CHAPTER

4

The Right Scientist for the Job

Although Paul Sabine's initial reaction his first day at Riverbank is not known, it stands to reason that, he would have been anxious to see the unique sound test chamber (reverberation room) designed by and named after his cousin. No doubt, too, Fabyan took great delight in showing him the chamber, which, thanks to the manpower, raw materials (the stone came from a Riverbank quarry), and engineering skills (Bert Eisenhour was in charge) available to the colonel, only cost about $100,000 to build.[11]

By today's standards, the test chamber is still considered one of the best of its kind. Its walls consist of bricks, concrete, sand, mortar, and spring steel. Each of the eighteen-inch-thick walls of the inner and outer rooms contains a fire-hardened brick core, which is, basically, two double layers of interwoven bricks combined with a meshing of sand, spring steel, and poured concrete. The core is covered on both sides with dense concrete followed by a very dense multilayered plaster that was painted on the inside surface of the test room. The chamber was designed in such a way that the highly reverberant walls, floor, and ceiling would resist any force from an external (outside) source, avoiding internal structural vibrations. The room effectively restricts being excited at audible frequencies other than those introduced internally into it.

The inner room is separated from the outer room wall by an eighteen-inch airspace and sits on jacklike supports that are seated on a special blend of sand and gravel, which, in turn, covers a bed of loose stones. The outer wall extends deeper into the ground, and both of these rooms are constructed within, and totally isolated from, the confines of the larger main building. The inside test-room volume is 10,311 cubic feet. The size indicates the considerable amount of work and material incorporated not only into the inner test room but also the larger second (exterior sound shield) room and the main building, giving rise to the nickname Fort Riverbank.

It is often asked whether Wallace Sabine ever had a chance to conduct a test in his Riverbank test chamber? The answer is yes. A logbook (now in the Riverbank Museum) includes notations regarding test results of sound absorption of hair felt.

What had puzzled researchers for years is that the data in Wallace Sabine's logbook and the three sets of data found in Paul Sabine's test chamber qualification files presented a mystery. Paul labeled the three sets of data as 1. Old room data. 2. New room data. 3. Jefferson Laboratory data. The researchers were able to establish that the new room data was obtained in the existing Riverbank main test chamber and the Jefferson laboratory data was obtained in Sabine's Harvard constant temperature room. The researchers were also able to show that both Wallace's and Paul's data were in agreement. It was the old room data that the researchers could not duplicate or recognize and thereby a mystery was created. Many researchers thought that the old room data was obtained in either one of the two Riverbank side chambers that adjoin the main test chamber or it was the main test chamber before the fixed diffusors and rotating vanes were installed. However, follow up tests in the two side chambers and in the main test chamber without the fixed diffusors and rotating vanes proved that there was no data agreement with Paul's old room data. The latter data indicating increased absorption of the empty room condition at two test frequencies. Additional "old room" data was found in other Paul Sabine files and one set was identified as Sabine's old room data. The latter also indicating the empty room, high absorption results at the same two test frequencies.

Finally around 1992 the mystery was solved. While browsing through some material stored at the Kane County Fabyan villa museum, I came across a drawing of the colonel's scientific barn that has long since been torn down. On the drawing in the southwest corner of the scientific barn there was a room designated as "W. C. Sabine, Sound Test Chamber, all hard wood." Underneath that line was the words "Old Room" pencilled in. Apparently, Wallace Sabine had an all hardwood reverberation room constructed at Riverbank before the existing test chamber was built. As it turned out, both Wallace and Paul recognized that the all hardwood reverberation room had unwanted resonances at two test frequencies and therefore was not acceptable to their research needs.

Paul Sabine was forty years old when he came to Riverbank in January 1919. Many modern-day acousticians believe, perhaps because of the student-teacher relationship Paul had with Wallace Sabine, that Paul must have been in his twenties and, in essence, just beginning his scientific career when he went to work for Colonel Fabyan. This was not the case.

Paul Earls Sabine was born in Albion, Illinois, on January 22, 1879. He graduated from McKendree College in Lebanon, Illinois, in 1898 and received his Bachelor of Arts from Harvard University in 1903. On December

27, 1906, he married Mabel Johnson of Newton, Illinois, the daughter of lawyer Hale Johnson. From 1906 to 1912, Paul Sabine was an instructor at the Worcester Academy in Massachusetts. His first son, Hale Johnson Sabine, was born October 23, 1909, in Worcester.

