KLEINHANS MUSIC HALL:
A STUDY IN MODERN SOUND

by

Denise Gail Prince
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ABSTRACT

The thesis examines the acoustics of Eliel Saarinen's masterwork, Kleinhans Music Hall, in Buffalo, New York. The hall, which opened in 1940, was planned in conjunction with acoustical engineers, who served as consultants to the architect. At the time of Kleinhans' construction, the field of room acoustics was significantly advanced over its early modern beginnings. A discussion of the history of modern acoustics will be included as well as an explanation of the culture of "modern sound," which was prevalent at the time Kleinhans Music Hall was planned and constructed. By closely examining the historical records of the acoustical planners and Kleinhans management, the thesis will determine to what extent the acoustical planning of the hall was affected by a desire to emulate this sound, and will explain what the acoustical planners hoped to achieve. In addition, several scientific studies of the acoustical results of Kleinhans Music Hall will be evaluated, and recommendations for improving the acoustics of the hall will be discussed.

Chapter I INTRODUCTION

Kleinhans Music Hall opened to rave reviews with a dedicatory concert by the Buffalo Philharmonic Orchestra on October 12, 1940. The local press hailed the new hall as "one of the world's finest centers of musical culture,"[1] and praised its "sweeping simplicity of design and beautifully-appointed interior."[2] Known for its sleek, modern design and fine acoustics, Kleinhans Music Hall was a brilliant addition to the collection of early modern architectural masterworks found in Buffalo at the time, including Adler and Sullivan's Guaranty Building, and Frank Lloyd Wright's Larkin Administration Building and Darwin Martin House. The Hall was designed by an architect of international renown, Eliel Saarinen. Eero Saarinen, employed in his father's firm, was also involved in the Kleinhans Music Hall project (fig. 1).

This study will concentrate on the acoustical aspects of Kleinhans Music Hall: the acoustical plans for the hall, the resulting "sound," and the acoustical testing of the hall. My research allows for a more complete treatment of the acoustical planning of Kleinhans Music Hall than in previous scholarship. In addition to examining details of these plans, I will also demonstrate how Kleinhans fits into the culture of modern architectural acoustics as well as the culture of listening at the time of its construction. My analysis will elucidate how the consideration of sound, reverberation in particular, was planned for during the construction of a building for music. Kleinhans Music Hall is an important case study revealing how modern acoustical science influenced the treatment of surface area and volume as well as the textures of surfaces in an effort to achieve a particular sound. Kleinhans thus informs our understanding of

[1] "Kleinhans Hall, Ready Today, Hailed Among World's Finest," *Buffalo Courier-Express*, 12 October 1940.

[2] "Orchestra Has Its Rebirth in Grand New Music Hall," *Buffalo Evening News*, 14 October 1940.

how architects and acousticians in the first half of the twentieth century endeavored to create ideal aural spaces, an ideal which shifted over time. Kleinhans Music Hall was built when the trend in modern American acoustics to minimize reverberation or resonance in auditoriums had begun to reverse course. As such, Kleinhans represents the culmination of decades of acoustical experimentation and ultimate refinement.

At the time of the hall's construction, the country was still in the midst of the Great Depression, and anxiety over the military conflict in Europe added to uncertainty about the future. In a ceremony attended by one hundred people and in the pouring rain, Edward Letchworth, President of Kleinhans Music Hall Inc., laid the cornerstone of Kleinhans Music Hall on September 12, 1939. Referring to the unfinished walls, and piles of brick and stone surrounding them, Letchworth described the scene thus, "It is a picture similar to those received from war-torn Europe, pictures of destruction, desolation, death… But the picture before us typifies construction, fulfillment, life. May this symbolize the role our country is destined to play in the world and may it symbolize the saving of civilization itself from the threat of annihilation."[3] Shortly after completion of the building, Letchworth defended the allocation of precious resources toward the building of a music hall at a time when money was needed to prepare for the eventuality of war. Letchworth states, "we should not forget our duty as cultured men and women to keep alive in our midst the ideals of beauty and truth, poetry, and art and music… After all, it is such things that endure long after war and the memories of war shall have passed away."[4] The project generated one-half million hours of employment and paid more

[3] "Kleinhans Angle Stone Laid," *Buffalo Evening News*, 12 September 1939.

[4] Quoted in "Music Hall Termed a Pillar to Idealism in Era of Strife," *Buffalo Evening News*, 17 October 1940.

than $600,000 in wages.[5] In addition to fulfilling the utilitarian need of employing the unemployed during the Great Depression, the new music hall served as a symbol of hope in an anxious time.

During its construction, Kleinhans Music Hall was not unanimously praised as the gala opening reviews suggested. In an attempt to generate positive press for the new hall, Esther Link, Acting Director of Kleinhans Music Hall Inc., gave a speech on local radio station WEBR on January 12, 1939, advising those who oppose the modern design of the hall to "withhold judgment until they have had a longer acquaintance 'with this new architecture.'"[6] During its construction, underwhelmed citizens suggested the building might be used for grain storage or a bus terminal, while others thought it bore a resemblance to a lake freighter.[7] It is possible that they were reacting to the simplicity of the exterior's curved brick and stone walls, which faithfully reflect the contours of the music chambers within (fig. 2). Yet those attending concerts in its first season found the hall very comfortable and the aesthetic visually appealing.

From the forming of the Buffalo Philharmonic Orchestra in 1935, until the opening of Kleinhans Music Hall in October 1940, the orchestra was without a permanent home. Just prior to the formation of the orchestra, Edward L. Kleinhans, a local businessman and his wife, Mary Seaton Kleinhans, both music devotees, left a small fortune dedicated to the construction of a new music hall (fig. 3). In a touching tribute to the women in his life, Mr. Kleinhans declared that the chamber music hall would be named for his wife, Mary Seaton Kleinhans, and the rehearsal room would be named for his mother, Mary Livingston Kleinhans. Today, the two

[5] "New Kleinhans Hall Declared Princely Gift," *The Courier-Express*, 13 October 1940.

[6] "Critics Asked to Defer Judgment on New Hall," *Buffalo Evening News*, 14 January 1939.

[7] "Award to Kleinhans Recalls '39 Controversy Over Design," *Buffalo Evening News,* 5 July 1967.

halls are referred to as the Mary Seaton Room and Livingston Hall. Mr. Kleinhans died on February 2, 1934, and his wife followed her husband to the grave soon after on April 29, 1934. A commemorative plaque on the wall of the lobby of Kleinhans Music Hall cites the "public spirit, the vision and the generosity of Edward L. and Mary S. Kleinhans, who devoted their entire estates to the building of this center of musical culture for the use, enjoyment and benefit of the people of the City of Buffalo."

Charged with overseeing construction of the new music hall, the Buffalo Foundation established a committee responsible for initiating the project. On April 29, 1938, as the result of a local competition, the F.J. and W.A. Kidd firm was chosen by the Kleinhans Music Hall committee as architects for the project. The Kidd firm was established by two brothers: Franklyn J. Kidd, architect, and William A. Kidd, engineer. Their firm planned a neoclassical building with Art Deco flourishes in the decorative program (fig. 4), but by the end of the year, an unusual turn of events demoted the Kidd firm to supervising architects in charge of executing Eliel Saarinen's design.

How Saarinen came to be involved in the Kleinhans project remains something of a mystery. Around the time when local architects first submitted their plans, at least one member of the Kleinhans Music Hall committee had begun to seriously consider a more forward-looking, modern design for the new hall. Shortly before the Kidd firm was first awarded the commission, the chair of the committee and future president of Kleinhans Music Hall Inc., Edward Letchworth, received a communication from the president of the Buffalo City Planning Association, Fenton Parke. Parke strongly supported a modern design for the new hall, and also recommended a book by Walter Curt Behrendt, *Modern Building: Its Nature, Problems and*

Forms.[8] Behrendt was an architect and critic who emigrated to the United States from Germany in 1934, and taught architecture at the University of Buffalo from 1937-41.[9] His polemical book on modern architecture explains why old forms of architecture are no longer viable in modern society. It appears likely that Letchworth followed Parke's recommendation and at least perused the book.

In addition to the city planner, another party, the formidable Esther Link, supported a modern design for Kleinhans Music Hall. On July 11, 1938, before her appointment as Acting Director, Link sent Edward Letchworth a letter in which she encourages a modernist design for the new hall from such notable architects as Frank Lloyd Wright or William Lescaze. She writes, "Both these men are eminently practical, infinitely resourceful, interested in solving the client's problems adequately, practically, and according to the economic limitations of the client and indisputably original, creative. The building won't be a cross between freak classic and someone's vague impression of 'modernistic.'" Link's letter was sent from Philadelphia, where she was visiting her sister and where she may well have seen and admired Lescaze's PSFS building. Link mentions the future architect of Kleinhans Music Hall just once in her letter by referring to Letchworth's "interest in Saarinen's [train] station," but she does not specifically recommend Saarinen. Letchworth, by contrast, appears seriously interested in Saarinen.

To increase funding for the new hall, the Kleinhans committee sought additional aid through the Federal Emergency Relief Administration of Public Works (PWA). The committee's proposal was accepted and the PWA agreed to award $584,000, or approximately forty-five percent of the construction cost of the hall. The remaining balance of $752,000 was to

[8] Parke to Letchworth, 19 April 1938, Kleinhans Music Hall archives.

[9] *A Dictionary of Architecture*, 2000, s.v. "Behrendt, Walter Curt."

be paid by the Kleinhans estate. Conditions set forth in the PWA grant required an eleven member Board of Directors of Kleinhans Music Hall, with the majority comprising City of Buffalo officials. Negotiations with PWA were completed by June 1938, and Kleinhans Music Hall Inc. was formed a month later.

Esther Link was appointed Acting Director of Kleinhans Music Hall in August 1938. A graduate of Mount Holyoke College where she majored in English, Link also studied music at New York University before beginning her career as a music teacher. Link served as vice-president of her family's high-end retail store, Pitt Petri, where she supervised renovations of their stores. This experience combined with her work as head of the music department at Hutchinson-Central High School made her an ideal candidate to oversee construction of the hall. Throughout the summer and fall of 1938, discontent with the Kidd's conservative design was growing, and the Kleinhans board, along with Esther Link, was seriously exploring alternatives.

On October 19, 1938, the vice-president of the Kleinhans board, Philip Wickser, sent Eliel Saarinen a contract inviting him to submit plans for the new music hall. The two-part contract specified that if Saarinen's plans were rejected, the commission would be retained by the Kidd firm, and Saarinen would be paid a flat fee for his efforts. Should Saarinen's plans be accepted, the contract spelled out terms of the deal, and included a provision for Kidd and Kidd to serve as supervising architects. In a meeting on December 5, 1938, the board voted narrowly to award the commission to Eliel Saarinen, thereby demoting the Kidd firm to supervising architects for Saarinen's design.[10] This extraordinary development occurred despite the fact that the majority (six of eleven) of the Kleinhans board consisted of city officials. These officials

[10] For a complete history of the commission, see Herko, "Saarinen's Music Halls," (1999), 39-55. Herko describes a personal communication from Esther Link in which she states that at the decisive board meeting, the group realized there would be a tie (due to some absences, there was an even number on each side present). One city official generously abstained from voting, giving Saarinen the edge.

tended to be conservative in outlook, wary of modern design, and naturally opposed to hiring an architect from outside the City of Buffalo. Due to the fact that Eliel Saarinen was not licensed to practice architecture in New York State, F.J. and W.A. Kidd remained the official architects of record of Kleinhans Music Hall, while Eliel Saarinen is credited simply as the "designer."

Eliel Saarinen (1873-1950) was a Finnish architect, who gained international attention for his monumental design of the Helsinki Train Station (fig. 5). Saarinen's second place award in the Chicago Tribune Tower competition in 1922 is perhaps the best known losing entry ever in the history of competitions, and proved to be very influential in the design of office towers in the 1920s (fig. 6). This design brought him commissions in the United States, and precipitated his emigration in 1923. Saarinen taught at the Cranbrook Academy and designed many of its buildings, in addition to serving as president of the art school from 1932-1942. It was during this time that he accepted the Kleinhans Music Hall commission.

Before Saarinen was officially awarded the commission, the Kleinhans board solicited the opinions of prominent architects from around the country to evaluate both the Kidd and Saarinen proposals. For example, John Holabird, of the renowned firm Holabird and Root in Chicago, could not participate, but did send a letter to the president of the Kleinhans board in which he apologizes for being unable to review the plans for the new hall. In the letter, he vouches for his fellow architects who are capable of providing, he writes, "the best architectural advice obtainable in this country."[11] The three nationally known architects who reviewed both firms' plans were Ralph Walker of Voorhees, Gmelin and Walker; J. André Fouilhoux of Harrison, Fouilhoux and Abramovitz; and Harrie Lindeberg. In a visit to Buffalo on December 2, 1938, the three studied the plans and met the architects (the Kidd brothers and Saarinen). At

[11] Holabird to Letchworth, 2 December 1938, Kleinhans Music Hall archives.

the conclusion of their visit, all three unanimously recommended Saarinen's design. In their report to the directors of Kleinhans Music Hall, they write: "It seems to us to be thoroughly practical and moreover very distinguished in its design. We believe that the association of Mr. Saarinen and Messrs. Kidd will result in a distinguished design of which the City of Buffalo may be proud."[12]

All three architects wrote individual letters of commendation after their visit. Walker writes, "We were immediately struck, upon going into the room, with the entire quality of Saarinen's design. It has a quality of power and a creative beauty that is very rare in architecture these days."[13] Fouilhoux says Saarinen's design "was brilliant with its simplicity of plan, ease of circulation and adaptation to the lot."[14] Lindeberg writes, "I have observed and admired Saarinen's work in Finland, Sweden and Detroit for over a period of years and I feel that in his concert hall design he is at his best. It is because of its simplicity of design that it will prove to be one of our most distinguished buildings. Please realize that Saarinen is a master in the use of material and that he can make a simple brick wall glow with life."[15] Holabird also wrote a follow-up letter praising the selection of Saarinen, and commenting on the apparent concern that conservative opinions might have prevailed. He states, "Your committee has made a fine selection. I did not know that there were enough classicists left to cause any worry."[16]

Kleinhans Music Hall is situated in a historic neighborhood, on a picturesque site adjacent to Symphony Circle. "The Circle," as it was originally called, was planned in 1868 by

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[12] Press Release, 5 December 1938, Kleinhans Music Hall archives.

[13] Walker to Letchworth, 15 December 1938, Kleinhans Music Hall archives.

[14] Fouilhoux to Link, 27 December 1938, Kleinhans Music Hall archives.

[15] Lindeberg to Board of Directors, Kleinhans Music Hall Inc., 12 December 1938, Kleinhans Music Hall archives.

[16] Holabird to Link, 11 January 1939, Kleinhans Music Hall archives.

Frederick Law Olmsted and Calvert Vaux as part of their grand addition to Buffalo's street system. Saarinen appears to have been inspired by the curves of the circle in his curvilinear design of the music hall. The parabolic plan of Kleinhans Music Hall is faithfully reflected in the exterior, conversing nicely with Olmsted's street circle. The hall is dominated by two parabolic-shaped lobes revealing the contours of the large orchestral hall and the smaller chamber music hall contained within (fig. 7). The chamber music hall, located on the east side of the complex, faces Symphony Circle. A reflecting pool forms a semicircular ring around the exterior of the chamber music hall, emulating Symphony Circle to the east while balancing the mass of the large hall to the west (fig. 8).

Inside, the large auditorium seats 2,839 people, the small chamber music auditorium, known as the Mary Seaton Room, seats around 800, and a backstage rehearsal room, Livingston Hall, can hold up to 200 people (figs. 9, 10, and 11). Connecting the main auditorium and the Mary Seaton Room is a wide spanning bow-shaped lobby, with entrances at both ends. Enormous wooden doors open between the Mary Seaton Room and the lobby, creating what Saarinen refers to as a "spacious effect of festivity."[17]

Eliel Saarinen wrote an essay for a booklet commemorating Kleinhans Music Hall in which he describes the organic philosophy which guided him and gives details of his plans for the music hall.[18] Saarinen cites three important factors which influenced his design of the main auditorium, the first being acoustics. He acknowledges that acoustical requirements considerably influenced the, "general form of the auditorium and the disposition of the stage,

[17] *Kleinhans Music Hall* (1953), 25.

[18] The booklet first appeared in 1942. I will refer to the most recent edition of this booklet, published in 1953.

seats and surfaces."[19] Saarinen's solution to the plan of both the main auditorium and the chamber music hall involved the spatulate or fan shape, popularized by silent movie theaters in the first quarter of the twentieth century and later adapted to concert hall designs. The radial arrangement of seats in a fan-shaped hall gives the advantage of good sightlines, even from the rear-most seats.

Saarinen notes that acoustical considerations of Kleinhans Music Hall also decided the "character and texture of ceilings, walls and of floor covering, so as to ascertain satisfactory reverberation."[20] It is interesting that Saarinen mentions floor covering, since the effect of the wall-to-wall carpeting on acoustics in the main auditorium proved to be a matter of controversy almost as soon as the concert hall opened. Saarinen emphasizes that obtaining satisfactory reverberation is a key factor in acoustics.

The second factor Saarinen considered paramount to his design of Kleinhans is the relationship between the performers on stage and the members of the audience. Not simply the practical matter of good sight lines from every seat (which Kleinhans can easily boast), but the psychological character of a successful performance, "where the performer and the public influence and inspire one another," was important to Saarinen.[21] To this end, he designed an open platform to serve as the stage, with raked seating on the main floor and a large, rather steeply graded balcony at the rear. The finned walls of the fan-shaped auditorium telescope from the house to the sides of the stage and prove to be the defining characteristic of the hall, directionally focusing our attention to the platform. The lack of a proscenium arch framing the performers and demarcating their space as privileged serves to diminish the psychological and

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[19] Ibid., 23.

[20] Ibid.

[21] Ibid., 24.

visual separation between audience members and performers. The simple platform in Kleinhans is unusual in music halls and theaters, which generally have an architectural feature separating the audience from the stage. According to Saarinen, the removal of a distinct division between the stage and the audience serves two purposes: it helps performers to perform to the audience, and makes audience members more receptive to the performance. JoAnn Falletta, the current Music Director of the Buffalo Philharmonic Orchestra, concurs: "I've performed in much smaller halls, where there is a tremendous feeling of division between the stage and the audience; in Kleinhans, there is none of that. There is a sense of closeness that I think is astonishing for a hall of so many people."[22] The hall, which seats nearly three thousand people, is considered large for a music hall, and many concert halls around the world feature far fewer seats.

A third consideration Saarinen cites in his design is the lighting effects, which were important to bringing "forms and proportions into their full value, and also in bringing the varying light effects into accord with corresponding variations of performance and intervals."[23] Those who have visited the main hall in Kleinhans know the serene feeling created by both the recessed lighting in the fins of the telescoping walls, and the golden hues of the wood paneled walls. Acoustics expert Leo Beranek writes that Kleinhans' "well-proportioned lines and primavera wood interior render an immediate feeling of intimacy, warmth, and comfort."[24] In addition to the union of the platform with the seating area, the sense of serenity and repose described here no doubt serve "to tune both performers and public toward a musically constructive disposition of mind," as Saarinen would have it.[25]

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[22] Quoted in Sommer, "Celebrating a Musical Marvel," *The Buffalo News*, 19 November 2010.

[23] *Kleinhans Music Hall* (1953), 24.

[24] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 51.

[25] *Kleinhans Music Hall* (1953), 22.

Saarinen's design sought to orient musicians and audience members toward a musical frame of mind. In order to maximize auditory conditions for actually listening to music in the concert hall, the planners of Kleinhans engaged acoustical engineers from the outset. A major focus of this study is the acoustical plans for Kleinhans Music Hall and the resulting "sound" of the hall. Two prominent consultants contributed advice on the acoustical planning of Kleinhans Music Hall: Paul Sabine, the director of the prestigious Riverbank Acoustical Laboratories in Geneva, Illinois, and Charles C. Potwin of Electrical Research Products Inc. The famous maestro, Leopold Stokowski, conductor of the esteemed Philadelphia Orchestra, also contributed informal advice on acoustics. All three advisors were consulted by the spirited Acting Director of Kleinhans Music Hall Inc., Esther Link. As a musician, Link had very particular ideas as to what constituted good acoustics, and she was adamant in her desire for good sound in the new music hall.

By the time of construction of Kleinhans Music Hall the science of acoustics had reached a significant level of technological mastery. The planners of the hall relied on this science in order to obtain the best possible listening conditions in the concert hall. A concise history of the modern science of acoustics in the decades preceding the construction of Kleinhans is provided in the next chapter.

