, W. Waterfall and C. F. Stoddard. These four officers, along with D. C. Miller, J. P. Maxfield, F. A. Saunders, R. V. Parsons, F. K. Richtmeyer, and F. R. Watson, were appointed to draft a constitution and bylaws.

In 1929, the Acoustical Society of America (ASA) was formed.[19] The first open meeting was held in May of that year in New York City. It was a joint session with the motion picture industry, attended by 168 members and held in the auditorium of the Bell Telephone Laboratories. The first paper given on May 10 at the society's portion of the session was a thirty-minute presentation by Paul E. Sabine entitled "The Measurement of Sound Absorption Coefficients by the Reverberation Method," followed by a paper dealing with absorption coefficients given by Vern O. Knudsen. Also on the program was V. L. Chrisler of the NBS.

The ASA conducted its first election of officers as follows:

Officers
President: Harvey Fletcher, Bell Telephone Laboratories, Inc.
Vice-President: Vern O. Knudsen, University of California at Los Angeles
Secretary: Wallace Waterfall, The Celotex Company
Treasurer: Charles Fuller Stoddard, American Piano Company

Executive Council
Paul E. Sabine, Riverbank Laboratories
G. R. Anderson, University of Toronto
J. P. Maxfield, Electrical Research Products, Inc.
Dayton C. Miller, Case School of Applied Science
C. W. Hewlett, General Electric Company
F. R. Watson, University of Illinois

Publication Committee *(later called the Editorial Board)*
Wallace Waterfall, Chairman
Paul E. Sabine
F. R. Watson
Charles Fuller Stoddard

The first honorary member of the ASA was Thomas Alva Edison, who was unanimously nominated by the executive council. Edison graciously accepted in writing from his Florida residence.

The first official ASA constitution and bylaws were adopted May 10, 1929. In addition to the business of the organization's formation, talks were given at the meeting on such topics as description and demonstration of artificial larynx, the hearing of speech in auditoriums, acoustic properties of the Salt Lake Tabernacle, and the science of musical sounds. On May 11, six papers were presented on speech as well as papers on a spark chronograph, piano playing as used in making Ampico records, a new just scale (with a proof that an additional just scale is impossible), human factor in piano-tone production, methods for measuring the noise audiogram, and psychological measurements of annoyance as related to pitch and loudness.

The ASA's second scheduled meeting was held in Chicago in Lincoln Hall at the Northwestern University School of Law on McKinlock Campus on December 13 and 14, 1929. Attendance at the meeting was low, primarily because of two events that had occurred earlier in the year: the stock market crash and the St. Valentine's Day Massacre. Both gave members second thoughts about attending any meeting in Al Capone's backyard.[20]

The year 1929 also marked Paul Sabine's tenth year at Riverbank and the end of a significant decade in the advancement of architectural acoustics. Because of Sabine's efforts in establishing a standardized testing technique for sound absorption and because of the data repeatability obtained in the experiments he directed, findings could finally be documented and circulated with a great deal of confidence in their validity. He had, in essence, helped make a science of architectural acoustics.