Paul returned to Harvard in 1912 and, while serving as an assistant instructor, took graduate courses in pursuit of a Ph.D. Most of his courses were offered in the Graduate School of Applied Science, the dean of which was his cousin Wallace. Hale Sabine recalled asking his father if he ever took a course by, or worked on any projects with, Wallace. His father replied that although he never took a course offered by Wallace, on occasion, he was able to sit in on some lectures and also assist with a few experiments.

In 1915, Paul received his Ph.D. and remained at Harvard as an assistant instructor until 1916, when he accepted the position of assistant professor at the Case School of Applied Science in Cleveland, Ohio. On February 17, 1916, Richard *Wallace* Sabine, the Paul Sabines second son was born.

During World War I, Paul Sabine took a civilian position with the United States Navy in Washington, D.C., where his principal work involved the calibration of a wind tunnel for experimental studies centered on airfoils and airplanes. The development of the NC-3 and NC-4 flying boats, the latter used by naval aviators to make the first successful transatlantic flights, was owed in part to the scientific findings of Paul Sabine.

While Paul was working on the navy project, Wallace Sabine was also in Washington — as director of the Department of Technical Information in the Bureau of Aircraft Production. One task of this department was to cooperate closely with the Naval Aviation Department and exchange technical information. Given the connection, there is no doubt that Wallace and Paul Sabine conversed on various matters associated with their respective positions; families; and, perhaps, Riverbank. Wallace Sabine might even have asked his cousin if he were interested in running the operation for Colonel Fabyan.

This conjecture is not that far fetched because had Wallace Sabine lived, chances are he would not have made Geneva, Illinois, or Riverbank Laboratories his permanent residence. Besides his commitment to Harvard, he had a strong attachment to the Boston area. His wife, Dr. Jane Kelly Sabine, was a physician with a thriving practice; their two daughters were involved in their schooling; and Wallace's mother, Mrs. Hylas Sabine, was still alive and very much a part of the professor's life. When Professor Sabine completed a similar research facility for the Johns Manville Corporation and was offered the directorship, he declined, suggesting a former student, Clifford Swan, be hired to fill the position.

If Wallace Sabine were reluctant to leave Boston and the family ties there, whose name would he have given to Colonel Fabyan as his choice to run the new lab? John Connors, the professor's assistant at Harvard, any other assistant or student, or perhaps Riverbank engineer Bert Eisenhour could all have been put forth as likely candidates. Contrary to the Sabine historian Leo Beranek's opinion that either an assistant or a student was more likely, however, I believe that Wallace Sabine's candidate would have been Paul Sabine.

Unlike his cousin, at the end of World War I, Paul Sabine was not bound to any institution. Although he was still working for the navy, his duty was to end soon. He could have returned to the Case School of Applied Science, but no evidence suggests that this was his plan. Given his uncommitted status and his presumed knowledge of Riverbank, I believe that Wallace's conversations with Paul during the war years would have addressed the laboratory facilities and the family connections in Illinois, which would have contributed to Paul being the man Wallace Sabine would suggest to oversee the lab.

If the two men did discuss Riverbank and their respective futures there, the ease with which Paul Sabine assumed his duties at the facility might in part, be explained. Under similar circumstances, many individuals would have required a much longer breaking-in period than did Paul Sabine. In 1984, a copy of his first report to Colonel Fabyan was discovered. The date on the report was April 1919, only two months after Paul Sabine arrived at Riverbank; it contained significant information pertaining to the research program he initiated.

Much of the research relied on the Wallace Sabine formula for measuring sound absorption. Briefly stated, the modified Wallace Sabine formula used today measures the time it takes sounds at different test frequencies to decay 60 decibels (dB) when all the other variables in the testing room — volume, temperature, speed of sound, etcetera — are constant. The amount of time it takes for the sound to decay 60 dB (for example, from 100 dB to 40 dB) is called the *reverberation time.*

In a typical experiment, a sound source is turned on. After a stabilized sound level is obtained, the sound source is turned off. The time it takes for the sound to decay in the test room 60 dB is recorded. A highly reverberant room is preferred because it provides a longer period of time for the sound to decay, which, in turn, provides for more accurate overall time measurements. Typically, in an empty reverberation room, the reverberation time for low frequencies is longer than it is for high frequencies. In the Riverbank test chamber, the low frequency of 100 hertz (Hz) (the sound of a transformer hum or a fog horn) takes almost 7 seconds, and the high frequency of 5000 Hz (the sound of a whistling tea pot or a navy boatswain's pipe) takes approximately 3 seconds.