Chapter II   A BRIEF HISTORY OF MODERN ACOUSTICS

The beginning of early modern acoustics can be traced back to 1895 and the completion of Richard Morris Hunt's Fogg Art Museum and lecture hall at Harvard University. The acoustics of the Fogg lecture hall were decidedly poor and made listening to and understanding lectures within the hall nearly impossible. The President of Harvard, Charles Eliot, asked a young assistant professor of physics at the university, Wallace Clement Sabine, to study the problem and to propose a solution. Focusing his research on the very evident sense of reverberation in the room, Sabine carefully employed the scientific method in his study of the acoustics of the lecture hall, conducting his research in the middle of the night when extraneous noises would be kept at a minimum. Additionally, he relied solely on his own ear and not the ear of an assistant in order to minimize individual variations in sense perception and reaction time. By sounding an organ pipe attached to a pressure tank and using a chronograph to mark the time, he measured the length of reverberation between the time when the pipe stopped sounding and when the sound in the room fell below the threshold of hearing.[1] He found the Fogg lecture hall to have an impressive reverberation time of 5.6 seconds, comparable to reverberation times of the great cathedrals in Europe. To reduce variables, Sabine always used an organ pipe tuned to a midrange frequency of 512 counts per second (one octave above middle C).

Sabine conducted this experiment several thousand times, varying the conditions by introducing seat cushions from a similar style lecture hall on campus, the Sanders Theatre. Sanders Theatre was comparable in proportion and design to the Fogg Hall, but the Sanders had carpeted floors and fabric seat cushions and a decidedly lower reverberation time. Sabine used

[1] For a thorough account of the experiment, see Paul Sabine, "The Beginnings of Architectural Acoustics" (1936), 244.

the "Sanders Theatre seat cushion" as a mathematical variable in his results. However, he was intent on finding a more general mathematical model than the "Sanders Theatre seat cushion" clearly could provide. After nearly two years of meticulous study of the problem of the Fogg lecture hall, President Eliot insisted that Sabine propose a remedy. Although Sabine believed his research to be incomplete, he did recommend the application of sound absorbing felt to the walls of the hall in order to reduce the reverberation time and therefore improve acoustical conditions for lectures in the hall. His advice was taken and we can assume went some way toward improving the acoustics of the lecture hall, although it apparently was never as good as the Sanders Theatre's acoustics.[2] Unfortunately, we cannot experience the acoustical properties of the Fogg lecture hall today as it was demolished in 1927.[3]

After the remediation of the Fogg lecture hall, Wallace Sabine continued to puzzle over the data he had painstakingly collected. He was searching for a unifying equation. Finally, on one day in 1897, while pouring over his data yet again, it occurred to him that the graph of reverberation time plotted against the Sanders seat cushion variable was best modeled by a hyperbola (fig. 12). He was then able to devise a formula for predicting reverberation time, the variables of which include the volume of a room and the sound absorbing properties of its surfaces. Sabine's reverberation time formula ushered in a new era of empirically based acoustics. Although sound in large halls was still subject to fluctuations and imperfections, no longer did architects have to rely solely on guesswork or chance in planning for acoustics. Sabine's formula offered the possibility of predicting this critical element of room acoustics:

[2] Thompson, *The Soundscape of Modernity* (2002), 37.

[3] At that time, a new Fogg Art Museum was built on Quincy Street, away from the Fogg's original location in Harvard Yard. Harvard Art Museums, "About/History," www.HarvardArtMuseums.org. Accessed 25 January 2011.

reverberation time (RT). A simplified version of Sabine's formula is: RT = $0.164V/A$, where V is the volume of the room in cubic meters, and A is the surface area of the room in square meters with "absorption coefficients" taken into account for each surface. To put the reverberation time formula in context, reverberation time is proportional to the size of a room, that is, it *increases* as the volume of a room increases, and reverberation time is inversely proportional to sound absorbing surface areas, that is, it *decreases* as the absorptive material in the room increases. To appreciate this formula, imagine a large, indoor sports arena of colossal volume and the booming, echoing acoustics which accompany it. Conversely, imagine an average sized room in a house with fabric curtains, upholstered furniture and carpeting, and the lack of accompanying reverberation within such a room.

Moving beyond the Sanders seat cushion factor, Sabine carefully examined the effect various building materials exerted on reverberation time. He assigned to each material an absorption coefficient, with "1" being the highest possible theoretical coefficient representing *total absorption* of sound energy and "0" being the lowest theoretical coefficient representing *no absorption* (no loss) of sound energy.[4] Sabine was working with the conception of sound as a wave (analogous to the waves created by dropping a pebble in a still pool), and the theoretical idea that energy produced by a single blast of sound could reflect off the surfaces in a room for an unlimited amount of time. Sound waves move in three-dimensions throughout an enclosed space, bouncing back and forth off the walls, ceiling, floor and other surfaces in the room including furniture and even people (although people tend to absorb sound more than reflect it). Sabine calculated absorption coefficients for numerous building materials including wood-

[4] Hall, *Musical Acoustics* (2002), 330. No typical building material has these extreme properties. However, an open window was considered by Sabine to theoretically possess the highest coefficient of "1" since all sound passing through a window gets carried away from the room thereby eliminate the possibility for reflections of sounds waves, the principle cause of reverberation.

sheathing (hard pine), plaster on wood lath, plaster on wire lath, glass (single thickness), and brick set in Portland cement.[5]

Around the time that Sabine was still puzzling over the results of his experiments on the Fogg Art Museum lecture hall, a local Boston businessman and Boston Symphony Orchestra supporter, Henry Lee Higginson, was making plans for a new symphony hall for the orchestra. Higginson was keen on building a hall that would rival Europe's greatest halls such as the 1884 Gewandhaus of Leipzig. In particular, he wanted a new music hall that would be especially fitting for the music of his favorite composer, Ludwig van Beethoven.[6] To realize his vision, Higginson sought the technical advice of Harvard's President Charles Eliot, who recommended Wallace Sabine as an acoustical consultant for Higginson's hall. Sabine initially refused to accept the position of consultant since he believed his command of the acoustical properties of rooms was incomplete. But it was around this time when he discovered the hyperbolic connection between reverberation time and sound absorbing surface area, thereby leading him to the famous reverberation time formula discussed above. After this breakthrough, Sabine agreed to serve as consultant on the new symphony hall, and Higginson hired the prestigious architecture firm of McKim, Mead and White to design it. Charles McKim tackled the problem of constructing a hall to seat 2,300 patrons with a proscenium stage to accommodate the Boston orchestra. Sabine studied the plans and made recommendations designed to result in an ideal reverberation time of approximately 2.3 seconds, similar to Sabine's estimation of 2.4 seconds reverberation time for the Leipzig Gewandhaus (based upon his reading of architectural drawings

[5] Thompson, *The Soundscape of Modernity* (2002), 40.

[6] Ibid., 15.

of the Gewandhaus).[7] Boston's Symphony Hall opened in 1900 as the first auditorium whose plan was informed by new scientific principles (fig. 13). In particular, the key acoustical element of reverberation time for the hall was predicted by Sabine's reverberation time formula based on the volume and surface areas derived from the architect's plans. In its first years, reaction to the hall was mixed. Once the concert-going public acclimated to its sound, however, and the Boston Symphony Orchestra increased the number of musicians to 120, Boston Symphony Hall came to be considered a success. Today, the hall is thought to be one of the finest music halls in the country.[8]

Aside from the predictive value of Sabine's reverberation formula, there were other factors which contributed to the eventual acoustical success of Boston Symphony Hall. For example, the simple, rectangular shoe-box shape of the hall is considered today to be among the best plans for music acoustics. The hall's lack of concave curvature, like a domed ceiling or barrel vaulting, is fortunate since such geometry can generate focused echoes which are highly undesirable in a music hall. Another fortunate acoustical condition of Boston Symphony Hall can be attributed to the Beaux-Arts style which features plenty of architectural details such as a coffered ceiling, arcaded walls with arches, pilasters, and niches supporting large statues. These three-dimensional decorations of various shapes and sizes, including balcony surfaces and ceiling chandeliers, add to the richness of the sound by distributing it more uniformly throughout the hall.[9] Rooms with purely flat-surfaced walls and ceilings are to be avoided since they produce strong reflections which can be perceived as echoes or slap-backs – analogous to

[7] Ibid., 44.

[8] Blesser and Salter, *Spaces Speak* (2007), 118-19; Beranek, "Boston Symphony Hall: An Acoustician's Tour" (1988), 923.

[9] For an explanation of this phenomenon see Hall, *Musical Acoustics* (2002), 321.

undesirable acoustical "glare." A variety of three-dimensional surfaces, like those found in the lavish interior of Boston Symphony Hall, create a desirable acoustic ambience.

After the success of Boston Symphony Hall, Wallace Sabine continued to work in the field of acoustics for the remainder of his life. Other scientists joined the new field of inquiry. One critical issue that these early researchers encountered was the problem of how to measure the intensity of sound. There were a number of variables confounding this basic requirement. For example, there were different timbres of sound – imagine the sound of a saxophone playing a middle C in comparison to the sound of a violin string playing the same middle C. There were also different pitches or frequencies in the musical scale from very low bass notes (some of which can be sensed resonating in the body better than they can be sensed by the ear), to stratospherically high (and higher) coloratura registers. Scientists had the ability to measure these pitches or frequencies in *hertz* or cycles per second, which were well understood and employed by scientists by the time of Wallace Sabine.[10] However, measuring the degree of loudness of different instruments playing different frequencies was a challenge. There was no standard method of determining the volume of sound. It would seem that a pipe organ playing a middle C and a violin playing the same middle C will produce differing impressions of loudness. Further, depending on how the instruments are played, the volume of each instrument can vary from barely perceptible to extremely loud. The number of variables (pitch or frequency, timbre, volume) was problematic and would have to be addressed in order to enhance and expand the possibilities of scientific research.

Sabine followed the principles of the scientific method by reducing variables in his research of the Fogg lecture hall. He used the same organ pipe with a constant frequency of 512

[10] These frequencies, given in cycles per second, are named after German scientist Heinrich Hertz (1857-1894).

hertz, a machine to force air through the pipe in order to produce a constant volume, and he relied on his ear alone (not an assistant's ear) to collect the data. This methodology would eventually prove to be hopelessly old-fashioned. Wallace Sabine first tackled the problem of the Fogg Lecture Hall in 1895, and several decades were to elapse before technological developments in acoustical measurement – like the invention of microphones, loudspeakers, and the "decibel" – caught up to his theoretical achievements.

In his work as a consultant, Wallace Sabine experimented with creating sound absorbing building materials to remediate poor room acoustics. Sabine collaborated with the Guastavino Tile Company of New York to create special sound absorbing tiles which, in addition to their acoustical qualities, were structural in character.[11] In 1913, Sabine and Guastavino filed a patent application for Rumford tile (precursor to Akoustolith tile), emphasizing its "peculiar porosity" as an aid in absorbing sound.[12] In that same year, Colonel George Fabyan, a wealthy scion of an old Massachusetts textile trade family, had learned of Wallace Sabine's acoustical work through Fabyan's connection to Harvard. Highly interested in Sabine's work, Fabyan invited him to set up a laboratory in Geneva, Illinois, where Fabyan owned a large estate of six hundred acres. An acoustical facility with a reverberation chamber was eventually constructed there according to Sabine's specifications. The crisis of World War I intervened, however, and Sabine's plans to set up shop at Riverbank were put on hold. At the conclusion of the war in November of 1918, Sabine resigned from his post in the War Department, where he had been active in "military aviation and sound ranging."[13] Sadly, he died in Boston on January 7, 1919, before beginning

[11] Thompson, *The Soundscape of Modernity* (2002), 178.

[12] Ibid., 183.

[13] Paul Sabine, "The Beginnings of Architectural Acoustics" (1936), 247.

work at the Riverbank Acoustical Laboratories and did not live to see the remarkable technical advances about to be made in his field. Following Wallace Sabine's untimely death, Paul Sabine, Wallace's distant cousin and a Harvard trained physicist like his famous cousin, was offered the post of Director of the Riverbank Acoustical Laboratories (fig. 14). Although his original field of study was spectroscopy, Paul Sabine soon excelled in acoustical work as the director of the laboratories, a post which he held from 1919-1947. As a leader in his field, Paul Sabine also served as the fourth president of the Acoustical Society of America from 1935-1937. In addition to publishing many technical papers, Paul Sabine wrote papers on the history of acoustics. For example, describing the history of acoustical research, Paul Sabine writes that

> Up until 1925, the stopwatch and ear method was the only available means of timing reverberation with the old reliable organ pipe as the source of the sound… The microphone, amplifier, and electrically operated timer replaced the ear and the stopwatch. At a still later date came the high speed level recorders giving a complete graph of the decay of reverberant sound. With the improved technique, came a remarkable increase in the field of acoustical measurements.[14]

As a result of these developments, several important acoustical research centers such as Bell Telephone Laboratories, Electrical Research Products Labs in New York City and Los Angeles, and Vern Knudsen's Lab at the University of California were established by 1930.[15] While Paul Sabine himself provided advice on the acoustical design of Buffalo's Kleinhans Music Hall, it was Charles Potwin of the New York office of Electrical Research Products Inc. who was the official acoustical consultant of record hired by Kleinhans Music Hall Inc. in 1938 (fig. 15).

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[14] Paul Sabine, "Architectural Acoustics: Its Past and Its Possibilities" (1939), 25.

[15] Ibid., 25-26.

In her book *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America 1900-1933*, Emily Thompson gives a thorough account of the technologies which propelled the discipline of acoustics into the modern age. As she discussed, by the mid-1920s, acoustical research had changed significantly from Wallace Sabine's time. The invention of microphones and loudspeakers and the introduction of amplifiers and alternating current meters completely changed the culture of acoustical science. As researchers began to use electrical equipment like microphones and recorders to capture sound, they increasingly began to see sound as analogous to electrical circuitry.[16] Mathematical equations used to model electrical systems would now be applied to the problem of acoustical systems which had previously been viewed as kinetic mechanical systems. In his 1936 paper "The Beginnings of Architectural Acoustics," Paul Sabine notes that at the time of Wallace Sabine's first forays into acoustical research, the "commonplace equipment of every acoustical laboratory today, linear response microphones, vacuum tube amplifier and oscillators, sensitive alternating current meters, and telephonic loud speakers were as yet undreamed of. Even the decibel, without which no acoustical investigator today can keep house still lacked some thirty years of being born."[17]

By the late 1920s, the decibel became the gold standard of measuring the intensity of sound and is still used today. Named in honor of the father of electroacoustics, Alexander Graham Bell, one decibel measured "approximately the smallest change that the ear can detect in the level of sound."[18] The original derivation of the decibel refers to, "the loss suffered by a

[16] Thompson, *The Soundscape of Modernity* (2002), 96.

[17] Paul Sabine, "The Beginnings of Architectural Acoustics" (1936), 243.

[18] "Drive Opens to End Din of Auto Horns," *New York Times* (15 January 1930): 25, quoted in Thompson, *The Soundscape of Modernity* (2002), 162.

signal as it traveled through one mile of standard telephone cable."[19] Decibels increase on a logarithmic scale such that ten decibels corresponds to increasing a single decibel by a factor of ten, twenty decibels corresponds to an increase by a factor of one hundred, and thirty decibels corresponds to an increase by a factor of one thousand. As an example, a quiet whisper measured two feet away measures about twenty-five decibels, and the noise inside an uninsulated airplane is about 110 decibels.[20] An article in the New York Times from 1931 stated that subway noise can reach 120 decibels (about a trillion times louder than one decibel), and this crosses the, "threshold of pain for normal human beings."[21] Acoustical scientists and civil authorities began to use the new decibel system of measuring sound to study chronically irritating noise such as street traffic in cities.

By the time that decibels became common currency in acoustical science, a small group of physicists, industrial scientists, and engineers, united by their academic or commercial interest in acoustics, formed the Acoustical Society of America in 1928. It was initiated in part by acoustical researchers who sought validation within a professional society, "free from the criticism of others who might look down on the inherently applied nature of their work or look askance at the distance that separated it from the exciting new theoretical developments in relativity and quantum mechanics."[22] By 1932, there were eight hundred members from a variety of disciplines including musicians, psychologists, otologists, phonoticians, and anyone with a particular interest in sound. Members of the Society also included acoustical consultants

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[19] Thompson, *The Soundscape of Modernity* (2002), 375, note 182.

[20] Knudsen, *Modern Acoustics and Culture* (1937), 3, note 1.

[21] "Subway Din Worse inside of the Cars" *New York Times* (7 January 1931): 27, cited in Thompson, *The Soundscape of Modernity* (2002), 162.

[22] Thompson, *The Soundscape of Modernity* (2002), 105.

who developed and applied sound absorbing building materials, and sound engineers who worked with recording equipment, radio, phonographs, telephones, and talking motion pictures. From the time of its formation in 1928, members of the Acoustical Society set about to standardize their profession's nomenclature, instrumentation, and methodology and by 1934 acoustical standards were fully codified.[23]

In 1942, Paul Sabine strongly encouraged the Acoustical Society of America to participate in the nation-wide Noise Abatement Program, which was initiated in the 1920s.[24] By first measuring decibel levels of various offending noises, it was thought that acoustical scientists would be in a better position to address the issue. Many members of the Society were closely linked with commercial interests that produced and promoted the use of sound insulation and sound control, so it was natural that they should offer their help in reducing noise pollution. Unfortunately, efforts to curb noise in cities were largely unsuccessful. It appeared to be much easier to measure the decibel level of street traffic, trains, subways, sirens, police whistles, dogs, cats, and newspaper boys, than to reduce their clamor. However, acoustical experts did begin to have increasing command over indoor environments, and by "controlling private space, by turning inward and creating acoustically efficient refuges from the noise of public life, acousticians offered a compelling alternative solution to the problem of noise."[25] This alternative involved the use of sound absorbing materials which were first produced and promoted during Wallace Sabine's lifetime, and became increasingly common in the decades following the First World War.

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[23] Ibid., 105-110.

[24] Paul Sabine, "The Acoustical Society and Noise Abatement" (1942), 207-9.

[25] Thompson, *The Soundscape of Modernity* (2002), 168.

In the next chapter, I will document the rise of the “modern sound” in the first decades of the twentieth century. I will discuss how electroacoustic technologies like the telephone, phonograph, radio and talking pictures, and sound absorbing building materials designed to control sound in rooms contributed to establishing a new culture of listening at this time.
In addition, I will describe the technological advancements in acoustical science which had taken place by the time of the planning and construction of Kleinhans Music Hall.

Chapter III THE MODERN SOUND

In her thorough study of the development of electroacoustic technologies and the sound control industry, Emily Thompson documents the rise of the singular “modern sound” in the first third of the twentieth century. She begins by defining the term “soundscape” as an auditory or aural landscape which is,

> simultaneously a physical environment and a way of perceiving that environment… The physical aspects of a soundscape consist not only of the sounds themselves, the waves of acoustical energy permeating the atmosphere in which people live, but also the material objects that create, and sometimes destroy, those sounds. A soundscape’s cultural aspects incorporate scientific and aesthetic ways of listening, a listener’s relationship to their environment, and the social circumstances that dictate who gets to hear what... The American soundscape underwent a particularly dramatic transformation in the years after 1900. By 1933, both the nature of sound and the culture of listening were unlike anything that had come before.[1]

Thompson documents how physical environments in which sound was created and heard changed through the use of sound absorbing building materials and the invention of electroacoustic technologies that created sounds never before heard in human history. The telephone, the radio, the recorded sounds of turntables and talking motion-pictures produced aural phenomena through loudspeakers or telephone receivers giving people for the first time an electroacoustically based auditory experience. Like many other products of the Machine Age, these technologies were embraced with enthusiasm by the public. Excessive reverberation came

[1] Thompson, *The Soundscape of Modernity* (2002), 1-2.

to be seen as unwanted noise. A quiet, sound-dampened environment, particularly in the workplace, was considered efficient and hence, modern. By transforming traditional relationships between sound, space, and time, acoustical technologies demonstrated human beings' technical mastery over the environment. This modern sound, described by Thompson as "clear, direct, and nonreverberant… was easy to understand, but it had little to say about the places in which it was produced and consumed."[2] Like the International Style of architecture, stripped of any identifying features demarcating the unique place in which it was found, the modern sound – clear, direct and nonreverberant – could be produced or reproduced anywhere, but it made anywhere sound like every other place. This was the acoustical culture in which Kleinhans Music Hall was planned.

The 1920s witnessed a remarkable increase in the technics of acoustics and a parallel growth in the development of professional standards in acoustics: the invention of the decibel, the initiation of noise abatement programs in the United States, the rise of acoustical consulting as a profession, and finally, the founding of the Acoustical Society of America at the end of the decade. With these developments came an increase in the advertising and marketing of sound absorbing materials as well as an increase in demand for professional consultants to advise on the use and installation of these materials. Thompson writes of aggressive advertising campaigns which contributed to the proliferation of acoustical material in the 1920s.[3] A number of sound absorbing building materials became available which were marketed for a variety of spaces.

Initially, these acoustical treatments were sought for auditoriums, lecture halls, and churches – places which required acoustics especially suited for the demands of listening to

[2] Ibid., 3-4.