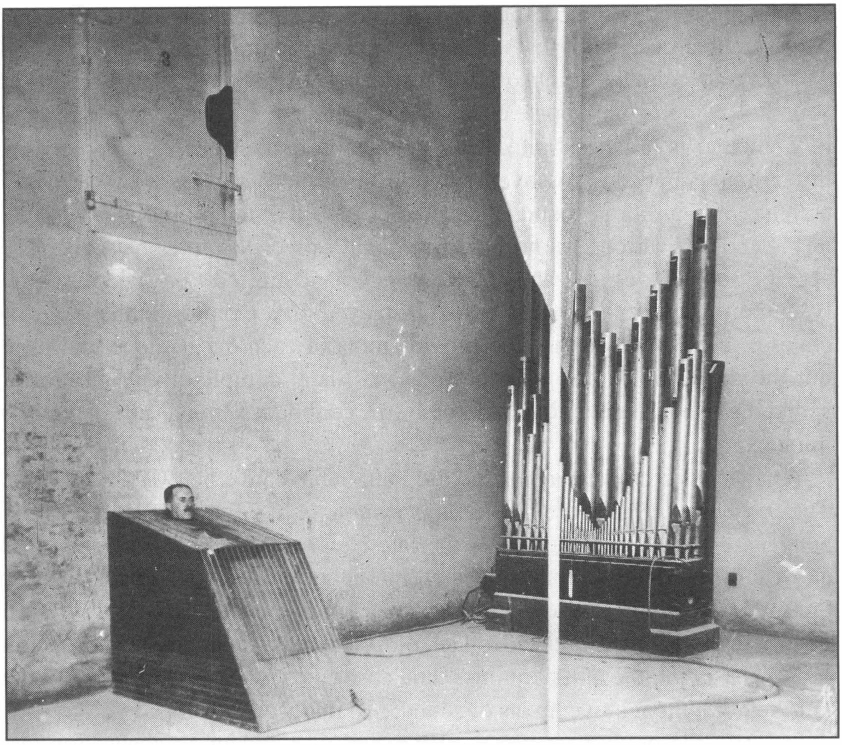
Basically, to determine the absorption of a test specimen, one measures the reverberation time of the empty room at the prescribed test frequencies and then repeats the measurements with the specimen installed in the room. The ratio of the reverberation times is inserted into the appropriate formula. The absorption of the specimen is determined at each test frequency in units of sabins. From there one can determine the absorption coefficients and calculate the noise reduction coefficient of the test specimen. This value serves as a one-number designator that ranks the various specimens.

Today, to conduct an absorption test at Riverbank, a shaped broadband sound of white or pink noise consisting of all the test frequencies controlled by computer is broadcast into the designated test chamber. After proceeding through an equalizer, crossover networks, amplifiers, and an array of speakers, the input airborne sound is detected by sensitive microphones, which, in turn, send the various sound levels through a precision filter network. The specific sound levels of each test frequency band are fed to a spectrum analyzer, compiled by the computer and displayed on a monitor. If the tester so chooses, the computer can also provide plots of each decay slope and print out the decay times and all other required data, complete with the corresponding standard deviation and combined confidence limits, in a matter of minutes.

What acoustical instrumentation did Paul Sabine have in 1919? Very little. The September 1923 issue of *Scientific American* highlighted Riverbank and emphasized radio engineering as the latest craze. Battery, transformer, and electron-tube advertisements appeared throughout. One article disclosed that the cathode ray oscillograph was just being considered for laboratory use. In other words, there was a decided lack of reliable instrumentation available in 1923. The *sabin,* the unit defining sound absorption, and the *decibel* (dB), the unit, relating the relative levels of sound, had not been developed yet.

In 1919, the equipment used at Riverbank to conduct an absorption test consisted of a rank of organ pipes. The test frequencies were individual musical notes generated by the organ. The measuring device was a listener sitting in a wooden box with only his head protruding through an opening at the top, similar to a person sitting inside a steam box. The listener's ears were the microphone. The range of decay was determined from the instant the listener stopped the relay-controlled organ note at the prescribed test frequency until the listener could no longer hear the diminishing sound of the note. The listener timed the sound-decay limit of audibility with a chronometer or stopwatch his only instrumentation, and recorded the time using a pencil and pad, his data-acquisition equipment. There was a small observation window on top of the box so that the observer could see the notepad and the timing device.

In a 1930 article on the history of architectural acoustics, Paul Sabine wrote that in 1925, the "man-in-the-box" test was still the most reliable method used by the various laboratories. The listener sat inside a reflective wooden box so that he remained in a fixed location for all tests, ensuring that the sound absorption or reflection by his body and clothing did not affect the results of the test. These restrictions and the crudeness of the measurements made the information in the following report, Paul Sabine's first, all the more interesting and remarkable.



Conducting an Absorption Test.

RIVERBANK LABORATORY OF ACOUSTICS.

Report for April, 1919.

The first stage in the general problem is the calibration of the Sound Chamber for notes of the various pitches used. This consists in finding the absorption of the room for these tones. The rate of emission of the pipes must be known for this purpose. This latter can be determined in the first instance only by doing the four organ pipe experiment in a room. In the present case, the pipes to be used have been timed in the large lecture room of the Jefferson Physical Laboratory, where Professor Sabine did the four organ pipe experiment in 1906. Two sets of C pipes had been thus timed. The Austin pipes, #1 at 5 1/4" pressure had been timed by Professor Sabine and John Connors. For this reason these pipes were chosen for the calibration of the Sound Chamber rather than the Laws pipes, which had been timed only by John Connors. The mean of the three sets of observations together with the known absorption of the Lecture room with the settees, was used for the determination of the rates of Emission of the pipes. From this, together with the measured duration of the residual sound, the absorption,

> and finally the absolute rate of decay of sound in the Sound Chamber can be determined for each of the seven C pipes. From this, a curve can be drawn giving the absorption for intermediate tones. Knowing the absorption for any frequency, the rate of Emission of any pipe of that frequency can be determined by determining the period of the residual sound produced by the given pipe.
>
> The work for April has been:
>
> 1. The training of observers.
> 2. The determination of the period of the residual sound for each of the seven Austin pipes.
>
> Trials by a number of observers showed that considerable practice is required before the observations of a novice are reliable. This is particularly true in this Sound Chamber where the rate of decay is small, making the instant when the decaying sound crosses the line of minimum audibility hard to determine with precision. As a result, most of the observations have been taken by Mr. Eisenhour and myself.
>
> The period of residual sound has been found to depend in a marked degree upon the position of the reflectors and also that of the observer. Therefore, for the work of calibrating the room, considerable pains have been taken to insure getting enough observations to make the average reliable with a high degree of precision. Five hundred independent timings of each pipe with the observer in a single position have been made. In addition, to allow for variation in time with position of observer, fifty observations, using each of the seven pipes in each of eight different positions in the room have been made. The completion of this part of the work will call for four more positions. In this way the final time taken for the residual sound from each pipe will be the mean of 1100 observations. This may seem excessive, but when one considers the number of variable factors, and the extremely fundamental character of this work for all measurements that are to follow, extreme care justifies itself. When completed, data will be available for the determination, with a relatively small number of observations of the absorption of any material brought into the room, the rate of emission of any pipe sounded in the room, and the transmission of wall surface that replaced any portion of the present wall.

It is incredible to imagine listening to and timing the decay of the same note 1,100 times and then proceeding to the next note. Shortly after these initial experiments, Sabine conducted a linearity calibration on all seventy-three notes of the organ. If he maintained the same precision requirements, it meant that some duty-bound individual(s) sat in the box and timed 80,300 notes. Then, to calibrate a room accurately, the same individual would have had to repeat the observations at another time to determine repeatability and then periodically do them again to show that none of the room's qualities had changed. Because Paul Sabine, in the tradition of a true scientist, calibrated the room often, it is indeed a wonder that the employee turnover rate among those assigned to sit in the box and listen was negligible.

In his next report to Colonel Fabyan, Sabine outlined his plans for the month of May:

PROGRAM FOR MAY, 1919.

1. Continue time of residual sound of 7 C-pipes of Austin #1 set in bare room with all doors closed, observer in different positions.
2. Determine the time of residual sound with observer's position fixed and the organ in each of five different positions.
3. Determine the time of residual sound from the set of Laws' pipes. Five sets in each of different positions.
4. Determine the time of residual sound from the pipes of the small portable set. Five sets in each of five different positions.
5. Begin the study of the fine wire sound detector.