[3] Ibid., 193.

music or speech.[4] However, as awareness of the problem of noise as a public nuisance grew, so did the idea that noise in the workplace was problematic and should be reduced if not eliminated altogether. Acoustical planning thus extended to commercial spaces. By the 1920s, offices and other workplaces were designed to dampen sound energy and create quiet environments in which to work. The first modern skyscraper in the United States, Howe and Lescaze's Philadelphia Saving Fund Society (PSFS) building of 1932, was acoustically designed to be highly absorptive. Thompson writes that, "in the PSFS building, the modern look was only catching up to the modern sound that had evolved over the course of the past two decades."[5] By 1932, Americans had grown accustomed to quiet, sound-dampened interiors, of which PSFS is just one example.

Industrialization and the increasing use of technology throughout the nineteenth and early twentieth centuries produced the Machine Age which is characterized by the development of mass production and assembly lines, heavy industrial machinery including machines which raised skyscrapers to previously unimaginable heights, the widespread use of electric power and electric appliances, and the invention of the combustion engine and subsequent marketing of the personal automobile to a broad segment of the population. The Machine Age, which brought the clang of trolleys and the roar of automobile traffic, also made possible the business of soundproofing indoor environments, thereby providing an escape from the clamor of the modern world. Nonreverberant, sound controlled interiors became the backdrop for modern life. This singular modern sound – lauded as the ideal sound – was supported by scientists and manufacturers responsible for electroacoustic technologies and the sound control industry. Electroacoustic technologies of the Machine Age, noise abatement programs, and the prevalence

[4] Ibid., 195.

[5] Ibid., 216.

of sound control changed the way people perceived their aural environments. In the following pages, I will explain how this aural culture had a profound effect on concert halls at the time of Kleinhans Music Hall.

The Machine Age produced new ways to generate and deliver sound, and changed the ways in which people listened. To describe transformations in the culture of listening during this time, Emily Thompson outlines the development of electroacoustic technologies beginning with Alexander Graham Bell's invention of the telephone in the 1870s. Thompson describes the novel phenomenon of telephone conversations: by eradicating the physical distance between two conversants and transmitting sound "virtually instantaneously," the telephone effectively annihilated space and time.[6] Telephone conversations do not transpire within ordinary architectural settings where the acoustics of the room and the distance between those conversing affect the perception of speech. Rather, the sound of speech is electronically reproduced through the receiver directly into the ear of the listener. Telephone users have grown accustomed to this "direct sound" and find it irritating when technical issues, like trace echoes or static noises, interfere with the signal. Similarly, most people dislike the slightly reverberant sound of calls from a speaker phone. Although composers and musicians historically have had to deal with various degrees of reverberation in spaces where music was performed, echoes are considered, by any standard, a defect in concert halls. An echo is described as a delayed reflection that is loud enough to irritate listeners or performers.[7] For example, in order for staccato passages

[6] Ibid., 235.

[7] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 33.

(short disconnected series of notes, or rapid, abrupt percussive strikes) to sound clear and accurate, echoes must be prevented from forming, or the crisp effect of the staccato will be lost.[8]

Shortly after the invention of the telephone, Thomas Edison's phonograph appeared. The listening public, who had never before heard anything quite like the electronically reproduced sound of phonographs, "generally enjoyed this kind of sound… the characteristic qualities of electroacoustic reproduction became a desired feature, a commodity to be experienced and enjoyed."[9] This new sound appealed to the aesthetic taste of the listeners who were eager to consume these novel products. Describing the early history of radio and phonographs, acoustical engineer Brian Blesser and social scientist Linda-Ruth Salter write, "As sound and auditory art became a commercial commodity, spatial acoustics were removed from performed and recorded music alike."[10] The setting in which the phonograph was played was often the living room of a home, frequently decorated with carpeting, drapery and stuffed furniture. This environment served to dampen any reverberation produced by the sounds generated by the phonograph. Similarly, the method of recording music removed any sense of spatial acoustics (like reverberation) of the room in which the recording was made. Blesser and Salter give the following account of why the spatial acoustics of recordings and also radio broadcasts have historically sounded so dry (that is, have lacked reverberation): "recording natural acoustics was difficult if not impossible; artificial reverberation was primitive and inadequate; commercial recording enterprises could not afford to build high-quality reverberant spaces," and perhaps most importantly, "the listening public was already educated to consider deadened acoustics as

[8] Bagenal and Wood, *Planning for Good Acoustics* (1931), 335.

[9] Thompson, *The Soundscape of Modernity* (2002), 239-40.

[10] Blesser and Salter, *Spaces Speak* (2007), 113.

synonymous with quality."[11] After being conditioned to the direct sound of the telephone, the phonograph, and radio broadcasts, and having grown accustomed to sound-dampened interiors, people came to accept a dry, nonreverberant sound as acoustically correct and desirable.

Two contemporary voices of dissent – Hope Bagenal, lecturer in acoustics at the Architectural Association School in London, and Alex Wood, lecturer in physics at the University of Cambridge – strongly resisted the shift to dry acoustics precipitated by electroacoustic technology. They believed such acoustics had a detrimental effect on musical tone. Bagenal and Wood opposed the downward trend in reverberation, stating that music hall acoustics should not be "superseded by the conditions suitable to the mechanical speaker or the mechanical ear."[12] That is, acoustical design for musical performance should not conform to the requirements of the loudspeaker or microphone. Rather, they insisted that studio microphones and loudspeakers should reflect the concert hall: *"The studio should be developed to reproduce the tone conditions of the best concert-halls, while microphone and loud-speaker are developed to transmit them without pitch selection so that the whole tonal affect is conveyed"* [italics original].[13] Bagenal and Wood argued that studio acoustics ought to mimic concert hall acoustics, and they expressed concern about the tendency of microphones and loudspeakers to artificially magnify a particular register, like the bass, thereby transmuting natural live acoustics into an artificial electronic aesthetic.

By 1927, over one hundred million records were being played on one million phonographs, and a single broadcast by Arturo Toscanini's NBC radio orchestra reached more

[11] Ibid., 116.

[12] Bagenal and Wood, *Planning for Good Acoustics* (1931), 129.

[13] Ibid., 271.

listeners than all the concerts ever given by the New York Philharmonic in its ninety-year history.[14] It is therefore not surprising that in the 1930s, the musical style and deadened acoustics of radio broadcasts and recordings became a universal reference. Because it was easier to record or to broadcast from dry, nonreverberant spaces, and owing to the large numbers of people who listened to radio or phonographic recordings, dead acoustics became the cultural norm.[15] Eventually, music halls came to mimic this home listening experience by providing clear, direct and mostly nonreverberant sound. These so-called "hi-fi" halls will be described below.

In the mid-1920s, when wireless radio became a staple in American households, talking films made their first appearances. The first feature length sound film was John Barrymore's *Don Juan*, which premiered in New York City on August 6, 1926. The key feature of this film was the synchronization of score and sound effects with the moving images which had been attempted unsuccessfully several times in the past.[16] Previously silent theaters around the country soon began to feature the new sound film technology. It quickly became apparent that acoustics in these theaters which had been adequate for live musical accompaniment was sometimes disastrous for the "talkies" sound technology. Many theater owners called upon Electrical Research Products Inc. (ERPI), the company responsible for installing and maintaining their sound film equipment, for help.[17] ERPI engineers soon realized that acoustical problems found in theaters were more than just a matter of sound equipment adjustments, and that the problem required remediation in architectural acoustics. In response to this issue, the company

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[14] Blesser and Salter, *Spaces Speak* (2007), 113, 115.

[15] Ibid., 115-16.

[16] Hochheiser, "AT&T and the Development of Sound Motion-Picture Technology" (1989), 23.

[17] Thompson, *The Soundscape of Modernity* (2002), 259.

rapidly gained expertise in architectural acoustics. Their acoustical surveys of theaters, which relied on Wallace Sabine's methodology, are described in ERPI's company letter, *Erpigram*. ERPI's acoustical surveys required determining "the exact volume and seating capacity, nature and thickness and amount of draping and decoration material use in the theatre, exact nature of all seats and furniture, etc. Also included is a noise survey and recommendations for eliminating all noises in the house."[18] In another issue of *Erpigram*, ERPI engineers are comically described as "warriors" equipped with cap pistols who "hunt out Reverberation, and his Echoes, and banish him from the theater."[19] It appears that ERPI engineers opposed not only troublesome echoes, but also any form of reverberation, which they should like to "banish" from the theater. Shooting a cap pistol is one method sometimes used to determine reverberation time within an auditorium. During an acoustical study of Kleinhans Music Hall performed in 1950 by the Acoustics Laboratory at the Massachusetts Institute of Technology, a cap pistol was shot in the main auditorium for just this purpose.[20]

Electrical Research Products Incorporated was founded in 1927 as a subsidiary of Western Electric. In addition to its role leasing and maintaining motion picture equipment, ERPI served as the research and development wing of Western Electric. In 1931, ERPI received the first ever technical Academy Award – the coveted "Oscar" – for their invention of noiseless recording technology. By the time of the construction of Kleinhans Music Hall, ERPI no longer

[18] "Acoustics Test for 75 Theatres a Week," *Erpigram* 1 (15 December 1929): 3, quoted in Thompson, *The Soundscape of Modernity* (2002), 260.

[19] "Inspectors War on Enemies of True Sound," *Erpigram* 2 (15 January 1930): 4, quoted in Thompson, *The Soundscape of Modernity* (2002), 260. Charles Potwin was referred to as an "echo-killer" in "Echo Expert Finds Hall One of Best in Country," *Buffalo Evening News*, 10 May 1941.

[20] *A Survey of Acoustics in the Kleinhans Music Hall, Buffalo, N. Y., July 1950*, MIT Acoustics Laboratory, Kleinhans Music Hall archives, 7.

leased film equipment to movie theaters, but they did remain active in providing equipment to movie studios and continued working in acoustical consultation.

The rise of electroacoustic technologies such as the telephone, phonograph, radio, and sound motion-pictures, as well as the rise of the sound control industry contributed to a change in the culture of listening in the early twentieth century. As listeners became accustomed to a clear and direct sound, reverberation came to be perceived as an undesirable form of noise. This state of affairs contributed to a culture in which prominent acousticians of the 1920s reduced their recommended reverberation times for auditoriums.

The auditorium which best exemplifies the soundscape of the early twentieth century, with its reduced reverberation and increased use of electroacoustic sound, is Radio City Music Hall (fig. 16). Radio City, which opened in December 1932, represents the ultimate in sound control and electroacoustic technologies developed in the first decades of the twentieth century. An enormous auditorium seating around 6,000, the interior of Radio City was filled with more than one thousand tons of sound absorbing material designed to reduce reverberation to very likely less than 1.0 second when fully occupied – quite a feat considering its enormous volume.[21] Hidden behind grilles in the ceiling were loudspeakers designed to pump clear, electronically reinforced sound from microphoned performers directly to the audience, making the distance between an audience member and the stage acoustically irrelevant. Blesser and Salter describe the new acoustics of Radio City Music hall thus: "The artistic and aesthetic function of reverberation in enclosed spaces was now replaced with 'cleaner' electroacoustics… By removing reflections and reverberation, and by providing sufficient loudness using electroacoustic amplification, the designer of the hall had created a space where every seat would

[21] Thompson, *The Soundscape of Modernity* (2002), 309.

have the acoustics of the home living room."[22] Thompson positions Radio City Music Hall at the end of an era: the culmination of decades of technological innovation and cultural transition in America's soundscape.

It was just five years after Radio City's opening season when Eliel Saarinen submitted his plans for a new music hall in Buffalo, New York. Many of the cultural and aesthetic values informing the construction of Radio City were still present during the construction of Kleinhans Music Hall. The two halls, however, had largely different purposes: Radio City Music Hall hosted large, popular musical shows and motion-pictures, while the main auditorium of Kleinhans featured a simple platform for classical music performances with no plans for electroacoustic reinforcement. A low-budget public address system was installed when Kleinhans first opened to be used for announcements and to amplify the spoken word during speeches. Planning for the future in which a better "high-fidelity type of amplification" might be desired, Kleinhans Music Hall Management chose to install larger conduits than necessary for the original public address system.[23]

In the decades preceding the construction of Kleinhans Music Hall, acousticians were documenting reverberation times of auditoriums and making recommendations for optimal times. Before the founding of the Acoustical Society of America, acoustical researchers published the results of their investigations in books and periodicals. One early researcher, Floyd R. Watson, published *Acoustics of Buildings, Including Acoustics of Auditoriums and Soundproofing of Rooms* (1923), the aim of which is to give "detailed illustrations for guidance

[22] Blesser and Salter, *Spaces Speak* (2007), 110-11.

[23] Link to Letchworth, 19 April 1939, Kleinhans Music Hall archives.

in the acoustic design of new buildings and in the correction of acoustic defects."[24] In a chapter on reverberation time in auditoriums, Watson displays a graph of acceptable reverberation times for music concert halls of different volumes. Because an audience at maximum capacity can reduce reverberation time in auditoriums by as much as 50 percent, Watson includes three curves in his graphs: reverberation times for Maximum Audience, 1/3 Audience, and No Audience (fig. 17).[25] The largest hall listed in the graph is the Eastman Theatre which has a long reverberation time of four seconds without an audience (recall that the larger the volume of a space, the longer the reverberation time). At maximum audience capacity, however, the Eastman Theatre clocks in at just two seconds, slightly under optimal reverberation time for a music auditorium of its size, according to Watson's graph.

Another prominent acoustician, Vern Knudsen, documents a gradual shift to lower recommended reverberation times, a resolution with which Watson eventually concurs. In 1930, Watson published a second edition of his book, *Acoustics of Buildings,* with significant changes. Regarding the changes, Watson writes that, "Experience indicates, however, that shorter times of reverberation… produce better results," and therefore, he lowered his optimal reverberation times for auditoriums.[26]

In a paper on intelligibility of speech, Knudsen recommends that in rooms used for speech, reverberation time should be kept below 1.0 second. He adds that, "Even for music, there seems to be no physical factors which would warrant a time of reverberation much in excess of 1.0 second (which is about the optimal reverberation time for speech and music in a

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[24] Watson, *Acoustics of Buildings* (1923), iii.

[25] Ibid., 30.

[26] Watson, *Acoustics of Buildings*, 2nd edition (New York: John Wiley & Sons, 1930), 34, quoted in Thompson, *The Soundscape of Modernity* (2002), 252.

small room)."[27] Describing the downward trend in optimal reverberation times, Knudsen writes in 1954, "This downward trend in reverberation time has had a wholesome effect on clean, precise musical performance – imperfections that were once masked by excessive reverberation are now recognizable."[28] The acoustics of Kleinhans Music Hall was planned during this downward trend in reverberation times, and since the hall first opened, some have complained about the dry or nonreverberant acoustics of the main auditorium. This subject will be closely examined in Chapter IV on the acoustical planning of Kleinhans Music Hall.

If the goal of acoustical planning for music rooms is to encourage precise musical performances by exposing mistakes, then lowering reverberation times is a good way to achieve this goal. While Knudsen was clearly a proponent of sound-dampened halls, it is doubtful that many musicians would unreservedly support such acoustics. In fact, Watson discovered that musicians find it "easy" to play in reverberant spaces and "hard to play if surrounded by sound absorbing materials."[29] Acting Director of Kleinhans Music Hall, Esther Link, a music teacher herself, found reverberation a desirable quality, and sought to ensure that Kleinhans would have a substantial reverberation time.

A strange example of the scientific bias of some acousticians at the time of Kleinhans Music Hall is found in Knudsen's 1937 book entitled, *Modern Acoustics and Culture*. Knudsen advocates replacing traditional music notation for volume (a scale including ***ppp*** or triple *pianissimo* and ***fff*** or triple *fortissimo*) with decibel notation in increments of five from twenty through one hundred. He claims that this decibel system for musical notation was approved by

[27] Knudsen, "The Hearing of Speech in Auditoriums" (1929), 77.

[28] Knudsen, "Review of Architectural Acoustics during the Past Twenty-Five Years" (1954), 648.

[29] Watson, "Optimum Conditions for Music in Rooms" (1926), 209.

the American Standards Association, and he envisions soloists and conductors having in their view "the dial of a sound-level meter which would register the loudness of the music they perform."[30] Suggesting that a musician rely on a number on a dial rather than her own ears and aesthetic sense is borderline absurd. Given Knudsen's immersion with technology and his theoretical understanding of sound, however, one can almost appreciate his enthusiasm for such a scheme.

Vern Knudsen was never a serious contender for the position of acoustical consultant in Buffalo, but his name was mentioned as a leader in the field during a business meeting held in New York City in September 1938 between Edward Letchworth, President of Kleinhans Music Hall Inc., and executives of Electrical Research Products Inc. (ERPI). Kleinhans Music Hall ultimately agreed to hire ERPI to consult on the acoustics of the new hall. Regarding the selection of ERPI, Letchworth praised the organization as having "the most experience in this particular type of work of any in the world."[31]

Plans submitted by the Kidd firm and later by Saarinen for the main auditorium of Kleinhans Music Hall were both fan-shaped in design (figs. 7 and 18). Eero Saarinen also submitted a fan-shaped auditorium plan in early 1939 which earned him first place in a competition for a theater project at the College of William and Mary (fig. 19).[32] Described alternatively as a parabolic, flared, or megaphone type, this plan was "more or less standard" in silent movie theaters by the 1920s.[33] Known mainly as a concert hall today, the fan-shaped Eastman Theatre of Rochester, New York, was built in 1923 to showcase silent movies

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[30] Knudsen, *Modern Acoustics and Culture* (1937), 27.

[31] Letchworth to F.J. Kidd, 8 September 1938, Kleinhans Music Hall archives.

[32] "Winners of National Theater Competition Are Announced" (1939), 61.

[33] Kelley, "Grauman Theatre, Hollywood, Cal." (1932), 125.

accompanied by a full orchestra.[34] By the time of the Kleinhans commission in 1938, concert halls and auditoriums typically adopted the fan-shaped plan, like that of the Eastman Theatre.

In his book, *Buildings for Music: The Architect, the Musician and the Listener from the Seventeenth Century to the Present Day*, architect Michael Forsyth documents a variety of music auditoriums from the Baroque era through today. In a chapter entitled "The Hi-Fi Concert Hall," Forsyth describes concert halls built primarily between the 1920s and 1950s whose plans were flared or fan-shaped, like Kleinhans Music Hall. He writes that,

> The "directed sound" auditorium, with its flared profile on the same principle as the early phonograph horn, became the model for a generation of concert halls… The phonograph analogy goes even further, for although these concert halls lack resonance because the sound is channeled directly toward the sound-absorptive audience, the immediateness of the sound has an attractive, live, "hi-fi" [high-fidelity] quality, comparable to what is produced by good loudspeakers in a carpeted room.[35]

Forsyth cites Kleinhans Music Hall as among the best directed-sound concert halls built in the prewar years. He describes the hall as having a comfortable, modern interior with "little apparent reverberation," but possessing an "attractive 'hi-fi' intimacy with good definition."[36] Definition or clarity refers to the degree to which "individual sounds in a musical performance stand apart from one another."[37] In a hi-fi hall, definition is emphasized by the direct flow of sound to the listener and this clarity is maintained by minimal reverberation where successive sounds are not permitted to overlap or blur together. Today it is generally agreed upon that some

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[34] Brayer, *The Eastman Theatre* (2010), 3.

[35] Forsyth, *Buildings for Music* (1985), 262.

[36] Ibid., 263.

[37] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 30.

degree of reverberation is highly beneficial to certain musical performances (for example, Romantic music of the nineteenth century benefits greatly from substantial reverberation), and ought not to be sacrificed to the modern ideal of definition or clarity. Some music genres, however, do benefit from reduced reverberation times. For example, the polyphonic melodic lines of Baroque chamber music (historically played in small rooms or "chambers") can lose their sense if blurred by too much reverberation. Hi-fi halls like Kleinhans tend to emphasize definition by reducing reverberation. The qualities of low reverberation and high definition which characterize hi-fi concert halls correspond with the ascent of the modern sound: clear, direct, and nonreverberant. These historic halls, according to Blesser and Salter, "With their weak reverberation and strong intimacy …were judged favorably by the standards of their time."[38] They are not judged as favorably, however, by more recent standards.

Forsyth informs us that acousticians and musicians have not always been in agreement regarding music acoustics. He writes,

> The scientific viewpoint of the acoustician has not always coincided with the instinctive preferences of the musician in the extreme stance that the former has sometimes taken in deliberately achieving concert hall acoustics of great clarity at the expense of adequate loudness and fullness of tone. Nearly all North American auditoria built between 1925 and 1940 were based on a philosophy that few would agree with today, which likened the ideal concert hall to the outdoor music pavilion. A number of these – such as the Hollywood Bowl, the Music Pavilion at the New York World's Fair, and the Tanglewood Music Shed – were designed as the summer homes of well-known orchestras.[39]

[38] Blesser and Salter, *Spaces Speak* (2007), 111.