Tasks 1 through 4 were for laboratory calibration, and from Sabine's outline, it is apparent that he settled on seven specific notes for calibration. Task 5 on sound-level meters addresses the first acoustical research project planned by Paul Sabine at Riverbank. Three sound-level meters were developed during this project and proved to be extremely sensitive and operated uniformly to sound pressure. These three meters are now located in the Riverbank museum; printed on the face of each are the words *"Riverbank Sound Meter."*

It is not clear what degree of influence Colonel Fabyan had on Paul Sabine and the type of acoustical activities that took place at the laboratory, but it appears that in the beginning, Paul Sabine had something of a free hand. Although records indicate that he and the colonel did not always see eye to eye on every issue, as long as Sabine was advancing the science of acoustics, not just architectural acoustics, his employer was satisfied.

Only after the stock market crash of 1929, which put a dent in the colonel's holdings, was there any indication that he insisted Riverbank conduct architectural acoustical testing to bring in additional revenue. This demand marked the beginning of the testing procedures, documentation, and standardization that are still used at Riverbank today, forever affecting the science of architectural acoustical testing.

Still uncertain is what the colonel's full intentions were in 1919 regarding Paul Sabine and the acoustics laboratory. The first letterhead contained a circle with *Riverbank Acoustical Laboratories and Geneva, Illinois,* written inside its perimeter. To the left of the circle was the title, *Faculty,* under which were listed two titles, *Dean,* followed by *Paul E. Sabine* and *Secretary,* followed by *Belle Cumming.* To the right of the circle were two addresses, one for the Geneva facility and the other for the Chicago office. It appears, then, that the colonel intended to establish a school of acoustics at Riverbank, but no actual indication other than the one letterhead exists to verify or refute this notion. Shortly thereafter, a new letterhead surfaced, listing Paul Sabine as laboratory director; all reference to faculty status was deleted.

It is difficult to say what Paul Sabine's first project or area of investigation was at Riverbank. He took a shotgun approach to his original research, simultaneously tackling various problems involving many different areas of acoustics. Besides room calibration and absorption measurements involving hair felt for measurement purposes, he continued Wallace Sabine's experiments on plastered walls. The latter work translated into the development of *sabinite,* an absorptive acoustical wall plaster.

During Paul Sabine's early laboratory work at Riverbank, he was assisted by Professor Floyd Firestone from the University of Michigan in testing the previously mentioned sound-level meters. With Dayton C. Miller, the dean of the Physics Department from the Case School, Sabine contributed to the development of a mechanical voice synthesizer. With Dr. Augustus Pohlman and Fred W. Kranz, he began his first studies on listening devices (ear trumpets). Of the many disparate tasks he undertook, it appears that the sound transmission of walls was Paul Sabine's first research effort and that his study of listening devices was his first completed project.

During that first summer, Paul Sabine also published two articles in *The American Architect.* The first article, dated July 2, 1919, was entitled "The Life Work of the Late Wallace C. Sabine: An Appreciation." The second article, published July 30, was entitled "The Wallace Clement Sabine Laboratory of Acoustics, Geneva, Ill." and began "This Laboratory was built for the research of the late Professor Wallace C. Sabine by his friend, Colonel George Fabyan." The article mentioned that the design of the Riverbank test chamber was suggested by the arrangement of the constant-temperature room in the Jefferson Physical Laboratory at Harvard.

Sabine further explained the purpose of the laboratory and discussed the sound source as a complete rank of seventy-three pipes, giving all the tones of the musical scale from C,64 vibrations a second to C,4096 vibrations per second.[12] The longest period of reverberation recorded and measured at Harvard by Wallace Sabine was 8.69 seconds at 100 Hz, compared to 12 seconds in the Riverbank chamber.[13]

Paul Sabine went on in the article to explain,

> The work in the laboratory so far has been by way of calibrating the sound chamber and the various instruments to be used in the continuation of the work. Fortunately, calibration had been carried far enough by Professor Sabine to make it possible to proceed without repeating for the new conditions experiments which he performed years ago. Two sets of pipes whose rates of emission were determined by him only a few weeks before his death are the basis of this calibration. Without this, work in the laboratory would have been delayed months, perhaps years.

He closed the article with this statement:

> The laboratory is dedicated to the task of carrying out so far as possible the research program that Professor Sabine had laid out for its altogether admirable equipment. The laboratory staff will value most highly the interest of those ar-

> chitects to whom its purpose appeals, expressed either as inquires or suggestions, regarding the practical aspects of problems in architectural acoustics with which they may be confronted.

Sabine's next article "The Absorption of Sound by Rigid Walls," appeared in the December 1920 issue of *Physical Review.* He compared the Wallace Sabine equation of absorption to the absorption theories of noted English mathematician and physicist Lord Rayleigh (1842-1919) and German physicist Gustav Kirchhoff (1824-1887), stating,

> Qualitatively, the theory of sound absorption is simple. The dissipative forces through which the sound energy is converted into heat are introduced in two ways. The yielding of reflective surface as a whole, or in large units of area under alternating pressures of the sound wave calls into play damping forces, which dissipate the sound energy.

The principle being described here is that one way sound is absorbed by means of a transfer of energy. When a sound wave enters an absorptive material, such as a mineral fiber, the pressure from the wave causes the fibers to vibrate accomplishing work. In doing work, heat is dissipated and the energy of the sound wave is exhausted. The energy transfer is from sound-pressure wave energy to mechanical vibrating energy to thermal energy.

After nine months of investigation Sabine published "Architectural Acoustics — The Transmission of Sound through Flexible Materials," a two-part article that appeared in the September 28 and October 12, 1921 issues of *The American Architect.* He followed up on the work originally published by Wallace Sabine in 1915 about the evaluation of sound transmission through various barriers. Interestingly, in comparison to the methodology of today, Sabine measured the decay rate of the source room against the decay rate of the same source but from the other side of the test barrier in the receiving room. The equation he utilized to achieve his results was

$$\log I_s/I_r = .126\, a\, (t_s - t_r)$$

where I_s = Intensity source chamber
I_r = Intensity receiving chamber
a = absorption source chamber
t_s = duration of audible sound heard in the sound chamber
t_r = duration of audible sound heard in the receiving chamber

The ratio $\log I_s/I_r$ called the *sound intensity reduction* by Paul Sabine was changed to *transmission loss* in 1930 at the suggestion of professor Vern Knudsen of University of California at Los Angeles. Knudsen felt it would avoid confusion because the term reduction factor was used for many other different meanings. Ironically, many acousticians today feel that the expression sound transmission loss is really an oxymoron and that it should be replaced by *sound insulation* or *sound isolation.* Also, some acousticians feel that trying to explain to concerned individuals that the greater the sound transmission loss is of a sound barrier the better it is for noise control purposes adds to the confusion in explaining the meaning of the expression sound transmission loss.

One question often asked is who were Riverbank's first transmission loss (TL) test clients. In a 1939 letter, Paul Sabine wrote that two of Riverbank's first clients for TL testing were the National Door Manufacturer's Association and United States Gypsum. In 1921, Paul Sabine was able to foresee the effects of an increasing population and the resultant increase in noise. He stated in his two-part article on sound transmission:

> The ever increasing congestion of living and working conditions of modern life, the rapid multiplication of mechanical devices, with their inevitable noise and the consequent wear and tear upon nervous and mental power, make the problem [of noise control] one of vital importance and would seem fully to justify the time and labor necessary to secure the quantitative data required for its solution.

Paul's versatility in his research was highlighted in his article entitled "The Efficiency of Some Artificial Aids to Hearing," which appeared in the November 1921 issue of *Laryngoscope*. This article marked the beginning of a twenty-year personal crusade on the study of the human ear, coming to the aid of the otologist and the hearing impaired. Once again, Paul Sabine cited the work accomplished in this area of acoustics by Wallace Sabine. As later discussion bears out, Paul Sabine reached the same pinnacle of achievement in studying the human ear as Wallace Sabine did in his study of architectural acoustics, despite the limited recognition he received for his accomplishments.

Although Paul Sabine's research in the 1920s dealt primarily with hearing trumpets, he was later instrumental in the development of the electronic hearing aid. During the early period, Sabine did research with Fred Kranz and two medical doctors, Dr. J. Gordon Wilson and Dr. A. Pohlman. Later, from 1935 to 1941, Pohlman and Kranz were still involved with hearing aids, but Kranz was also doing his own research for Bell Telephone Laboratories at the Western Electric Company near Chicago. Correspondence between Kranz and Sabine on the subject of hearing aids also attested to Sabine's knowledge and the assistance he provided his colleague.