[39] Forsyth, *Buildings for Music* (1985), 259.

Forsyth's allusion to the comparison of an ideal concert hall to an outdoor music pavilion likely refers to the work of Floyd Watson, who in his 1928 article on ideal auditorium acoustics states that for auditors, "the reception of sound appears most satisfactory under conditions resembling outdoors."[40] He bases this conclusion on his review of investigations into elusive perfect acoustics and states that results of these investigations "lead to the surprising and unexpected suggestion that ideal acoustics may be found with conditions resembling the open-air Greek Theater."[41] The open-air analogy refers to the fact that performers in outdoor spaces are often surrounded by a shell or other enclosure which allows for some degree of reflections of sound on stage, while the audience is located in the "dead" conditions of the "perfect absorption of the open sky."[42] Watson refers to his study of 1926, which showed that musicians prefer a reverberant space for playing, while auditors prefer dead surroundings for listening. Watson's auditors of 1926, immersed in the modern soundscape of their day, apparently preferred the listening conditions of sound-dampened environments.

Regarding ideal musical tone, Bagenal and Wood argue in favor of the historic tradition of reverberation in rooms for music:

> Hitherto good music has always had a good home. The history of music in relation to buildings shows that tone design has developed not in the open air nor in the laboratory but in the church, the opera house, and the concert hall. By their longer or shorter reverberation those buildings have favoured this or that type of music; but at all times they have set standards of tone that have been recognized. They should not be less

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[40] Watson, "Ideal Auditorium Acoustics" (1928), 263.

[41] Ibid., 260.

[42] Ibid., 264.

> recognized today, when the foundations of good mechanized music require to be laid intelligently.[43]

They challenge Watson's position that open air acoustics are ideal and deride "laboratory" acoustics, that is, the sound-dampened acoustics of recording and broadcasting studios necessitated by the invention of the microphone and loudspeaker, and made possible by sound-dampening building materials. Although they argue in favor of traditional music hall acoustics, Bagenal and Wood consider the modern fan-shaped auditorium the best plan for a concert hall.[44] They explain that in such a plan, the majority of listeners can be arranged within an ideal distance from the orchestra. They acknowledge the direct sound projected by the fan shape by explaining that "the wall and ceiling splays reflect sound immediately upon the audience."[45] Another advantage is that this shape will maximize the number of seats, a consideration for hall managers seeking to expand their audiences and ticket sales. Bagenal and Wood do suggest, however, that a large concert hall ought to have a reverberation time of about two seconds, substantially longer than the current reverberation time of Kleinhans Music Hall.[46]

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[43] Bagenal and Wood, *Planning for Good Acoustics* (1931), 89.

[44] A remarkable note regarding the fan-shaped plan of Kleinhans Music Hall was discovered in the record of Kidd and Kidd's meetings binder in the Kleinhans archives. A memorandum from Kidd and Kidd architect Stuart Cary Welch dated January 9, 1939, summarizes the analysis of famed architectural critic Siegfried Giedion, who during his time as the Charles Elliott Norton lecturer at Harvard University, was apparently invited to inspect Saarinen's plans for Kleinhans. Welch writes that Giedion, "questioned the parabolically curved walls of both auditoriums and said that such forms were now largely in the discard, owing to the structural and acoustical difficulties involved, and that the latest practice showed a return to the older, rectangular forms for auditoriums." As Carl Herko notes (page 58) in his paper on Saarinen's music halls, this second-hand information was written by an employee of the firm who lost the Kleinhans commission to Saarinen, and therefore must be taken with a certain degree of skepticism. It is interesting to note, however, that the fan-shaped plan was eventually surpassed in popularity by a return to the traditional oblong plan, but not until at least a decade after the time Giedion allegedly made his critique.

[45] Bagenal and Wood, *Planning for Good Acoustics* (1931), 129-30.

[46] Ibid., 335.

For another acoustician's point of view regarding the benefits of reverberation particularly with respect to music, let us turn to Paul Sabine. Paul Sabine was selected by Eliel Saarinen to provide early advice on the acoustics of Saarinen's proposal for Kleinhans Music Hall, and Sabine continued to provide advice at various times throughout the hall's construction. It is worth noting that Sabine, like Bagenal and Wood, is sympathetic to a musician's sense of reverberation as a positive force in music. Sabine writes,

> If the reverberation time is too great, the overlapping of successive sounds blurs the fine effects of music, and is fatal to the clear understanding of speech. If it is too small, the effect is to produce dullness and loss of tone volume, objectionable chiefly to the performers, who experience a sense of not securing musical results commensurate with their efforts. One seeks for the golden mean.[47]

Sabine raises another important feature of reverberation which is that it serves to reinforce volume: a significant feature in the dynamics of musical performance. The acoustics of a hall can serve to reinforce or impede volume. In the latter case, musicians may strain to double their efforts while in the former, resonant acoustics can aid the performers by reinforcing the sound they produce.

For a musician's account of how reverberation can aid in performance, master violinist Isaac Stern has this articulate statement:

> Reverberation is of great help to a violinist. As he goes from one note to another the previous note perseveres and he has the feeling that each note is surrounded by strength. When this happens, the violinist does not feel that his playing is bare or "naked" – there is a friendly aura surrounding each note. You want to hear clearly in a hall, but there

[47] Paul Sabine, "Acoustics of the Chicago Civic Opera House" (1930), 602-3.

> should also be this desirable blending of the sounds. If each successive note blends into the previous sounds, it gives the violinist sound to work with. The resulting effect is very flattering. It is like walking with jet-assisted takeoff.[48]

We can see by this account that reverberation is appreciated by some musicians. Stern does refer to the desire for hearing "clearly in a hall," but clarity should not supersede some measure of reverberation in Stern's estimation. According to Beranek, Isaac Stern who was, "usually critical of a dry sound," said about Kleinhans Music Hall that the sound on the stage was quite good, and that "he felt a sense of immediacy and support" while playing there.[49]

Since Wallace Sabine assisted with the acoustical planning of Boston Symphony Hall in 1899, every major music hall has engaged an acoustical consultant in its design. Kleinhans Music Hall, built just forty years after Boston Symphony Hall, was very different from McKim, Mead and White's Beaux-Arts design. Simple, modern, and streamlined, Kleinhans not only looked different from its heralded predecessor, it sounded different. The mid-frequency reverberation time of Boston Symphony Hall with a full audience is approximately 1.93 seconds, while the mid-frequency reverberation time of Kleinhans Music Hall with a full audience is approximately 1.50 seconds – less than optimal.[50] Although there are other desirable acoustic attributes besides reverberation, such as blending of orchestral voices and a listener's sense of being enveloped by the music, reverberation is one important quality that is quantitatively measurable and hence less subjective. Kleinhans does indeed have very desirable acoustic

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[48] Isaac Stern quoted in Beranek, *Concert Halls and Opera Houses* (2004, 1996), 7.

[49] Beranek, *Concert Halls and Opera Houses* (1996, 2004), 51.

[50] Ibid., 586, Appendix 2.

qualities such as clarity, blending, and envelopment (particularly in the balcony seats), however, its reverberation time is considered low for a symphony hall.

While planning Philharmonic Hall at Lincoln Center in New York City, the New York Philharmonic Symphony Society sent a letter on April 20, 1959 to the architect, Max Abramovitz, stating their acoustical preferences. They wrote,

> in the Society's judgment, the acoustics of the Hall should approximate as closely as possible those of the Boston Symphony Hall, when filled, but in no event should the reverberation time be shorter… We understand, however, that it is much more feasible to adjust from a longer reverberation to a shorter than vice-versa. If this is true, special care should be taken not to run any danger of too short a time. In our opinion, the acoustics of Kleinhans Hall in Buffalo… [is] disappointing, whether due to the fan shape of the hall or the shortness of reverberation time, we are not prepared to say.[51]

Similarly, Beranek has this to say about the acoustics of Kleinhans Music Hall: "Controversy has surrounded its acoustics largely because its parabolic shape brings the music directly to the listener, emphasizing the early sound, at the expense of the reverberant sound and giving the hall the reputation of being too dry."[52] The acoustics of Kleinhans is considered to be dead or dry rather than lively owing to a combination of the fan-shaped hall and considerable sound absorption. The low reverberation time also means that the sound is not as loud as it might be, and Beranek laments that the *fortissimos* (very loud passages) in Kleinhans are not as impressive as in Boston Symphony Hall.[53] Nonetheless, Beranek, who attended several concerts at

[51] Quoted in Leo Beranek, et al., "Acoustics of Philharmonic Hall, New York, during Its First Season" (1964), 1247.

[52] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 51.

[53] Beranek, *Concert and Opera Halls* (1996), 83.

Kleinhans, praised the hall, stating that "the brilliance of the string tone is excellent, particularly on the main floor, and the sound is warm with rich full bass."[54]

While clear, direct, and nonreverberant sound was the dominant soundscape at the time of the construction of Kleinhans Music Hall, Esther Link, Acting Director of Kleinhans Music Hall from 1938-1940, strongly opposed this sound. Link, a high school music teacher, had very clear ideas as to how a music hall should sound. Granted a leave of absence from her teaching position in Buffalo Public Schools, she worked tirelessly as acting director to help build the best possible music hall with the most convenient and state-of-the-art facilities. The acoustics of Kleinhans Music Hall were planned and executed under her careful supervision and scrutiny. While the governing board of Kleinhans Music Hall generally desired a modern facility, at least one person, Acting Director Link, desired a traditionally resonant music hall – one cloaked in a modernist design.

In the following chapter, I will explain how the science of acoustics was applied to Kleinhans Music Hall by Charles Potwin of ERPI, and Paul Sabine, of Riverbank Acoustical Laboratories. It was hoped by Kleinhans management that the finest possible acoustics would be achieved with the most up-to-date technical advice provided by these consultants. The story of the acoustical planning of Kleinhans Music Hall follows.

[54] Ibid.

Chapter IV THE ACOUSTICAL PLANNING OF KLEINHANS MUSIC HALL

In planning Kleinhans Music Hall, the executive board sought to build the best building for music they could possibly achieve. In addition to the sizable bequest left by Mr. and Mrs. Kleinhans, they arranged for federal funding from the Public Works Administration to pay for nearly forty-five percent or $584,000 of the construction cost.[1] By hiring Eliel Saarinen as the designer of the new hall, they ensured that Kleinhans Music Hall would be unique and modern. Kleinhans Music Hall Board of Directors also considered hiring an acoustical engineer, "to assure outstanding results in the Kleinhans Music Hall" just before Esther Link was officially appointed acting director.[2] Esther Link, considered well qualified based on her musical knowledge and supervisory experience, was hired on August 25, 1938 (fig. 20). Link had business experience running her family's gift shop, Pitt Petri, which sold luxury items like crystal, china, jewelry and other high-end merchandise. Pitt Petri employed the services of a local architect, Harvey S. Horton, to remodel their stores, and Link worked with him on the planning and execution of the design.[3]

Six weeks before Esther Link's appointment, she sent a letter to the president of Kleinhans Board of Directors, Edward Letchworth, an attorney employed by Pitt Petri, which likely helped her gain the position (fig. 21).[4] Regarding the construction of Kleinhans Music Hall, Link writes, "having determined our needs, I should sit humbly but absorbingly at the feet of innumerable experts (sound proofing, air-conditioning, etc.) engineers, builders, especially of

[1] Kleinhans Music Hall Management, "Kleinhans Music Hall" (1953), 7.

[2] "The Kleinhans Music Hall Chronicle," Kleinhans Music Hall archives.

[3] Ginal, "The Development of the Kleinhans Music Hall Commission" (1989), 30.

[4] Herko, "Saarinen's Music Halls" (1999), 47.

acoustic experts. I should meet the man who designed that masterpiece, Radio Center, and find the why of the excellent acoustics of Radio City movie hall [*sic*]." Once appointed acting director, Link did indeed establish a correspondence with the man affiliated with the acoustics of Radio City Music Hall, prominent acoustician Paul Sabine. She probably did not realize it at the time, but the dry acoustics of Radio City differed significantly from the resonant acoustics she desired for Kleinhans Music Hall.

The Kleinhans Music Hall governing board had begun the search for an acoustical consultant before Link's appointment. They no doubt realized the importance of having acoustical guidance in the planning phase. The following account will trace the history of the acoustical consultation of Kleinhans Music Hall which I gleaned from the archives at the music hall and from a sub-chapter of John W. Kopec's book, *The Sabines at Riverbank*. Kopec served as director of the Riverbank Acoustical Laboratories from 1972-1998. During that time he wrote a history of the members of the illustrious Sabine family who were associated with Riverbank: Wallace Sabine, his distant cousin Paul Sabine, and Paul's son Hale Sabine.[5] It should be noted that the archives at Kleinhans Music Hall are incomplete, although a few of the many letters between Link and Sabine to which Kopec refers can be found there. When Link was dismissed by the management in May 1940, she removed letters, stenographic notebooks, and other materials, claiming in a letter to Letchworth that they were "personal and informal" in nature.[6] In his reply, Letchworth demanded that Link return everything she removed from the office: letters, folders (including the Sabine and Stokowski folders), newspaper clippings, and

[5] A portion of Kopec's book, "The Hazards of Acoustical Consulting: The Kleinhans Music Hall Dilemma," is based on the Paul Sabine file at Riverbank, and details the correspondence between Paul Sabine and Esther Link. The Paul Sabine file was missing as of my visit to Riverbank in November 2010.

[6] Link to Letchworth, 5 June 1940, Kleinhans Music Hall archives.

stenographic pads.[7] It appears, unfortunately, that some of the material was never returned to Kleinhans Music Hall, and other material may simply have been lost over the years.

Because files are missing from both the Kleinhans archives and the Riverbank Acoustical Laboratories, not every letter exchanged between Link and Sabine is available. Although Kopec gives a thorough account of their correspondence, he did not include the dates of each letter in his narrative, thus leaving to conjecture some of the timeline. According to Kopec, Sabine completed a final report on the acoustical treatment of the main auditorium, but that report could not be located in either the Kleinhans archives or at the Riverbank Acoustical Laboratories. I, therefore, must rely on Kopec's brief summary of Sabine's final acoustical report. According to Kopec, Sabine wrote in his final report of March 12, 1940, "While in detail it is not exactly what I should have recommended, yet I feel sure the results will be satisfactory."[8]

The first attempt to hire an acoustical consultant occurred just before the appointment of Esther Link. On August 18, 1938, Edward Letchworth sent a telegram to Richard Fay of Massachusetts Institute of Technology requesting he consider employment as the acoustical engineer for Kleinhans. Fay was highly recommended by G.E. Judd, manager of the Boston Symphony Orchestra, for his acoustical work on the Tanglewood Shed, the symphony's new summer home which had just opened in 1938. Explaining the early search for a consultant, Link later wrote to Sabine:

> At that time you [Sabine] were on holiday, Vern Knudsen in California was too far away and Fay was on an island off the Maine coast. Then Leopold Stokowski who had great success working with ERPI on his radio broadcast recommended that in the east Mr.

[7] Letchworth to Link, 5 June 1940, Kleinhans Music Hall archives.

[8] Quoted in *The Sabines at Riverbank* (1997), 123.

> Stanton was the best man. Stanton also was recommended by Ralph Walker, an architect for the New York telephone company. Since one of our directors also is a director for the same telephone company and since ERPI is a subsidiary of theirs, ERPI was given the contract.[9]

Link refers to Stokowski's recommendation of Stanton of ERPI. Leopold Stokowski was conductor of the Philadelphia Orchestra, a champion of modern music and architecture, and soon to be famous for his iconic role as the figure of the conductor in Walt Disney's movie *Fantasia*.[10] Link would turn to Stokowski for acoustical advice in the months ahead. Although it seems that Stokowski's recommendation of Stanton might rate highly with Link – who held Stokowski's opinion in great esteem – she explains the appointment of ERPI as the result of business connections between a Kleinhans board member and New York Telephone.

Before ERPI was officially engaged by the Kleinhans Board of Directors, Edward Letchworth paid a visit on September 7, 1938 to their New York offices where he met G.T. Stanton, Manager of Technical Consulting (Stokowski's recommended consultant). At the meeting, Stanton gave Letchworth a copy of C.C. Potwin's article, "Theater Acoustics," published in *Architectural Record* in July 1938. Potwin, a technical consultant with ERPI, eventually became the lead acoustical consultant for Kleinhans. His article on theater acoustics details basic precepts of acoustical planning and control. Perhaps the most interesting point in Potwin's article – considering the final acoustical results of Kleinhans Music Hall – is his reference to sound absorbing "aisle carpetings," which he states can be removed in cases where

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9 Quoted in Kopec, *The Sabines at Riverbank* (1997), 119.

10 Stokowski was known for performing modern music in Philadelphia; see Thompson, *Soundscape of Modernity* (2002), 139, 141, 154. William Lescaze decorated Stokowski's apartment in a modern style; see "Philadelphia's Fancy," *Fortune* 6 (December 1932): 68.

reverberation time is deemed too short.[11] The day after their meeting, Letchworth wrote to Stanton thanking him for the Potwin article and advising him that ERPI will be employed as "acoustical engineer or consultant" for the new hall in Buffalo.[12] After some negotiation, ERPI was officially engaged by the Kidd firm on October 25, 1938 to design the acoustical work at Kleinhans Music Hall for a lump sum payment of $1500, plus travel expenses.[13]

Early in Esther Link's tenure as acting director, she enlisted the help of Leopold Stokowski: mostly in matters of acoustics, but also for his advice on the logistical needs of an orchestra (fig. 22). Stokowski served as an unofficial advisor in the planning phase, and there is a total of ten letters dating between November 1938 and April 1939 between the maestro and Link in the archives at Kleinhans. Stokowski did not appear to receive any remuneration for his advice, and the nature of his relationship with Link is unknown. Since Link's sister lived in Philadelphia, it is possible that she may have met Stokowski while visiting that city. Stokowski appeared very willing to share his opinions with her. Unlike the letters between Link and Sabine which are sometimes lengthy, more personal and occasionally humorous, the Stokowski letters are cordial and brief.

In a letter dated November 21, 1938, Stokowski sent Link two very rough sketches of a fan-shaped auditorium plan, and a section showing a coved ceiling and a raked seating area with a stage at the bottom (fig. 23). In the letter, Stokowski writes regarding concert hall acoustics that, "The main consideration is reflection of the music from the walls, ceiling, etc… the back

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[11] Potwin, "Theater Acoustics" (July 1938): 119. In the large concert hall at Kleinhans, the main floor and most of the balcony are completely covered, wall-to-wall, in carpeting. This carpeting, which goes far beyond "aisle carpetings" in floor area, contributes to lowering reverberation time. The comment by Potwin demonstrates that he is not opposed to increasing reverberation time when desired.

[12] Letchworth to Stanton, 8 September 1938, Kleinhans Music Hall archives.

[13] F.J. and W.A. Kidd to Stanton, 25 October 1938, Kleinhans Music Hall archives.

wall of the concert stage can be made the reflecting surface – if you curve over the ceiling as in the enclosed rough sketch. And the side walls of the stage can also reflect as in the enclosed sketch of the plan."[14] In Stokowski's plan, the rear of the stage shows a slightly convex "reflector" wall, which was in fact incorporated into the design of Kleinhans Music Hall and exists today. I believe it is unlikely that Stokowski's suggestion influenced the inclusion of this feature in the final design. Acoustical experts at the time understood that concave surfaces, like domes and barrel vaults, were to be avoided since they tended to create focused echoes, an imperfection to be avoided in any auditorium. Convex shapes, like the rear reflecting wall, however, were deemed useful in reflecting sound. Stokowski's section shows a gently sloped concave ceiling. This ceiling was not incorporated into the design for Kleinhans. The ceiling that was eventually built in the hall consists of a series of convex coves undulating ever higher from the shallow back of the stage to the full height of the large balcony.

Link appeared more inclined to follow Stokowski's recommendations than those of the Buffalo Philharmonic's conductor at the time, Franco Autori (fig. 24). For instance, Autori requested risers in order to seat different orchestra sections on separate planes.[15] Link solicited opinions on the use of risers from Stokowski, Sabine and one of the architects (possibly Eliel or Eero Saarinen). Stokowski replied that risers, "are not good for orchestral tone. It is better to put the orchestra down on the firm wooden surface of the platform."[16] Giving his personal preference in favor of the visual advantages which risers provide, Sabine wrote that he enjoys watching the musicians "during dull moments in the music… Yet a departure from tradition

[14] Stokowski to Link, 21 November 1938, Kleinhans Music Hall archives.

[15] Link to Letchworth, 22 May 1940, Kleinhans Music Hall archives.

[16] Stokowski to Link, 12 January 1939, Kleinhans Music Hall archives.

needs something more than a personal preference to justify it. There is of course no weight or authority in the forgoing so do not breathe this to Leopold [Stokowski]."[17] Regarding the architect's opinion, Link wrote in a letter to Letchworth, "An objection to risers was made by one of the architects that with the ceiling coming down by coves and the wall receding by fins, with risers you would also have the floor brought into motion and the whole thing would be very restless."[18] She also recommends in the same letter that Saarinen design the risers should they ultimately be desired.

The use of risers is a matter of taste and is still something of a controversy today. While some orchestras and conductors believe that superior sound is produced with risers, others are convinced that a flat platform is best for musical tone. For example, while Stokowski opposed their use for the Philadelphia Orchestra, Serge Koussevitzky, conductor of the renowned Boston Symphony Orchestra, was a proponent of risers and used them in Boston Symphony Hall (fig. 25). Sound quality aside, I have to agree with the unnamed architect: from a visual point of view, risers would create a restless, unsettled quality in the main auditorium of Kleinhans Music Hall. Saarinen never did design risers for Kleinhans Music Hall and they are only used sparingly depending upon the repertoire and instrumentation requirements by the Buffalo Philharmonic Orchestra today.[19]

Another piece of advice Stokowski offered Link is that high humidity is important for good sound.[20] Ever vigilant, Link solicited opinions from both Sabine and Potwin on this issue.

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[17] Quoted in Kopec, *The Sabines at Riverbank* (1997), 124.

[18] Link to Letchworth, 22 May 1940, Kleinhans Music Hall archives. Link does not name the architect.

[19] Daniel Hart, Director, Buffalo Philharmonic Orchestra, personal communication, 14 July 2011.

[20] Stokowski to Link, 12 January 1939, Kleinhans Music Hall archives.

Sabine suggested to her that the, "comfort of the public must determine the humidity."[21] Potwin responded that "variations in humidity do have an effect upon the absorption of sound in large auditoriums but only for the very high frequencies. This factor was of course given very careful consideration in planning both the interior form and acoustical treatment for the Music Hall."[22] Given that air conditioning was installed when the building was constructed, we can assume that the comfort of the audience prevailed, and perhaps that Potwin's assurances were accepted.

Link continued to keep Stokowski informed of the evolving plans for the new hall. For example, on March 1, 1939, she wrote to Stokowski informing him that, "ERPI wants the side walls of the stage as well as of the auditorium to be jogged." In his reply, Stokowski asks if the jogs (or fins) at the side of the stage are for lighting, ventilation or acoustics.[23] Link responds with a very nice description of the hall as it was eventually to be built:

> The fins on the wall are for acoustical purposes. I know your attitude on this subject that a straight ceiling, straight walls, and a straight back would be very satisfactory, but the acousticians in Stanton's office [ERPI] wanted it the other way. Inasmuch as the stage is merely a raised platform in the front end of the auditorium, the walls and ceiling of the stage are really a continuation of the walls and ceiling of the hall. In the hall fins have been introduced for acoustical purposes and so carried through the walls of the platform. The ceiling of the entire hall including the stage ceiling is shaped like a succession of ripples, lights being place in coves for indirect illumination.[24]

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[21] Hand-written note by Link in the margin of Stokowski to Link, 12 January 1939, Kleinhans Music Hall archives.

[22] Potwin to Link, 28 July 1939, Kleinhans Music Hall archives.

[23] Stokowski to Link, 18 March 1939, Kleinhans Music Hall archives.

[24] Link to Stokowski, 27 March 1939, Kleinhans Music Hall archives.

Link shows a willingness to accept ERPI's recommendations regarding the jogs or fins in the walls against Stokowski's alleged preference for flat surfaces. Perhaps Link was familiar with a basic principle of room acoustics which is that smooth, flat surfaces can produce harsh, glaring sounds or "slap-backs," and that multidimensional surfaces (like those in Boston Symphony Hall) actually produce the best results.[25]

In a final letter between Link and Stokowski dated April 19, 1939, Link sent an attachment (missing) in which she asks how Philadelphia's orchestra has solved the problems listed on the sheet. She suggests that Stokowski turn the matter over to an assistant.

When drawing his plans for Kleinhans Music Hall, Eliel Saarinen initially consulted with Paul Sabine, director of the Riverbank Laboratories, for acoustical advice. Soon after Saarinen won the Kleinhans commission, Sabine visited him at his office in Bloomfield Hills, Michigan on January 26, 1939. Sabine has very positive things to say about the visit in a letter to Link:

> I had a most interesting conference with Mr. Saarinen and his son, and I feel sure that we can work out designs for both rooms [main auditorium and chamber hall] that will not only be beautiful from the architectural point of view, but highly satisfying acoustically.
>
> I have worked with a great many architects in this manner and I am convinced that only by including acoustics as a design requirement and by close cooperation between the architect and acoustical consultant can the best results be secured. I think I have never had the pleasure of working with an architect who was more intelligent and receptive of the requirements which acoustics imposes on design than Mr. Saarinen. I

[25] See Chapter II above for a brief discussion of this phenomenon.

> feel sure that the completed design will not call for any apologies either on the score of good acoustics or good architecture.[26]

In Link's reply, she informs Sabine that Saarinen was only permitted to use his services until the preliminary design was completed. Although both Saarinen and Link prefer Sabine, ERPI is already under contract for the work at this time. In a letter to Sabine, Link expresses her mistrust of ERPI and her wish that Kleinhans Board of Directors:

> would still retain Paul [Sabine] and relegate ERPI to the position of technical consultant. Yet to explain away an organization of such magnitude and unlimited self confidence, plus such tremendous output and the backing of Stokowski would indeed be most difficult. Although the Saarinens prefer you, they under the circumstances are forced to recognize ERPI. Representing ERPI is Mr. Potwin. Fortunately he did study violin for nine years and since I do prefer a musician who is a physicist or a physicist who is a musician, rather than a non-musical engineer, I still feel confident that ERPI will be inclined to make the hall overly dull.[27]

In his reply, Sabine reminds Link that ERPI has consulted on many successful theaters and auditoriums, but admits the existence of a downward trend in reverberation times in acoustical planning. He writes, "I have a feeling that unless the acoustical engineer has someone like yourself to hold them in check the music halls are apt to come out on the dull side."[28] Sabine appears to be encouraging Link in her bias against ERPI. He informs Link that although he would be very glad to render his services as an acoustical consultant, neither the Board of

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[26] Sabine to Link, 30 January 1939, Kleinhans Music Hall archives.

[27] Quoted in Kopec, *The Sabines at Riverbank* (1997), 119.

[28] Ibid., 120.

Directors nor the Saarinens have officially retained him. Link, a staunch supporter, presses Sabine to continue his consulting work. Sabine reacts to the state of affairs by writing that it would be wise of him to "withdraw from this situation entirely." Many months after his visit to Bloomfield Hills, Sabine resigned his unofficial position as acoustical consultant on August 28, 1939, and billed the Saarinens $99 for his services (far less than the $1500 ERPI bill). Sabine did receive payment along with a note from Eero Saarinen, who writes, "I am a little embarrassed about the way we left the whole situation unsettled for such a long time. I believe, however, that the electrical research products engineers should finish the job as they are now working quite hard on it."

Link continued to insist upon Sabine's involvement and on the paramount importance of good sound in the music hall. On October 4, 1939, she writes to the Saarinens that, "The acoustical problems are the crux of the hall. Therefore, we should give great consideration to any recommendations that Mr. Sabine might make." In a follow-up letter to the Saarinens, Link avers that Sabine had permission to do the "final conditioning" of the hall. It seems that the Saarinens, probably aware of Link's bias, were somewhat skeptical of this communication. Eero Saarinen, although reportedly pleased with this development, nevertheless requested that the president of Kleinhans Board of Directors, Edward Letchworth, "put it all in writing." Letchworth did so, but not until several months later in a letter dated January 25, 1940.[29]

In her correspondence with Sabine, Link, in my view, is unfairly critical of Potwin's early writings about the acoustical planning of Kleinhans Music Hall. She writes,

> I read in Potwin's two articles in the architectural forum where he expounded on the principle of acoustics and how they were applied in the Kleinhans Music Hall apparently

[29] Ibid., 120-23.

> by him. When you consider that the main acoustical problems were determined by you and the essential design of the hall determined by the Saarinens and/or us, the Forum article is really astonishing.[30]

Link is referring to a two-part series in *Architectural Forum* dated August and September 1939. The first article, presented as a primer in architectural acoustics, was actually written by Stephen Macdonald, with assistance from Potwin in arranging the material for publication. The second article, written by Potwin, describes factors governing room acoustics including shape, volume, and sound absorbing materials, and the best practices regarding these factors. The introduction to this article refers to Potwin as, "one of the country's foremost authorities on acoustical correction," and a "leading expert of the position that good acoustics may best be achieved in new work primarily by way of functional design rather than by relying solely on corrective materials."[31] In fact, Potwin authored or co-authored several journal articles from 1938-1940 in which he advocated "functional planning" for good acoustics, one result of which is to reduce excessive use of sound absorbing materials. In the article, "A Modern Concept of Acoustical Design," Potwin and co-author J.P. Maxfield refer to the fact that reverberation times in acoustically treated rooms are often lower than optimal due to the overuse of acoustical treatments. Additionally, they write, "The present values of so-called optimum times of reverberation can probably be raised."[32] Thus, Potwin appears poised against the trend of low reverberation times in room acoustics, and we can assume is less likely than Link believes he is to reduce Kleinhans Music Hall to the status of a "dead" auditorium.

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[30] Ibid., 121-22.

[31] Potwin, "Architectural Acoustics: 2" (1939), 201.

[32] Potwin and Maxfield (1939), 55.

Potwin briefly describes the acoustical treatment of Kleinhans Music Hall in the *Architectural Forum* article. He begins by stating that the hall was built in close collaboration between the architect (Saarinen) and acoustical consultant (Potwin) in an effort to arrive at ideal acoustics. The balcony, he explains, often a problem area "because of its tendency to 'blanket' the rear seats on the first floor, has been worked out actually to improve sound-reception at this point, by supplying needed [sound] reflections from a ceiling sloped up to the orchestra."[33] That is, the underside of the balcony – extending cantilever-like over several rows of seats at the rear of the first floor – is not horizontal. Rather, it slopes slightly upward to capture and reflect sound from the stage (fig. 26). In my experience, sound does not carry that well from the orchestra to the rear of the ground floor, in spite of the unusual upward slope of the balcony. The feeling of envelopment by the music is lacking beneath the balcony, and the sound seems remote and confined to the front of the auditorium. While Potwin's design may indeed have a positive effect on sound distribution in the area beneath the balcony, it is not as effective as he suggests.

A goal of auditorium acoustics is to have uniformly good sound distributed evenly throughout. This is not always possible and some seats may be more "live" while others "dead." Addressing the distribution of sound in Kleinhans Music Hall, Potwin describes the design of the stage and auditorium as, "a single unit, with the sidewall splays and convexly curved rear wall of the stage designed to direct first reflections uniformly to the audience area."[34] This design aids in the distribution of sound, which is generally very good throughout the main auditorium of Kleinhans. The seats at the rear of the first floor, however, are not as lively as elsewhere.

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[33] Potwin, "Architectural Acoustics: 2" (1939), 202.

[34] Ibid. "First reflections" are the initial waves of sound which bounce off the walls, ceiling, floor, and other surfaces before reaching the ears of listeners.

In the *Architectural Forum* article, Potwin states that the walls and ceiling of the hall are "shaped and treated to disperse and absorb sound with a small amount of absorption material distributed non-uniformly in panels of various sizes." This sound absorbing material is irregularly placed behind perforated panels along both sides of the walls of the auditorium from beyond the stage to the balcony. Potwin refers to the small amount of sound absorbing material distributed non-uniformly. He supports the use of scattered, nonsymmetrical absorption and dispersion areas rather than uniform sound absorption areas in order to achieve better acoustics. This approach, he explains, allows for areas of sound reflection in all parts of a room, giving it "more 'life' acoustically" and obviating "the effects of overcorrection and spottiness often present in rooms with large, uniform absorption areas."

Regarding reverberation time, Potwin writes, "With the widespread use of absorption materials characteristic of the past several years, there has been a tendency downwards in what are regarded as the best times of reverberation for various types of rooms. As acoustical designs are gradually refined, however, there is every indication that this trend will be reversed." Potwin is correct in his prediction since optimal reverberation times did, in fact, edge back upward over time. His article concludes with a graph displaying recommended reverberation times of rooms of various sizes. This graph shows that for auditoriums the size of Kleinhans Music Hall (662,000 ft^3 or 18,750 m^3), the desirable reverberation time for a symphony orchestra approaches 2.0 seconds (fig. 27). Thus, Link's fears about Potwin's predilection toward lower reverberation times are ill-founded.

One subject of controversy regarding the acoustical treatment of Kleinhans was the use of a patented wall finish called Flexwood, which Potwin proposed for the main concert hall. Flexwood is a thin wooden veneer with a linen backing measuring 1/16 inch (1.6 mm) in width, and has been compared to wooden wallpaper.[35] Like wallpaper, Flexwood must be glued or cemented onto a wall. In a letter Link sent to Sabine at the end of December 1939, she refers to Flexwood as looking "chewed up and tacky."[36] This description of Flexwood is difficult to understand. Perhaps the samples Link saw were worn around the edges, poorly cut, or contained perforations in a haphazard design. In any case, Link hoped that Sabine's influence with the Saarinens could prove useful in preventing Flexwood from being installed. After Sabine was officially engaged by the Kleinhans Board of Directors in January 1940, the Saarinens did in fact decline the use of Flexwood. In a Kidd firm memorandum dated February 9, 1940, it was reported that Potwin had received Saarinen's revised drawings of the acoustical treatment of wall surfaces – presumably lacking a Flexwood finish – and that he did not approve.[37] Several months later in May 1940, Potwin was still promoting the use of Flexwood, and Saarinen finally acquiesced by finding an acceptable pattern for the perforated holes to be inserted in some of the Flexwood panels according to Potwin's directive.[38]

In the minutes of a Kidd and Kidd meeting, it was reported that Mr. Saarinen would be in Buffalo on August 17, 1940 to give final approval to the Flexwood samples.[39] Saarinen may have felt some pressure to approve the Flexwood panels at this time since it was stated in the minutes that a change in plans would result in a major cost increase. Saarinen did approve the final samples, and Flexwood was soon installed throughout the main auditorium where it can be

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[35] Theodore Lownie (Partner, Hamilton, Houston and Lownie – Kleinhans Music Hall restoration architects), personal communication, 17 May 2011.

[36] Quoted in Kopec, *The Sabines at Riverbank* (1997), 123.

[37] *F.J. and W.A. Kidd Architects* binder, Kleinhans Music Hall archives.

[38] Kopec, *The Sabines at Riverbank* (1997), 124.

[39] Minutes, 15 August 1940, *F.J. and W.A. Kidd Architects* binder, Kleinhans Music Hall archives.

seen today. Completely at odds with Link's criticism, the Flexwood panels look smooth and opulent, and the golden-hued wooden panels lend the cavernous room a feeling of warmth which it might otherwise lack.

Small, round perforations in the Flexwood appear in ten panels on each of the two walls in the main auditorium beyond the stage. Sound absorbing material is arranged randomly behind these panels. Potwin's method of randomly arranging sound absorbing material of various sizes was designed to distribute sound more uniformly. As explained by Potwin above, scattered, nonsymmetrical sound absorption areas (coupled with areas of reflection) are designed to give a room more acoustical liveliness.[40] In a letter sent March 6, 1940, Potwin assures Link that the amount of acoustical sound absorbing material used in Kleinhans Music Hall is "exceedingly small" [Appendix A]. Potwin also mentions in the letter that he has heard from Eero Saarinen that Dr. Paul Sabine has been asked to compute reverberation times, and he will be glad to cooperate with him. This appears to be the only time that Potwin was informed that Sabine continued to play some role in the acoustic conditioning of the music hall.

Approximately two months after Potwin agreed to cooperate with Sabine, Sabine was consulted by Saarinen regarding a change to the rear wall beneath the balcony. Saarinen (or the Kidd firm) had been advised to glue fabric directly onto the finished plaster surfaces of this rear wall. Skeptical of this advice, Edward Letchworth, the president of the Kleinhans Board of Directors, "would rather not make this change unless Sabine agreed."[41] Letchworth, like Link, seems to have placed more faith in Sabine's assessment than in the advice given by ERPI. Sabine must have agreed to covering the rear wall in fabric because it can be found there today.

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[40] Potwin, "Architectural Acoustics: 2" (1939), 204.

[41] Quoted in Kopec, *The Sabines at Riverbank* (1997), 125.

The fabric, a heavy woven monk's cloth, serves to absorb sound at the rear wall.[42] Monk's cloth is a cotton fabric with a rough basket weave. It is possible that acousticians recommended installation of this soundproofing material because they were concerned about echoes forming by sound reflecting between the rear and front walls.[43]

Around this time, after nearly two years of dedicated service, Esther Link was dismissed from her job as acting director of Kleinhans Music Hall as of July 1, 1940, before the building's completion. Still very much interested in the progress of her cherished music hall, Link continued to correspond with Sabine. Upon hearing the news of her dismissal, Sabine wrote in a humorous vein that he did not know whether to extend his "condolences or congratulations," but he then kindly reminded her that she had undertaken a "most difficult task and, therefore, had the greatest satisfaction of a job well done."[44]

Link had a tendency to work independently of the Board of Directors which likely led to her dismissal. For example, in October 1939, Philip J. Wickser, Vice-President of the Board of Directors, sent Link a letter warning her not to "interfere" with Mr. Saarinen, and referring to the fact that the board had experienced similar difficulties with Link in the past.[45] In the October 1939 incident, Link had made an unusual request of the architect: she asked Saarinen to not stagger the seats in the main auditorium. Considering the detrimental affect non-staggered seats would likely have on sight-lines, it is hard to imagine what compelled her to make this request. I can only conclude that she believed that by aligning the audience in strict rows, the considerable

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[42] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 54.

[43] Bagenal and Wood recommend that absorbing material be placed on the back wall of concert halls in order to prevent echoes returning to the platform in *Planning for Good Acoustics* (1931), 335.

[44] Kopec, *The Sabines at Riverbank* (1997), 125.

[45] Wickser to Link, 19 October 1939, Kleinhans Music Hall archives.

sound absorbing properties of people and clothing might be reduced. In any case, word of Link's unusual request got back to the board and Link was admonished by Wickser. The seats in the main auditorium were originally installed in a staggered fashion and remain so today. Seven months after this incident, on May 24, 1940, the Board of Directors voted to replace Link and appoint Winifred Eaton Corey the first official director of the music hall. Corey was to take over duties from Link on July 1, 1940. At the time of this change in leadership, the music hall was still not complete, and the opening concert and dedication ceremony were not scheduled until October 1940.

I have attempted to outline the broad considerations applied to the acoustical conditioning of Kleinhans Music Hall and to give an idea of how they came to be. These acoustical considerations include the fan-shaped auditorium which channels sound directly to listeners (as described in the previous chapter), finned walls coupled with small sound absorbing surface areas which together serve to distribute sound in the best manner. Other acoustical treatments include the rear wall covered in monk's cloth and wall-to-wall carpeting of the main auditorium, which both serve to absorb sound. Additionally, in the essay, "Acoustics," from the Kleinhans Music Hall commemorative booklet first published in 1942, Charles Potwin described another formal consideration which he took into account in planning the acoustics of Kleinhans: the volume per person in the main auditorium, 230 cubic feet, is considered a desirable ratio for an auditorium of its size. In fact, Bagenal and Wood give the volume per seat for Boston Symphony Hall and the Eastman Theatre as 220 and 240 cubic feet, respectively.[46] Kleinhans

[46] *Planning for Good Acoustics* (1931), 119.

Music Hall's ratio fits neatly between these two halls which are known for their good acoustics and substantial reverberation times.

In the next chapter, I will present the results of technical studies conducted in the hall. I will review the final results and discuss opinions of auditors. Nearly every native Buffalonian to whom I have spoken about the acoustics of Kleinhans Music Hall is convinced that the sound is excellent, if not superior. Leo Beranek writes that, "Buffalo's audiences are proud of the hall and most find no fault with its acoustical properties."[47] When the Kleinhans Music Hall first opened, however, the accolades regarding acoustics were not as universal as they are locally today.

[47] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 51.

Chapter V THE ACOUSTICAL RESULTS IN KLEINHANS MUSIC HALL

Just two months after the official opening of Kleinhans Music Hall, the illustrious conductor Serge Koussevitzky performed at the hall with the Boston Symphony Orchestra. His enthusiasm for the new music hall was apparent as he walked onto the platform before the first performance. Taking time to inspect the hall, Koussevitzky said to the audience, "Ladies and gentlemen, you have here a most beautiful music hall. You have here a magnificent temple of music. Allow me to pay honor to the great architect who designed this. I understand he is in the audience." Koussevitzky gestured to where Eliel Saarinen was seated and the audience was reported to have applauded vigorously. Applause was inspired once again during intermission when Edward Letchworth, President of Kleinhans Music Hall Management, brought Saarinen on stage announcing, "I am bringing him to the platform so Buffalo can show how it appreciates his genius." After the concert, Koussevitzky told Winifred Corey, Director of Kleinhans Music Hall, "Never have I found any music hall so beautiful, so perfect acoustically, so great a work of art as this."[1] It should be noted that Koussevitzky, who regularly conducted in America's most highly regarded music hall, Boston Symphony Hall, might well have been biased as he was a personal friend of Saarinen, the two having met several years before on a trans-Atlantic crossing to Europe.[2] In fact, when Saarinen was first chosen for the Kleinhans commission, the manager of the Boston Symphony Orchestra sent Esther Link an assortment of seven quotations from

[1] Quoted in "Koussevitzky Lauds Music Hall," *Buffalo Courier-Express*, 11 December 1940.