In 1921, Sabine had this to say about ear trumpets:

> Viewed in the light of our present attainments in artificial aids to hearing, the immediate prospects for the alleviation of extreme deafness by such means are not bright. However, recent developments in telephony, notably in the use of the thermionic vacuum tube as a means of amplifying telephone currents, afford considerable grounds for hope of securing the necessary increase of intensity. The problem of securing increased amplitude without increased distortion of the wave form is one that presents many physical difficulties. It is essential to know at the same time the distortions of sound produced by the defects in the mechanism of hearing. It is obvious, therefore, that the general problem is one calling for highly specialized knowledge and skill in the fields of both otology and

> physics, and it is to be hoped that the very near future will see a combined attack upon the problem from both the physiological and physical sides.

In 1922 Paul Sabine began providing services as an acoustical consultant. His first large-scale consulting problem involved the Federal Reserve Bank Building in Boston. The work area was highly reverberant and noisy. Sabine remedied the problem and published three articles entitled "Architectural Acoustics 1, 2, & 3" and subtitled "The Nature and Reduction of Office Noises." The three articles appeared in the May 24, June 7, and June 21, 1922, issues of *The American Architect.* Photography of actual reflecting sound waves and the use of painted plaster, various absorption materials, and acoustical tiles were demonstrated. Paul Sabine also became involved with the noise contributed by typewriters, which later led to a specific project on quieting typewriters.

In 1922, another event of historic significance took place at Riverbank. A select committee, known as the National Research Council Committee on Acoustics, met and compiled a bulletin on thirteen topics in acoustics for the National Research Council. The committee consisted of G. W. Stewart, professor of physics, State University of Iowa; A. L. Foley, professor of physics, Indiana University; L. V. King, professor of physics, McGill University; D. C. Miller, professor of physics, Case School of Applied Science; P. E. Sabine, Riverbank Laboratories, Geneva, Illinois; F. R. Watson, professor of experimental physics, University of Illinois; and A. G. Webster, professor of physics, Clark University. All were physicists.

The historical significance of this meeting is that about seven years after the bulletin was printed, these same individuals were involved in the development of the Acoustical Society of America (ASA). Although the actual formation of the ASA in 1929 is credited to thirteen individuals, the previous association of these seven men has to be considered a significant forerunner to the development of the ASA.

The thirteen topics and the author(s) of each discussion, as printed in the first bulletin, were:

1. Audition, Sabine and Stewart
2. Acoustics in Navigation, King
3. Propagation of Sound in Liquids and Solids, Webster and King
4. Propagation in the Atmosphere, Foley and Webster
5. Reflection, Absorption, and Transmission at the Surface of and Within Certain Materials, Sabine and Watson
6. The Measurement of Sound Intensity in Absolute Units, Sabine and Webster
7. Detection and Measurement of Sound, Miller and Webster
8. The Efficiency of Sound Generators, Webster and King
9. Sounds of Musical Instruments and Speech, Miller

The National Research Council Committee on Acoustics.

10. Analysis and Synthesis, Miller
11. Photography of Sound Waves, Foley
12. Sound Waves of Finite Amplitude, Webster, Foley, and Stewart
13. Conical Horns, Webster and Stewart

Because Riverbank was the committee's meeting place, and because Colonel Fabyan was the official host, providing housing, meals, and whatever other services were required, when a group picture was taken of all the scientists, the tall gentleman in the center would be none other than the colonel himself.

In 1923 Paul Sabine published the article, "Transmission of Sound by Standard Masonry Partitions," which appeared in *Industrial and Engineering Chemistry Journal* (Volume 15). In that article Paul states:

> The ratio of sound intensities in two rooms separated by a given partition has been called the *reduction factor* for that partition. The logarithm of this factor is a fair measure of the relative loudness as perceived by the ear, and may be used as a numerical measure of the sound insulating merits of the partition in question. A logarithmic reduction of six would render loud conversation in an unfurnished office room inaudible in an adjoining room; one of four would render it faint and unintelligible, but still fairly audible.

From the above Sabine developed a graph that showed a theoretical relationship between the mass (pounds per square foot) and the reduction factor, commonly referred to as the *mass law.* He stated that there is a definite relationship between mass and noise reduction and ended the segment stating:

> Sound reduction and mass per square foot follow the same order regardless of material. On the other hand there is no obvious correspondence between stiffness and sound reduction and that mass rather than stiffness is the determining factor in the general reduction of sound intensity.