[2] Herko, "Saarinen's Music Halls" (1999), 25.

Koussevitzky regarding Eliel Saarinen and his work – one more glowing than the next – to aid in publicizing the plans for the new hall.[3]

Other visiting artists also praised the design of Kleinhans, its modern appointments, and its acoustics. Quotations lauding the new hall from such luminaries as Marian Anderson, Eddy Cantor, Nelson Eddy, Jascha Heifetz, Sergei Rachmaninoff, Paul Robeson, Eleanor Roosevelt, Artur Rubenstein, and the Baron Josef von Trapp are included in the commemorative booklet of 1942, *Kleinhans Music Hall*. Rachmaninoff declared at the time of the hall's opening, "Never have I performed in such a beautiful auditorium,"[4] and told the *Buffalo Evening News*, "The resonant qualities of the hall's acoustics are marvelous."[5] Nelson Eddy is reported to have signed the Kleinhans guest book, "If all music halls were like this I'd die happy."[6]

Contrary to the initial praise, concerns were voiced by some regarding what they perceived as the less than desirable acoustical results of the music hall. Within a month of the opening, Edward Letchworth wrote a letter to supervising architects Kidd and Kidd in which he notes that complaints have arisen from "many sources" regarding the acoustics of the main hall.[7] Letchworth also inquires as to what steps had been taken to scientifically test the acoustics. In fact, acoustical consultant, Charles Potwin, was engaged to conduct scientific testing of the hall, but this would not take place for several months.

Not surprisingly, one of the harshest critics of the sound of the hall was Esther Link, who as acting director was single-minded in her determination that the auditorium possess reverberant

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[3] Judd to Link, 12 December 1938, Kleinhans Music Hall archives.

[4] *Kleinhans Music Hall* (1953), 39.

[5] "Praise Heaped on Music Hall," 21 December 1940.

[6] Quoted in "Report on Survey Praises Acoustics of Kleinhans Hall," *Buffalo Evening News*, 20 June 1941.

[7] Letchworth to F.J. and W.A. Kidd, 5 November 1940, Kleinhans Music Hall archives.

acoustics. In a strongly argued letter to Paul Sabine some time after the opening, Link details her complaints about what she considers to be the excessive clarity of the hall. She blames the perforations in the Flexwood-covered side walls for the hall's clear, direct and nonreverberant sound:

> The hall is dead – acoustically. Singers complain they cannot hear each other, tones are not permitted to build up and develop overtones. Everything is very precise, even transparent. The hall is super sensitive and very critical. The tone stops too quickly. Such a condition will mitigate against the cause of music. I do not care if every last note of the clarinet and viola comes transparently to the fore. I and every other ardent musician will want opulence of tone, the color of overtones, the arabesque of musical splendor, and this cannot be secured where precision is the only ideal… You were right, the perforations on the side walls should be eliminated. The problem is most prominent people are perhaps insensitive tonally. Some of them were so beglamoured by the entire building that they just knew everything must be right.[8]

Link alludes to the fact that most people found the hall so impressive they must have assumed the acoustics were on par with the dazzling design.

In a letter to Saarinen dated November 2, 1940, Link again mentions her objection to perforated Flexwood, and blames Charles Potwin for his insistence on using this material.[9] Link declares she found the acoustics "thrilling" when she heard Buffalo Philharmonic conductor Franco Autori play the piano in the main auditorium, but this was before the carpet was laid. After the carpet installation, however, she compared the sound to "putting a heavy mute on a

[8] Quoted in Kopec, *The Sabines at Riverbank* (1997), 125-6.

[9] Kopec, *The Sabines at Riverbank* (1997), 126.

violin."[10] Thus, it would appear that perforations on the side walls were not the issue, but rather the carpet, laid wall-to-wall, which posed a problem. Minutes of a Kidd and Kidd meeting from August 15, 1940 note that the carpet in the main auditorium had to be installed before the seats could be installed. Thus, if Link heard the piano before the carpet was installed, she must have heard it before the cushioned seats were installed as well. At the same time, there was most likely a very small number of auditors present for this privileged performance thereby reducing any additional sound absorption created by people and their clothing. These three conditions: no carpet (bare concrete floor), no seats (as opposed to 2,839 padded seats), and few audience members would definitely contribute to a marked increase in the reverberation time of the hall. Link should have realized that the sound would naturally change with the addition of wall-to-wall carpeting and padded seats, yet she continues to blame Potwin's acoustical treatment of the side walls for the low reverberation time.

Although no longer affiliated with Kleinhans Music Hall in an official capacity, Esther Link nevertheless detailed her complaints in a letter to Charles Potwin.[11] Remarkably, Potwin replies, and in a very informative letter dated November 8, 1940, clarifies his acoustical treatment and reports his expectations for the completed hall [Appendix B]. He describes his surprise at seeing carpet under the seats in the main auditorium when he arrived for the opening concert. He states that the wall-to-wall carpet was done "without our knowledge and without our recommendations." Potwin contrasts the relatively small amount of sound absorbing material in the side walls with the much larger amount of carpeting on the floor: "When you compare approximately 8,000 square feet of carpet under seats on the main floor with only a small amount

[10] Ibid.

[11] This communication could not be located in the Kleinhans Music Hall archives.

(800 square feet) of absorbing material on the side walls, I believe you can readily understand the difference in resonance or liveness that you observed after the carpet was installed." He documents his use of the famous Sabine formula to predict reverberation time of 1.93 seconds with a full audience for the highly regarded Boston Symphony Hall.[12] For Kleinhans Music Hall without carpet under the seats, Potwin calculated a reverberation time of 2.00 seconds (very close to the Boston Symphony Hall time), and he adjusted the formula to include carpet under the seats for an expected reverberation time of 1.70 seconds (less than desired). Potwin would not gather empirical results on reverberation time of the hall until his scientific study in March of 1941.

Kleinhans Music Hall has been the subject of several acoustical studies over the years. In addition to studies commissioned by Kleinhans management, studies have been conducted by independent researchers eager to test the hall's acoustics: the Acoustics Laboratory at Massachusetts Institute of Technology, and Dr. Grant Hector, physics professor at the University of Buffalo. The results of these acoustical studies, and Potwin's study of 1941, are analyzed below. In the final chapter, the most recent acoustical study of Kleinhans, conducted in 2006 by the Acoustic Dimensions firm, will be assessed. Suggestions for improving the sound of the hall as well as a description of how acoustics are treated in contemporary music halls will also be discussed.

On March 18, 1941, Charles Potwin and an assistant, J. J. Butler, completed their scientific study of the acoustics of the main auditorium of Kleinhans Music Hall.[13] In his six-

[12] This prediction was remarkably close to Leo Beranek's 1997 study of Boston Symphony Hall where he reports mid-frequency reverberation times between 1.90 and 1.95 in an occupied hall. Beranek, *Concert Hall and Opera Houses* (2004, 1996), 586, Appendix 2.

[13] "Music Hall Acoustics Pass Test," *Buffalo Courier-Express*, 19 March 1941.

page report to the management of Kleinhans, Potwin describes the method used to gather data and presents his findings [Appendix C]. To test the hall, loudspeakers were placed on the platform to generate tones which were then picked up by twenty-seven microphones scattered throughout the main floor and the balcony. A total of forty-five different frequencies or pitches were measured in order to provide comprehensive results. Potwin describes the process whereby tones are produced through loudspeakers and then suddenly stopped:

> At the moment the sound is stopped a stylus, or needle on the recorder, draws an actual line on a chart which shows the manner in which the sound is dying away at the particular frequency being measured. From these lines, or curves, not only can the time of reverberation (the time it takes the sound to die out to inaudibility after the sound source is stopped) be determined at each frequency, but one may also analyze the way in which sound is reflecting from surface to surface and is being distributed to the ears of the audience. This latter analysis often proves to be of greater importance than the time of reverberation.[14]

While reverberation time has been a focus of this paper, Potwin contends here that the diffusion of sound – which is very important to good acoustics – is excellent in Kleinhans Music Hall. Analyzing "die-away" or sound decay curves, Potwin writes that in some auditoriums, sound decays, "by sudden jerks and delays, with the result that the curve for the tone being measured consists of a few large irregularities or 'bumps.' In other cases the decay of sound may be relatively uniform, producing a fairly smooth curve with a large number of small irregularities superimposed upon it."[15] He explains that research has shown that sound measured in

[14] *The Acoustical Measurement of Kleinhans Music Hall*, Kleinhans Music Hall archives, 2.

[15] Ibid, 5.

auditoriums of the first type is disliked by musicians and audiences, whereas the sound of the latter type is considered satisfactory. According to Potwin, the results of curves measured at Kleinhans Music Hall indicate that "the splayed and angled sections of the walls and ceiling are functioning efficiently as planned, to distribute the sound evenly and smoothly over the seating area. This result is particularly gratifying to the acoustical engineers because within their experience no other auditorium measured in this country or abroad has shown as many uniform 'die-away' curves of sound as were obtained in the auditorium of Kleinhans Music Hall."[16] A study conducted in 1950 by the Acoustical Laboratory of the Massachusetts Institute of Technology supports Potwin's observation that the sound in the hall is uniformly distributed. The MIT report states, "the general shaping of the Hall, including the slope of the floor and the shape of the stage, ceiling, and walls, has contributed greatly to the realization of… good hearing conditions, namely, uniform and adequate loudness of sound throughout the seating area."[17]

Potwin admits that analysis of the various curves shows that reverberant sound on the main floor, particularly toward the front, is slightly lower than that in the balcony. He writes that, "This result is obviously caused by the complete carpeting of the main floor, and tends to lower slightly the net average or over-all values of reverberation time for the entire auditorium."[18] Potwin contends that if measurements could be made both with and without carpet, a difference in reverberations times would be demonstrated. He states that with a capacity audience, however, the difference between a full carpet and no carpet would be negligible. According to Potwin, the carpeting does "produce an effect of slightly greater

[16] Ibid., 6.

[17] *A Survey of Acoustics in the Kleinhans Music Hall, Buffalo, N.Y., July 1950*, Kleinhans Music Hall archives, 8.

[18] *The Acoustical Measurement of Kleinhans Music Hall*, Kleinhans Music Hall archives, 4.

definition and slightly less blending" for the seats in the front of the auditorium, but he states that this "probably could be detected only by a critical listener."[19] To remediate this situation, Potwin recommends in a letter to Letchworth and in his report for the local press that the carpet under the seats in front of the cross aisle on the main floor might be removed.[20]

Regarding reverberation time observations, the MIT results are, "in good agreement with Potwin's measurements" (fig. 28).[21] The MIT study, however, did not confirm Potwin's finding that sound in the front of the auditorium is poorer than elsewhere. This conflict could be due to the fact that the MIT study used only two microphones on the floor and one in the balcony, whereas Potwin used twenty-seven microphones in various positions throughout the floor and balcony.

The MIT researchers, trained acousticians and hence "critical listeners," attended both a rehearsal and a concert by the Buffalo Philharmonic Orchestra. They were allowed to move freely about the auditorium during rehearsal and they moved several times during the concert itself. Each researcher found the loudness of the music to be, "uniform throughout the Hall, with no pronounced dead spots or echoes perceptible."[22] Thus, based on their personal observations, the MIT researchers found the distribution of sound to be evenly diffused throughout the hall. The MIT study agrees with Potwin's conclusion regarding the negligible sound absorption of the carpet with a full audience. They write that "the effect of the carpet on the reverberation time is of marginal importance in the presence of an audience," and therefore the researchers disagree

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[19] Ibid.

[20] Potwin to Letchworth, 12 June 1941, Kleinhans Music Hall archives; "Report on Survey Praises Acoustics of Kleinhans Hall," *Buffalo Evening News*, 20 June 1941, 40.

[21] *A Survey of Acoustics in the Kleinhans Music Hall, Buffalo, N.Y., July 1950*, Kleinhans Music Hall archives, 10.

[22] Ibid., 7.

with his recommendation to remove the carpet. In their opinion, "the comfort provided by the carpet, together with the quieting effect that it has on audience noise, more than outweighs any acoustic improvement that might be effected by its removal." Indeed, it is somewhat difficult to understand why Potwin would recommend removing carpet if he believed the result would be negligible with a capacity crowd and imperceptible to most people. Perhaps he is attending to the "critical listeners," or he is considering the circumstances whereby reverberation time would be significantly increased with a less than capacity crowd. In any case, Potwin does not mention carpet removal in his official report to Kleinhans management, but he does so in personal communication to Letchworth, and in an article for the newspaper. Potwin appears to have downplayed the negative impact of the carpet in his final report.

It is interesting to note that in both the Potwin and MIT reports, reverberation time is not reported as a number, say, at middle frequencies, but is rather represented graphically with reverberation time plotted against frequency or musical pitch (figs. 28 and 29). The average reverberation time at middle frequencies for both graphs appears to hover around 1.5 seconds, significantly less than the desired 2.0 seconds, and less than Potwin's prediction of 1.7 seconds with full carpeting.[23] Perhaps Potwin chose to omit specific reverberation times because he did not wish to call attention to the less than desirable results. He makes a pointed observation in his report on Kleinhans that, "*Measured* values of reverberation times… *range from 15% to 20% lower* than those computed by the Sabine formula. The correction factor is well known to experienced acoustical engineers" [*emphasis original*].[24] While I am unaware of anything in the scientific literature to corroborate this, it was well known that a capacity audience serves to

[23] Beranek calculates mid-frequency reverberation times for Kleinhans between 1.40 and 1.60 in an occupied hall. *Concert Hall and Opera Houses* (2004, 1996), 586, Appendix 2.

[24] *The Acoustical Measurement of Kleinhans Music Hall*, Kleinhans Music Hall archives, 3.

decrease the reverberation time significantly over that of an empty hall. Given that both Potwin's and MIT's scientific measurements were conducted without an audience present, the reverberation time of Kleinhans Music Hall with a capacity crowd would indeed be lower than measured in the empty hall.[25] The low reverberation time clearly contributes to the hall's reputation for dryness. Potwin overstates his results by calling the reverberation time for the main floor "highly acceptable," while he labels the balcony reverberation time "completely acceptable."[26]

Potwin's graph compares the reverberation times for Kleinhans Music Hall against the reverberation times of Cleveland Orchestra's Severance Hall and Philadelphia Orchestra's Academy of Music Hall (fig. 29). Boston Symphony Hall, with its robust reverberation times, is conspicuously absent from the graph. The Kleinhans graph is very close to the results for Philadelphia's Academy of Music, and Kleinhans appears to have an advantage of greater reverberation time over Cleveland's Severance Hall. Recall that Leopold Stokowski, conductor of the renowned Philadelphia Orchestra from 1912-1940, served as an unofficial advisor to Acting Director Esther Link. Although no longer employed by Kleinhans management, Link could not remove herself from the life of the hall. In the summer of 1941, about one year after losing her position, she sent a letter to the vice-president of Kleinhans Music Hall Management, Philip Wickser, in which she regrets the bad publicity regarding the hall's acoustics. She writes, professing her innocence in the matter, "I need not tell you that I did not put Stoky [Stokowski]

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[25] One exception occurred during the MIT study in which a cap pistol was fired with an audience present in the hall. The recorded reverberation data from the pistol shot proved "inconclusive." *A Survey of Acoustics in the Kleinhans Music Hall, Buffalo, N.Y., July 1950*, Kleinhans Music Hall archives, 10.

[26] *The Acoustical Measurement of Kleinhans Music Hall*, Kleinhans Music Hall archives, 4.

up to finding fault with the acoustics. He tested them for himself in his own way. Moreover, he scolded me for not getting it more reverberant."[27]

The bad publicity to which Link referred was most likely two articles published in the *Buffalo Evening News* in May 1941 regarding the acoustics of Kleinhans. The first, "Acoustical Expert Measures Quality of Two New Halls," was written by a local University of Buffalo physics professor, Dr. L. Grant Hector, who conducted acoustical surveys of both Kleinhans Music Hall and the newly opened Memorial Auditorium in downtown Buffalo.[28] In his article, Hector faults the main auditorium of Kleinhans Music Hall for its lower than ideal reverberation time. Hector's graph of reverberation time plotted against frequency or pitch, unlike the Potwin and MIT graphs, is inverted away from the ideal graph (fig. 30). That is, reverberation time decreases at the low and high ends, rather than increases. Like the Potwin and MIT graphs, however, Hector's reverberation time in middle frequencies appears to be close to 1.5 seconds. It is difficult to explain the variance between Hector's and Potwin's results at the low and high ends. While Potwin clearly had reason to demonstrate superior acoustical results in Kleinhans Music Hall, both Hector and MIT – presumably neutral investigators – did not. The MIT study was done using state-of-the-art methods and technology nearly ten years after the initial scientific investigations by Potwin and Hector, and the MIT study tended to confirm Potwin's results. Therefore, I have confidence in in the veracity of Potwin's report and choose to rely on his conclusions over those of Hector.

Another troubling article published in the *Buffalo Evening News* about a week after the Hector piece details Leopold Stokowski's visit to the hall before a performance with his youth

[27] Link to Wickser, 2 June 1941, Kleinhans Music Hall archives.

[28] *Buffalo Evening News*, 16 May 1941.

orchestra. The method Stokowski used to assess reverberation was described as follows: "the first thing Mr. Stokowski did at the hall was to get up on stage and clap his hands and say 'pst… pst… pst.'"[29] He is then quoted as saying, "Too much absorption. You can tell it the minute you say a word. The hall swallows it up." Stokowski blames the floor covering for this state of affairs: "Too much carpet. Everything else is beautiful, but the thick carpet deadens the tone."

This report of Stokowski is unusual for two reasons. First, according to Potwin's graph, the reverberation times for Kleinhans and for the Academy of Music are virtually identical. Stokowski spent nearly three decades conducting the Philadelphia Orchestra in the Academy of Music, and he praised it thus: "The Academy of Music is the best concert hall in America. It has natural clear sound."[30] If Potwin's graph is accurate, the two halls should present roughly the same sense of reverberation. Stokowski claimed to find the Philadelphia hall superior, yet he found Kleinhans, presumably with a similar resonance, to be lacking. Another reason Stokowski's report that the hall "swallows" sound is unusual is because when empty of all except a small number of people, the main auditorium of Kleinhans definitely produces reverberation – bordering on echoes – even for people speaking in normal conversational tones. I have experienced this on several occasions, both from the stage and on the floor. Therefore, Stokowski must have heard some reverberation in his visit, although perhaps not enough to satisfy him. It is also possible that in spite of Link's protest, he had prior knowledge from her (or from other sources in the music world), that reverberation was wanting in the hall. Stokowski doubtless was aware that a hall filled to capacity with an audience would have a tendency to "swallow" the sound, although he did not mention this. In any case, in regard to

[29] Gorham, "Acoustics of Kleinhans Fail to Harmonize for Stokowski," *Buffalo Evening News*, 24 May 1941.

[30] Quoted in Beranek, *Concert Halls and Opera Houses* (2004, 1996), 5.

preparing for his upcoming performance with the youth orchestra, Stokowski ultimately pronounced that the acoustics of Kleinhans Music Hall were "good enough."

In addition to Leopold Stokowski and Charles Potwin, it appears that the carpeting under the seats in the main auditorium was a cause for concern for Paul Sabine. Sabine reportedly told Link in a letter dated November 29, 1940, "All my calculations and specifications were based on carpets in the aisles only."[31] In an attempt to get to the bottom of the carpet controversy, I examined the original carpet specifications for the floor covering contract issued by supervising architects Kidd and Kidd in August 1939. Much of Kleinhans Music Hall was to be carpeted including the auditorium, the foyer and mezzanine, the backstage conductor's and green rooms, and the board room. Regarding the main auditorium, the specification stated simply: "According to approved seating plan – All aisles and orchestra elevator to receive Bigelow Sanford's 'Looptuft' or approved equal. Areas under all seats and steps in balcony to receive Bigelow Sanford's 'Varsity' or approved equal" [Appendix D].[32] This last sentence appears to contain a slight ambiguity, "Areas under all seats and steps in balcony…" Does this refer to *all* seats on both the floor and balcony, or is it confined to seats and steps in the balcony alone? In any case, the winner of the flooring contract (with a bid of $23,770), Hoddick and Taylor, Inc., interpreted the contract to mean the entire floor area was to be carpeted, including the aisles and the floor beneath the seats. At least one carpeting firm interpreted the specification differently than Hoddick and Taylor. In fact, the cover letter of a bid submitted by Allen's Floor Covering stated that, "No carpet or cork tile is figured beneath seats in Auditorium. If carpet under seats in

[31] Quoted in Kopec, *The Sabines at Riverbank* (1997), 126.

[32] "Specifications for Contract No. 13, Floor Covering," Item #13-A, F.J. and W.A. Kidd, August 1939, 52, Kleinhans Music Hall archives.

Balcony is omitted, a savings of $4,211.00 from Base Bid could be effected."[33] Allen's Floor Covering's bid was approximately $3,000 more than Hoddick and Taylor's winning bid, and Allen's did not include the added expense of carpet (or cork tile) under the seats in the main auditorium.[34]

In describing the legal aspects of the contract to potential bidders, the specifications state explicitly that the work is subject to the control of the architect: "In the performance of the Work, the Contractor shall abide by all orders, directions and requirements of the Architect and shall perform all work to the satisfaction of the Architect."[35] This places control of the flooring squarely with the architect. There must have been some kind of miscommunication regarding the acoustician's plans for limited carpeting, since aisle carpeting alone was not stated explicitly in the contract specifications. How could this have happened? Confusion may have arisen between the acoustical consultants and Saarinen's office, or between Saarinen and supervising architects Kidd and Kidd. Poor wording in the carpet specifications might also account for the error.

In a letter written to Philip Wickser in May of 1941 regarding the hall's acoustics, Esther Link recounts the history of the floor treatment discussion from her time as acting director:

> Everyone felt that there should be carpet in the aisles but not under the seats, partly because of (1) initial cost, (2) difficulty and cost of maintenance, (3) unsuitability of

[33] Norman Shisler (Owner, Allen's Floor Covering, Co.) to Kleinhans Music Hall, Inc., 8 September 1939, Kleinhans Music Hall archives.

[34] An alternate specification, item #13-Q states that "in lieu of carpeting in the Main Auditorium (Room 101) all floor areas, stairs, treads and risers, orchestra elevators, are covered with – Armstrong ½" Cork tile." Cork tile was a flooring material commonly used for its sound absorbing properties. This alternative clearly specifies the use of cork floor tile throughout the entire floor area, balcony and steps of the main auditorium. "Specifications for Contract No. 13, Floor Covering," F.J. and W.A. Kidd, August 1939, 53, Kleinhans Music Hall archives.

[35] "Specifications for Contract No. 13, Floor Covering," F.J. and W.A. Kidd, August 1939, 39, Kleinhans Music Hall archives.

> carpet because of varied use, such as school children. That is, except for Mr. Saarinen and Mrs. Carlton Smith. He felt that a carpet would hush the disturbance of latecomers and give a background of elegance to the hall. Mrs. Smith was most anxious to have a carpet and was unwilling to relinquish her demand for it on any ground: cost, cleanliness, or suitability – frequently mentioned it.
>
> When the specifications were written up no carpet under the seats was specified. The bidders found them somewhat obscure. When the bids came out there was no uniformity as to the amount of the carpet to be used. Though no specification was made for the carpet under the seats it was included in the bids of several contractors.[36]

Link continues in her letter to blame Mrs. Carlton Smith and Smith's friend, Kleinhans Music Hall Secretary-Treasurer Sara Kerr, both original members of the Kleinhans board dating back to 1934. Once the successful bidder was known to have included carpet under the seats, Link claims to have been "simply flabbergasted" because she "immediately recognized the acoustic hazard it presented." This avowal seems backhanded due to Link's earlier objection to the acoustical treatment of the side walls. She now appears to be joining the others in blaming the carpet for the reduction in reverberation. Link implies in the letter that Kerr is especially close to Kidd and Kidd's lead architect for the Kleinhans project, Stanley Podd, and that they both somehow contrived to have carpeting installed under the seats when it was not specified. Link states that the full carpeting also came as a surprise to Edward Letchworth.

In a second letter to Wickser, Link writes of Potwin's amazement at discovering the carpet beneath the seats. Apparently no longer blaming Potwin for the dry acoustical results, she writes, "Potwin hoped that the hall would still be sufficiently reverberant – his plans without the

[36] Link to Wickser, 2 May 1941 (a), Kleinhans Music Hall archives.

carpet had aimed at a good deal of resonance. He realized immediately, however, that the carpet swung it much too far the other way. The hall was dead. In the Boston Symphony concert [10 December 1940] he said only two times in the entire concert was there the desirable condition of 'klang.' He is really sick about it – at least to me."[37] While it is certainly possible that Link is exaggerating Potwin's reaction to the hall, her feelings toward him and his work appear to have undergone a transformation by this time.[38] Link closes the letter by asking Wickser to "junk the carpet." She tells him, "you have it in your hands to do something. If only this building could be brought to the fulfillment for which we all worked so unselfishly."

While reading through the carpet specifications booklet, I discovered an intriguing scrap of paper slipped between the pages. It was neatly cut from typing paper, with a portion of the watermark still visible, and measures approximately two inches by four inches. On it was typed, "Miss Kerr says that her investigation so far indicates that Mr. Eames brought the carpet specifications from Saarinen. She thinks she can locate the original from the Kidds" (fig. 31). This little note was neither signed nor dated, so it is unclear who wrote it or when. Sara Kerr was Secretary-Treasurer of Kleinhans from 1938-1947. Charles Eames, the well-known architect and designer, was a friend of Eero Saarinen's and was employed by the elder Saarinen's architecture firm. Eames also taught at the Cranbrook Academy of Art in Bloomfield Hills, Michigan at the time of Kleinhans' construction (fig. 32). It is interesting to think of Eames' involvement – possibly as a courier described in the note – in the Kleinhans project.[39] Since the carpet specifications date from August 1939 and the contract was awarded to Hoddick and

[37] Link to Wickser, 2 May 1941 (b), Kleinhans Music Hall archives.

[38] Sadly, Charles Potwin died after a brief illness on 25 September 1941 at the age of thirty-three. Link's change in feelings about him preceded his untimely death.

[39] Eero Saarinen and Charles Eames collaborated on designing molded plywood chairs for Kleinhans Music Hall.

Taylor, Inc. in October 1939, the earliest this little note could have been written was in the fall of 1939. Esther Link was still acting director at that time, and it is possible that she, always vigilant, did look into the matter of the carpet once its full extent was known. Link was dismissed in June 1940, before the carpet was installed. It is also possible that the director of Kleinhans Music Hall, Winifred Corey, who came on board in July 1940, investigated the carpet situation and wrote the note, but I believe this is less likely. By the time complaints arose over the carpet, it was already covering the entire floor and nothing could be done to remediate the situation without considerable difficulty and expense. In any case, I was unable to locate any original carpet specifications from Saarinen or the Kidd firm other than the official specifications prepared by the Kidds and dating from August 1939. The case of the wall-to-wall carpet shall remain then something of a mystery. I can report that as of today, the main floor of Kleinhans continues to be fully carpeted just as it was in 1940.

The acoustical results in Kleinhans Music Hall are by most accounts favorable. Sound is distributed well throughout most of the hall, particularly in the balcony. Beranek writes that the tone of the string section of the orchestra is brilliant, and he ranks Kleinhans Music Hall among the top sixty music halls in the world.[40] There has been dissatisfaction in some quarters regarding the quality of resonance or reverberation, and in fact, the original acoustical plans intended for more reverberation than was achieved. This deficit is likely due to the installation of full carpet beneath the seats on the floor of the main auditorium. Most writers have concluded that Kleinhans Music Hall was designed as a "hi-fi" concert hall, as Michael Forsyth has termed it. The modern "hi-fi" sound with its high definition and short reverberation time was in vogue in the decade or two preceding the construction of Kleinhans. Although the hall does possess

[40] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 51; Table 4.1, 496.

aspects of that design: clear and direct sound radiating throughout the large, fan-shaped auditorium, Kleinhans was never intended to possess dry, non-reverberant acoustics. The acoustical consultants, Charles Potwin and Paul Sabine, along with Acting Director Esther Link, had aimed for a rich sense of reverberation in the new music hall.

In the conclusion which follows, I will discuss the most recent acoustical study of Kleinhans Music Hall which was conducted in 2006 by Acoustic Dimensions. I will summarize their recommendations for improving the sound of the hall, and I will briefly compare the arrangement of acoustical treatments in contemporary halls to the historical treatment of Kleinhans Music Hall.

Chapter VI CONCLUSION

Attempts made to improve Sabine's method so as to specify "optimum" conditions with the hope of securing perfect acoustics have not been very successful, the reason for the failure not being very evident. –F.R. Watson, *Ideal Auditorium Acoustics*, 1928.

Throughout this paper, I have emphasized the desire for a robust reverberation time approaching 2.0 seconds, like that of Boston Symphony Hall. Reverberation time is but one acoustical parameter of many associated with the sound of a hall. Owing to its measurability and its obvious effects, however, reverberation time has become an important standard in room acoustics. It should be pointed out that the ideal reverberation time of 2.0 seconds best applies to Romantic music of the nineteenth century – composers such as Brahms, Tchaikovsky, and Liszt – music that was popular at the time of Boston Symphony Hall's construction and music that remains popular in the repertoire of American orchestras like the Buffalo Philharmonic today. It is not the case, however, that all forms of music benefit from this amount of reverberation.

Many forms of chamber music (music intended to be played in small halls or "chambers"), actually benefit from lower reverberation times. In such cases, a strong reverberation with its overlapping tones might distort the lines of the music. For example, chamber music is sometimes contrapuntal, with two competing lines of melody played over one another at the same time. Distinct melodic lines run the risk of being blurred by reverberation, diminishing the effect of the counterpoint. Leo Beranek writes of Baroque chamber music, like that of J.S. Bach or Antonio Vivaldi: "Even today, we prefer to listen to this highly articulated music in a small space with fairly low reverberation time."[1] The Mary Seaton Room (the chamber music hall of Kleinhans), is a suitable venue for this music, but Baroque music is also

[1] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 9.

occasionally performed by a larger ensemble like the Buffalo Philharmonic in the main auditorium.

Although not an opera house, Kleinhans Music Hall does offer vocal music and sometimes has produced portions of operas (without staging). Opera and other vocal music, much like the spoken word, benefits from shorter reverberation times. As Wallace Sabine discovered at the Fogg Museum lecture hall in 1895, long, overlapping reverberation makes speech unintelligible. Beranek writes that in order "to preserve a libretto's intelligibility, especially at the tongue-twisting speeds of Mozart and Rossini, the performance space must provide a relatively short reverberation time, so that the reverberation from one sound or chain of sounds will not mask successive syllables."[2]

Modern music sometimes possesses complex and unique rhythms and harmonies. A robust reverberation time can make playing and listening to a challenging rhythm, especially at a fast tempo, very difficult. Similarly, modern music often delves into new harmonic territory, and lingering tones, perhaps jarring to begin with, just might clash unpleasantly with what follows. In their book on spatial acoustics, Barry Blesser and Linda-Ruth Salter describe a study conducted in 1954 by Walter Kuhl. Kuhl used twenty-eight short segments of music from different genres and analyzed 13,000 judgments of listeners regarding reverberation time. Kuhl discovered that for "Mozart's *Jupiter Symphony* and Stravinsky's *Le Sacre du Printemps*, listeners preferred 1.5 seconds, whereas for Brahms's *Fourth Symphony*, representative of Romantic music, they preferred 2.1 seconds."[3] These judgments are in agreement with Beranek's assessment. According to Beranek, for classical music, like that of Mozart, and for

[2] Ibid., 15.

[3] Blesser and Salter, *Spaces Speak* (2007), 225.

modern music, like that of Stravinsky, listeners tend to prefer a slightly lower amount of reverberation than for the Romantic music of Brahms.[4] Romantic music, with its *Sturm und Drang*, simply sounds better with the added drama of prolonged reverberation. Other forms of music, however, do not benefit from added reverberation. Thus, a single condition of reverberation will never be satisfactory for all genres of music. There is no single set of listening conditions that can be regarded as superior and different kinds of music benefit from different listening conditions. To deal with this complex situation, contemporary music halls provide variable acoustical treatments in order to change acoustical conditions to best suit the music or other use of the room.

The Meyerson Symphony Center in Dallas, Texas, designed by I.M. Pei and Partners, with acoustical work by Russell Johnson of Artec Consultants, is an example of a contemporary music hall that was built with the ability to transform acoustical conditions (fig. 33). The concert hall, which opened in 1989 and seats up to 2,062, has several acoustical features, including four acoustical canopies (two side, one center, and one rear), each weighing from twelve to seventy-five tons (11,000 to 68,000 kg), suspended above the stage. These canopies can be raised, lowered, and tilted to adjust sound clarity based on the number of performers, the instrumentation, and the kind of music to be performed.[5] In addition to the canopies, an enormous U-shaped reverberation chamber measuring 300,000 cubic feet (8,500 m^3) surrounds the upper part of the shoe-box shaped concert hall. Seventy-two concrete doors measuring four inches (10 cm) in thickness line the chamber. With all the doors open, the reverberation time is increased, while closing the doors reduces reverberation. In addition to the concrete doors, sixty-

[4] Beranek, *Concert Halls and Opera Houses* (2004, 1996), 8-14.

[5] "Technical Information," Meyerson Symphony Center, www.meyersonsypmhonycenter.com, accessed 1 October 2010.

two motor operated acoustical sound absorbing curtains are available throughout the auditorium in storage pockets. The curtains can be extended to cover most of the walls of the seating areas in order to reduce reverberation. All these acoustical features are designed to create a dizzying assortment of acoustical conditions, and can no doubt produce rather wide variations in reverberation time.

One reason why some musicians and listeners alike still prefer a good deal of reverberation in room acoustics is that the ambient reverberant sound can smooth over rough patches or poor playing, much like the sustain pedal on the piano can smooth over choppy playing by blending the sounds. Esther Link writes of her perception of the nonreverberant acoustics of Kleinhans Music Hall that "every slight error stands out like a mole under a magnifying mirror."[6] Reverberation results from the movement of sound waves: ricocheting off the walls, floor, ceiling and other surfaces throughout a room even after the sound which produced the initial waves has ceased. This sound energy can build, especially during loud passages, to incredible peaks, adding impact to the initial production of sound. Beranek complains that in Kleinhans Music Hall, the *fortissimo* (strength of sound, or loudness) was lacking due in part to the dryness of the main auditorium.[7]

In 2006, the Buffalo Philharmonic Orchestra commissioned Acoustic Dimensions of New Rochelle, New York to examine the main auditorium of Kleinhans and to make recommendations for improving the sound quality of the hall specifically with the orchestra in mind. Part of the study included interviews with the music director, JoAnn Falletta, the

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[6] Link to Wickser, 2 May 1941 (b), Kleinhans Music Hall archives.

[7] *Concert and Opera Halls* (1996), 83. Additionally, the large size of the auditorium, with a 2,839 seat capacity, serves to limit the loudness level regardless of the degree of reverberation; Beranek, *Concert Halls and Opera Houses* (2004, 1996), 31.

concertmaster, Michael Ludwig, and a few orchestra musicians who volunteered their opinions. Acoustic Dimensions attended a BPO rehearsal and concert in November 2006, they performed acoustical tests and analyzed the data, and they also studied architectural drawings of the hall. This most recent acoustical study has benefited from the growth of the science of acoustics over the more than sixty years since the completion of Kleinhans Music Hall. I will summarize and analyze the results of the study, and discuss possible changes to be made to the acoustics of the hall in the future.

In the executive summary, Acoustic Dimensions reports that Kleinhans Music Hall is generally well-liked by both musicians and audiences. Musicians find the sound on the platform to be very good. The report lauds the flowing design of the auditorium and the fact that there is no "discontinuity" between the platform and the audience – they are not separated by a proscenium arch or other division. Eliel Saarinen planned the hall in this way to eliminate the psychological barrier between audience and performers. As it turns out, it also eliminates sound barriers, allowing for "good acoustical feedback from the hall back to the platform." According to Acoustic Dimensions, "This is one of the key factors that makes Kleinhans Hall such a good concert hall. This is one of the primary reasons that musicians find this hall 'comfortable' to play in." They give quotations from interviews with musicians as follows: "We love our hall; we're used to it," "It's easy to hear," and "The hall is comfortable."[8]

There were several complaints, however, the main one being that the sound of the hall is too dry, or nonreverberant. For example, the researchers from Acoustic Dimensions found the reverberation after terminal chords played by the orchestra to be barely audible. Another criticism is that the sound of the double basses is somewhat weak. This weakness might be

[8]*Acoustics Study: Kleinhans Music Hall*, 22 December 2006, 3-6.

explained by Charles Potwin's original plans for sound absorbing material to be randomly placed behind the perforated panels in the side walls. The report by Acoustic Dimensions states that "original architectural drawings and specifications call for sound absorptive material behind these panels, specifically 1" thick mineral wool wrapped in muslin."[9] This type of material is known to efficiently absorb bass frequencies, and this may account for the lack of bass support in the hall. It was noted in the Acoustics Dimensions report that the balance and blending of various sections of the orchestra is better in the balcony than elsewhere. For example, the winds and brass sections are reported to have "greater presence" in the balcony than on the main floor. However, sound was observed to be louder in the front areas of the main floor than in the balcony.

Despite the careful planning of the architects and the acoustical consultants, ambient noise is a problem in Kleinhans Music Hall. A quiet environment free from noise is highly desirable for musical performance. Unfortunately, Kleinhans does not rate well in keeping background noise below the threshold of hearing. Noise from outdoors can be heard through doors which lead from the hall directly outside. The auditorium is not well isolated from backstage sounds or from sounds originating in the lobby or mezzanine. Additionally, noise from the HVAC system and fans above the ceiling tends to permeate the hall. Acoustic Dimensions suggests installing special doors with sound seals on the stage, between the auditorium and the lobby, from the hall to the outside, and between the fan room and the ceiling void in the hall.

The Acoustic Dimensions study explains at the outset that Kleinhans Music Hall is on the National Register of Historic Places, and therefore major changes to the interior are not possible.

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[9] Ibid., 5.

They write, "acoustical qualities of a hall are determined primarily by the shaping of the interior. Because of the landmark status of the hall, it would not be possible to make any significant changes to the hall, even if there was a desire to do so."[10] Clearly, none of the acoustical fixtures of the Meyerson Symphony Center described above, such as the reverberation chamber, massive canopies, and pocketed draperies, would make suitable or feasible additions to Kleinhans. To improve the sound in the main auditorium of Kleinhans Music Hall, Acoustic Dimensions offers suggestions which involve relatively modest measures for increasing reverberation time, and for improving the quality of loudness in the seating area. They also discuss the pros and cons of arranging musicians on risers, and give a more controversial recommendation for electronic reinforcement of the orchestra.

It appears that for the Buffalo Philharmonic Orchestra, their ideal sound requires a greater degree of reverberation than is currently heard in Kleinhans Music Hall. To that end, Acoustic Dimensions makes recommendations for increasing reverberation in the main auditorium. According to recording engineers, one of the benefits of greater reverberation is an improvement in the sound quality of audio recordings, a promising venture for the Buffalo Philharmonic Orchestra. Regarding reverberation, the report warns us that since the shape of the interior cannot be changed, any increase in reverberation time will likely result in some loss of clarity. The increase in reverberation brought about by implementing their recommendations is not expected to be dramatic, and therefore, "no significant loss in acoustical clarity is anticipated."[11] Lacking the ability to vary acoustic conditions as in Meyerson Symphony Center in Dallas, the

[10] Ibid., 3.

[11] Ibid.

Buffalo Philharmonic Orchestra and Acoustic Dimensions seek to create a more reverberant acoustical environment, at the expense of a slight loss in clarity.

Acoustic Dimensions does not mention specific reverberation times for Kleinhans in their report, nor do they offer reverberation time graphs such as those given by Charles Potwin and MIT. The Acoustic Dimensions report features one graph showing the amplitude of sound (comparative loudness) plotted over time. Their graph appears to show that sound dies precipitously away by 1,000 milliseconds, or one second, for both an empty hall and a 30-40% full hall. While this data is not equivalent to reverberation time plotted against various frequencies from low to high (as given by Potwin and MIT), the data does suggest a short reverberation time as the sound level in general dies down quickly. Rather than affirming an ideal reverberation time like 2.0 seconds, Acoustic Dimensions recommends that the level of reverberation in the hall when filled to capacity with an audience should be equivalent to the level of reverberation in the hall when it is currently empty. Although not a hard and fast standard, the empty hall does produce a fair amount of reverberation and so this suggestion seems reasonable. I have had the experience of listening to both a portion of a Buffalo Philharmonic Orchestra rehearsal and the following concert with approximately thirty to forty percent capacity attendance. The rehearsal, with no audience present, featured a richer, reverberant sound than the concert with an audience less than half full.