Today, the relationship between transmission loss and the mass (pounds per square foot or kilograms per square meter) is used by many architectural acousticians as an important guide for noise control. The relationship is commonly referred to as the *mass-law curve* or the *limp mass-law relationship.*

Paul Sabine followed this article with "Transmission of Sound by Masonry Partitions," which appeared in the July 4, 1923, issue of *The American Architect.* Although the primary discussion again dealt with massiveness and stiffness, the two articles are quite different. Most important in the second article was the discussion of the three most important factors (properties) that must be considered for good sound transmission results. Besides mass and stiffness, Paul inserted a third — damping. Many present-day technical publications discuss that the theoretical derivation of a barrier's performance is broken into three areas: (1) the stiffness region (low frequencies), (2) the mass-related region (middle frequencies), and (3) the damping and seals region (high frequencies), essentially the same areas documented by Sabine in 1923.

Also in 1923, Sabine applied for and received a patent on an absorptive plaster called sabinite. A room at Riverbank, called the Sabinite Room by Paul Sabine (but later changed to Hall B), has all its surfaces covered with this material. One wall bears the statement "Typical Modern Fireproof Construction Modified with the Resultant Reverberation as is." Hall D has the same inscription except for the word *modified,* which was deleted. In other words, one room is treated with sabinite, and the other is not.

In the September 1923 issue of *Physical Review* was an article by Sabine entitled "Acoustical Power of Certain Sound Sources in Absolute Units." With this article, Paul Sabine began his studies on sound intensity with regard to musical instruments (musical acoustics) and speech. Interestingly, the article mentions William Friedman, an accomplished violinist as well as a cryptologist, who assisted with the sound experiments. Friedman played what he referred to as his "junk fiddle" and a violoncello developed by a Cornell University professor and cited as very imperfect and sluggish. The instruments were bowed forte and maximum toned and were compared using vibrato tones and stopped string. Overtones were also investigated.

In the same article, Sabine described tests that compared loudness levels to twelve vowel sounds in speech. The male speaker was Professor Dayton C. Miller of the Case School of Applied Science, who correlated the tests to the development of a mechanical synthesizer. The female voice in these tests was a distant Sabine relation, Louise Wallace Hackney of New York.[14] A memento of this testing is still on display in the Riverbank museum. Framed and dated and signed by the speaker, Dayton Miller, is a photograph of a graphic recording of a one-second-long voice signature of Professor Miller saying FABYAN.

The same Sabine article also included information about his investigations of sound intensity. Paul's sound intensity investigations correlate with what we now refer to as our sound power tests. A sound power test is conducted on any noise-making device to determine just how loud that device is. A basic definition of sound power is the rate at which acoustical energy is radiated from a source. Sound intensity, a term often mistakenly used synonymously with sound power, is defined as the acoustical power that passes through a unit area.[15]

When Paul Sabine came to Riverbank in 1919, his son Hale, who would later become involved with Riverbank testing as a physicist, was just ten years old. By the mid–1920s, the young teenager was already participating in the events going on at his father's laboratory. Two accounts in Paul Sabine's early files refer to his son during this period. The first was in a letter to Dayton Miller in 1923 in which he mentions that Hale had the keenest sense of hearing available and was most valuable in helping Dr. Augustus Pohlman, Fred Kranz, and himself evaluate listening devices. The second account appeared in another 1923 letter to a family friend:

> Perhaps it would be wiser if I delayed penning this letter, for at the moment, I am having great difficulty in keeping presence of mind. It is the noon hour and the Riverbank bell is being struck with excessive force, or as you may say fortissimo. I fear that I have only but myself to blame, for I fully suspect that the perpetrator of this extreme effort is no other than Hale. For it was only yesterday, that while he and I observed the bell ringer going through his twice daily ritual of appearing and disappearing up the tower by holding on to the bell rope that I expounded upon, and in great length the many laws of Physics taking place. Then today when I mentioned to Hale that his mother will be a little late with the lunch, I should have been more suspect when he accepted the news most favorably, since we both are aware of how he usually regards mealtime. My immediate concern is that his mother does not arrive earlier than anticipated. Observing her son rising and falling while dangling precariously from a rope would be most injurious to her state of mind, if not her health.[16]