Acoustic Dimensions recommends, as might be anticipated, removing the carpet from beneath the seats on the main floor and in the balcony in order to increase reverberation time. All the musicians who were interviewed for the study approve this proposal. Another suggestion for increasing reverberation involves removing the perforated panels on the side walls and laminating Masonite and plywood on the back of each panel in order to reduce sound absorption.

Recall that Potwin's plans involved 800 square feet (75 m^2) of sound absorbing material to be placed randomly behind the panels. Acoustic Dimensions suggests changing these panels in the side walls so that rather than absorb sound, they reflect sound. Recall from the previous chapter that Esther Link and Paul Sabine considered the sound absorption in the side walls to be problematic, and Link initially blamed this acoustical treatment of Potwin's for the low reverberation time.

To increase loudness in the seating area, Acoustic Dimensions recommends moving the orchestra further downstage on the platform [Appendix E]. In addition to increasing loudness, this arrangement should improve balance or blending of different sections of the orchestra in the front of the main floor. It was noted in the report that the surface of the platform consists of untreated wood. A suggestion was made that if the wood were to be treated with a sealer, this would "provide some limited acoustical benefit."[12] It is unclear if the untreated wood of the platform was an original design criterion by the architect or acoustical consultants. In any case, Acoustic Dimensions cautions that any dramatic change in the flooring material of the platform (aside from treating the wood) should be undertaken with the advice of an acoustical consultant in order to avoid excessive sound damping surfaces.

Another recommendation for improving the sound of the orchestra is to implement the use of risers to arrange musicians on different planes on the platform. This idea is somewhat controversial and there is no uniformity among musicians as to the desire to use risers. Acoustic Dimensions lists the benefits of risers as: improving sightlines and communication on the stage, improving the balance of upstage and downstage instruments, and reducing the "disparity

[12] Ibid., 12.

between the listening experience on the balcony as compared to that on the main floor."[13] The last two points go especially toward improving the sound of the orchestra as it is heard in the hall, and thus are worthy of consideration. The drawbacks of risers include reduced stage flexibility since risers are difficult to arrange and tear down, the extra space that is required to store them, and the substantial cost of risers designed to match the hall's visual aesthetic. Recall from Chapter IV, when the subject first arose during the planning of the hall, one of the architects (unnamed) reportedly told Esther Link that because of the undulating form of the walls and ceiling, having the stage floor "brought into motion" with risers would create a "restless" quality.[14] When compared to the visual stability provided by the horizontal plane of the platform, adding risers next to the narrowing telescopic side walls and beneath the steeply sloped ceiling seems an inferior arrangement. Given budget constraints and the challenge of designing risers to coordinate with the unique visual aesthetics of the main auditorium of Kleinhans Music Hall, I believe risers should be placed at the bottom on a list of priorities for the hall.

The most controversial recommendation made by Acoustic Dimensions is the addition of electronic enhancement or reinforcement to the sound of the orchestra. They describe the way the system would function:

> In essence, this system utilizes a small number of very high quality microphones to pick up the sound of the orchestra. This sound is then processed through a specialize [*sic*] digital processor that carefully adds the required amount of additional reverberance to the signal and then projects this sound through multiple loudspeakers hidden around the room. It is important to note that this system is not intended to "amplify" the orchestra,

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[13] Ibid.

[14] Link to Letchworth, 22 May 1940, Kleinhans Music Hall archives.

> but to electronically simulate reflections from surfaces that would provide reverberance, envelopment, and spaciousness. This electronic system is not intended to interfere with the existing house sound system in any way and in fact will only be used to support musical performances that require additional reverberation. As this system is computer controlled, it is possible within reasonable limits to change the acoustics character of the room to suit various musical styles.[15]

Dry, nonreverberant "modern sound" – deemed superior by most acoustical scientists in the years preceding the construction of Kleinhans Music Hall – was in fact *not* the intended sound of the hall. Reverberation, desired by the original planners of the hall and also by the orchestra today, can be artificially introduced to live music through a system the likes of which the original planners probably never dreamed possible. The estimated cost of such a system is given as $475,000 to $550,000, a significant expense. This system would convert Kleinhans into a literal "hi-fi" hall, by introducing state-of-the-art electronic acoustics to its sound.[16] It is ironic that in this case, the electroacoustic system would create reverberation as a means of overcoming the historically dry "hi-fi" sound of the hall.

In their book on acoustics, Blesser and Salter address electronic enhancement systems and the history of their use.[17] Perhaps one of the first halls to attempt to increase reverberation through electronic reinforcement was the legendary La Scala Opera House in Milan. In 1958, R. Vermeulen mounted several loudspeakers equipped with audio delays over the stage. He concluded that his experiment showed, "evidence that electro-acoustics has come of age when

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[15] *Acoustics Study: Kleinhans Music Hall*, 22 December 2006, 14.

[16] So-called "hi-fi" halls were labeled as such based on their clear, direct and nonreverberant acoustics, reminiscent of listening to a stereo in carpeted living room. Forsyth, *Buildings for Music* (1985), 262.

[17] Blesser and Salter, *Spaces Speak* (2007), 198-203.

well-known musicians are willing to accept the assistance of loudspeakers, not to produce greater loudness but to improve the quality of their live concerts." Although successful at increasing reverberation time, the system ultimately failed since the injected sound also produced unwelcome feedback and distortion. Electronic reinforcement systems of today, more than fifty years after Vermeulen's experiment, clearly benefit from advances in technology and therefore possess higher fidelity. Blesser and Salter state that, "Unbeknownst to the audience, but appreciated by musicians, such systems have already been installed in many performance spaces. For example, in order to increase reverberation time from 1.5 seconds to over 2 seconds, a version [of the system] was installed in the Prague Congress Center, a multipurpose auditorium used for discussions as well as symphonic concerts."[18] They write here that musicians appreciate the electroacoustic enhancement, but I do not believe such support to be unanimous.

Spaces where electronic reinforcement systems are used today include the Elgin Theatre and the Sony Centre in Toronto, the Hilbert Circle Theatre (home of the Indianapolis Symphony Orchestra) in Indianapolis, the Deutsches Staatsoper in Berlin, the Mörbisch Festspiele in Austria, and the Hayden Planetarium in New York. These venues have apparently overcome any opposition to the use of electronic enhancement systems. One argument against such systems involves the distinction between naturally produced sound and sound that is broadcast electronically. Natural sound created by musicians which then reflects off surfaces in an enclosure is fundamentally different from sound that is electronically captured and broadcast through the medium of a loudspeaker. Electronically produced sound contrasts with sound produced by drawing a bow across a string, thereby setting the string into vibration. Sound waves produced by the vibration of a string reach the ears directly, and reflections off surfaces in

[18] Ibid., 200-2.

a room reach the ears within milliseconds of the initial direct sound. In my opinion, sound waves that have been transduced by a loudspeaker cannot have the exact same aural fingerprint as sound produced by the bow on a string, and reflected off surfaces in a room. For example, when cassette tapes were still a viable technology for recording and playing back sound, there was an advertising slogan from a cassette tape company: "Is it live, or is it Memorex?" I believe that anyone with sensitive ears will be able to recognize that it is in fact not live, but indeed, is Memorex. An electronic addition to the orchestra is controversial because electroacoustics might be perceived as alien to the natural sound produced by musicians and reflected by the surfaces in the room.

The Acoustic Dimensions report alludes to the potential for controversy in Kleinhans Music Hall: "installation of such electronic systems within spaces for live performance is a somewhat controversial step and should only be undertaken with the agreement of the Orchestra."[19] Like their historical counterpart, Electrical Research Products Inc. (ERPI), a large part of Acoustic Dimensions' business model involves outfitting theaters and arenas with costly electronic sound equipment. For example, Acoustic Dimensions designed sound systems in recent years for two local venues: HSBC Arena and Ralph Wilson Stadium, as well as many other arenas throughout the country.[20] If an electroacoustic reinforcement system was desired by the Buffalo Philharmonic Orchestra, Acoustic Dimensions would stand to profit.

[19] *Acoustics Study: Kleinhans Music Hall*, 22 December 2006, 14.

[20] "AD Profile| HSBC Arena." Acoustic Dimensions, www.acousticdimensions.com/projects/ sport_ent/hsbc.htm, accessed 1 October 2010. "AD Profile| Ralph Wilson Stadium." Acoustic Dimensions, www.acousticdimensions.com/projects/ sport_ent/ralhwilson.htm, accessed 1 October 2010.

Should an electronic enhancement system be approved by the orchestra and installed in Kleinhans, it would offer the advantage of creating a variety of different soundscapes otherwise impossible to experience in the hall. Blesser and Salter write,

> Without electroacoustic intervention, a fixed space cannot be optimized for lectures in the morning, Wagnerian opera in the afternoon, and Gregorian chants in the evening: the requirements for these three performances are contradictory. Electroacoustics thus provides a new dimension to aural architecture: instantaneous spatial changes by adjusting acoustical parameters… It can allow an aural architect to create temporary musical spaces to match the enduring legacy of our diverse musical heritage. It can allow a conductor to use aural space as a musical element rather than adapting music and musicians to an immutable acoustic structure. Although these prospects may seem to smack of science-fiction fantasy, science and technology are currently available to achieve them provided only society wishes to invest the necessary resources.[21]

In their view, the results clearly justify the expense of an electronic enhancement system.

During the period of its planning and construction, Acting Director Esther Link, relying on the advice of acoustical consultants Charles Potwin and Paul Sabine, sought to ensure that Kleinhans possessed a strongly resonant sound, thereby bucking the trend in the opening decades of the twentieth century toward "modern sound," with its directness and low reverberation time. Unfortunately for the planners, although the sound is generally very clear and projects well

[21] Blesser and Salter, *Spaces Speak* (2007), 203. Gregorian chants have historically been performed in cathedrals with reverberation times of five or more seconds. Such conditions are unlikely to be found in any music hall today. It should be noted that Barry Blesser is a recording engineer who during his career in the recording industry developed digital audio and artificial reverberation products, and hence, is a strong proponent of electroacoustic technology.

throughout most of the auditorium, the quality of reverberation in Kleinhans Music Hall has proven to be less than desired. The science of room acoustics, now more than one hundred years old, has evolved to become multifaceted, with new music halls possessing the ability to significantly vary their acoustical conditions to suit the needs of music or speech. Such flexibility contrasts with the singular, historic "modern sound."

For now it appears that Kleinhans Music Hall, unless it chooses to adopt the costly and controversial electronic enhancement system, will remain a hall with a single acoustical setting. Like its original planners, the stewards of the hall today prefer an acoustical environment with a robust sense of reverberation. Kleinhans, of course, is a building dedicated to the performance of music, but the main auditorium is used today for many purposes in addition to orchestral concerts. Kleinhans hosts rock concerts and events for which the spoken word is essential, like graduations and literary readings. It might seem that a problem arises here. The spoken word is best understood with a low reverberation time of around one second, possibly less. Increasing the reverberation time in the main auditorium to improve conditions for listening to music might reduce conditions for understanding speech, but the effects on speech comprehension would be more than compensated for by the positive effects of reverberation on musical performance. I would, therefore, like to see the reverberation time in the auditorium increased and hence fulfill the intentions of the original acoustical consultants and the directors of the orchestra today.

APPENDIX A

Electrical Research Products Inc.
SUBSIDIARY OF
Western Electric Company
INCORPORATED
195 BROADWAY, NEW YORK

ADDRESS REPLIES TO
ENGINEERING LABORATORIES
76 VARICK STREET
WALKER 5-3193

March 6, 1940

Miss Esther L. Link, Acting Director
The Kleinhans Music Hall, Inc.
361 Delaware Avenue
Buffalo, N. Y.

Dear Miss Link:

In reply to your recent letter, I am attaching copies of two reprints which I hope will prove interesting to you.

I am sure that when the Music Hall is completed the time of reverberation will please the most critical musician. The amount of acoustical material to be used is exceedingly small because the Hall has been planned basically for musical requirements.

Eero Saarinen tells me that it is proposed to have Dr. Paul Sabine check the acoustical plans from the standpoint of reverberation time. We shall be pleased to have him check the reverberation time and will be glad to cooperate with him in every way.

Yours very truly,

C. C. Potwin

C. C. POTWIN
Acoustical Consultant

Att.

APPENDIX B

COPY

November 8, 1940

Miss Esther L. Link
226 Southampton Street
Buffalo, New York

Dear Miss Link:

We appreciate your comments and attached letter from Mr. Quimby with whom I also talked at the opening.

Your statement with respect to the carpet seems to check with our original acoustical analysis. For your information, carpet was installed over the complete main floor area under the seats without our knowledge and was not included in our recommendations. I was surprised to observe it upon my arrival in Buffalo. Since this auditorium had not been designed on the "dead" side of optimum I had hoped when I saw that carpet had been installed, that it might not prove excessive. Presumably, this will not be the case. When you compare approximately 8,000 square feet of carpet under seats on the main floor with only a small amount (800 square feet) of absorbing material on the side walls, I believe you can readily understand the difference in resonance or liveness that you observed after the carpet was installed.

Our recommendations were based on carpeted aisles and standing space and allowed for carpet under the seats in only a limited area of the loge section at the front of the balcony. You will, no doubt, also recall our opposition to complete carpeting in the Chamber Music Room at the time this was considered, and where our original recommendations were based on the use of removable aisle runners only. We finally agreed to the use of carpet in this room only on the basis that the major part of it could be removed.

The time of reverberation of Carnegie Hall at 512 c.p.s. computed by the Sabine formula on the basis of a full audience is 1.75 seconds; Boston Symphony Hall 1.93 seconds; and Kleinhans Music Hall without carpet under the seats on the main floor 2.00 seconds, and with carpet under the seats on the main floor 1.70 seconds.

I was rather surprised to learn for the first time from the Buffalo papers that Dr. Sabine was associated prominently with the acoustical planning of the Hall. I shall appreciate any further comments you may have with respect to the Hall.

Very truly yours,

C. C. Potwin
Acoustical Consultant

CCP:HAS

APPENDIX C

THE ACOUSTICAL MEASUREMENTS OF KLEINHANS MUSIC HALL

C. C. Potwin -
Electrical Research
Products, Inc.

The acoustical measurements made by Electrical Research Products Inc. in the Kleinhans Music Hall show that:

(1) The requirements of design for proper acoustical conditions have been fulfilled in both the Main Auditorium and the Mary Seaton Room.

(2) The measured frequency characteristics of reverberation for both halls, that is, the times of reverberation ranging from the low tones to the high tones of sound, are of the correct aesthetic value for orchestral and vocal music.

(3) These characteristics are also within the limits found, from measured data on other halls, to be the most desirable for auditoriums of this size used primarily for music.

(4) The shapes of the "die-away" curves of sound for the various musical tones measured in each hall show that the changing patterns of the sound waves and the control of the first few reflections of sound from walls and ceiling are correct for the greatest enjoyment of music.

(5) The number of logarithmic (uniformly shaped) "die-away" curves measured in these halls is greater than those measured by ERPI in any other hall. This type of curve has been adjudged by artists, music critics, and engineers to be the one which gives the most pleasing qualities to sound produced in auditoriums.

METHOD OF MEASUREMENT

A High Speed Level Recorder designed by the Bell Telephone Laboratories was used for the tests made by ERPI in the Kleinhans Music Hall. This is the most accurate instrument known today for the measurement of sound. It records the exact decay, or"die-away", of sound for any frequency or tone selected in the musical range.

The tone is generated by a loudspeaker placed on the stage, and is picked up by microphones placed in a large number of positions throughout the seating area. At the moment the sound is stopped a stylus, or needle on the recorder, draws an actual line on a chart which shows the manner in which the sound is dying away at the particular frequency being measured. From these lines, or curves, not only can the time of reverberation (the time it takes the sound to die out to inaudibility after the sound source is stopped) be determined at each frequency, but one may also analyze the way in which sound is reflecting from surface to surface and is being distributed to the ears of the audience. This latter analysis often proves to be of greater importance than the time of reverberation.

If acoustical measurements are to be comprehensive, they must be made for a large number of frequencies, or variously-pitched tones, and also for a large number of microphone positions throughout the seating area. In the Main Auditorium, a total of 45 frequencies were measured in each one of 27 different microphone positions throughout the main floor and balcony. In the Mary Seaton Room the same number of frequencies were measured at 12 microphone positions.

The Main Auditorium

In order to avoid any misunderstandings, one very important factor should be clarified when reporting the results of acoustical measurements. The so-called "ideal reverberation times" (more correctly called desirable reverberation times) published in the literature are based on mathematical computations made by the Sabine formula, of halls judged as having good acoustics. Measured values of reverberation times obtained in these and other halls range from 15% to 20% lower than those computed by the Sabine formula. The correction factor is well known to experienced acoustical engineers.

Figure I shows three curves for the Main Auditorium in Kleinhans Music Hall. The dot-dash line represents the desirable computed values of reverberation time, and is referred to as the "desirable computed curve." The broken line shows the desirable measured values of reverberation time for a hall of this size and shape, and is noted as the "desirable measured curve." The line, or curve, marked A is the actual measured frequency characteristic of reverberation of the Main Auditorium, ranging from the low tones to the high tones of sound.

As an interesting comparison, curves are shown for two other well known music halls which have approximately the same cubical content as the Main Auditorium of Kleinhans Music Hall. These curves were also measured with the High Speed Level Recorder.

The shape of the frequency characteristic of reverberation times obtained for the Main Auditorium is very good, in that it follows the desirable measured curve. Also, its position, in general, lies within the desirable limits. These limits, or "band", if plotted on the chart would cover the range from 10% above to 10% below the desirable measured curve shown.

However, in analyzing the various positions of measurement independently, that is, the individual positions in which the microphones were placed for the tests, the curves for the main floor and particularly those obtained in the forward portion of this area are slightly lower than those obtained in the balcony. This result is obviously caused by complete carpeting of the main floor, and tends to lower slightly the net average or over-all values of reverberation time for the entire auditorium.

While it would be possible to show a difference in reverberation times if measurements were made both with and without the carpet installed, and without an audience seated, it is doubtful that the same difference could be upheld by measurements made under the/ same two sets of conditions, but with a capacity audience seated in the auditorium. The effect of the carpet is principally a subjective one. It absorbs the first few sound reflections that normally reach the ears of an audience from a hard floor under these seats. As a result, the reflections from the forward sections of the walls and ceiling stand out somewhat more markedly, and produce an effect of slightly greater definition and slightly less blending for sound produced on the stage. This applies only to the area that is carpeted and probably could be detected only by a critical listener. Under present conditions, the auditorium is highly acceptable from a reverberation standpoint on the main floor and completely satisfactory in the balcony.

The Mary Seaton Room

Figure II shows the desirable computed curve and the desirable measured curve for the Mary Seaton Room. The actual measured characteristic is shown as Curve A and falls well within the desirable limits of measured reverberation time for a room of this size and shape. This room may be classified as completely satisfactory for orchestral and vocal work.

ANALYSIS OF THE "DIE-AWAY" CURVES

One of the most important factors to consider in analyzing acoustical measurements made, in any auditorium, is the manner in which each tone dies away after the sound is stopped. In some auditoriums it dies away by sudden jerks and delays, with the result that the curve for the tone being measured consists of a few large irregularities or "bumps". In other cases the decay of sound may be relatively uniform, producing a fairly smooth curve with a large number of small irregularities superimposed upon it. Extensive research and experience have proved that the latter type of decay curve is pronounced "good" by musicians and audiences, whereas the first type described, if severe enough, is actually disliked.

The sound decay or "die-away" curves measured at each frequency in both the Main Auditorium and the Mary Seaton Room are for the most part logarithmic, or progressively uniform in shape, with a large number of small irregularities superimposed upon them. One of these typical curves (decay of 500 cycle tone), taken in the Main Auditorium, is shown on Figure III.

The shape of these curves indicates that the splayed and angled sections of the walls and ceiling are functioning efficiently as planned, to distribute the sound evenly and smoothly over the seating area. This result is particularly gratifying to the acoustical engineers because within their experience no other auditorium measured in this country or abroad has shown as many uniform "die-away" curves of sound as were obtained in the auditorium of the Kleinhans Music Hall.

APPENDIX D

CONTRACT # 13

GENERAL SPECIFICATIONS

FOR FLOOR COVERINGS

Carpeting shall be laid in the best manner known to the trade and unless otherwise specified shall be laid over padding weighing 48 oz. per square yard. Ozite, Allen, or Chapman quality or approved equal. All colors of carpet materials to be chosen.

ITEM #13-A - MAIN AUDITORIUM

Labor and material for covering the floor of Rooms 104 and 101 -

According to approved seating plan -

All aisles and orchestra elevator to receive Bigelow Sanford's "Looptuft" or approved equal.

Areas under all seats and steps in balcony to receive Bigelow Sanford's "Varsity" or approved equal.

ITEM #13-B - MAIN FOYER & UPPER FOYER

Labor and material for covering floors of Rooms 147, 145, 103, 146, 148, 134, 135, 201, 211, 219, 210, 212, 215, 216, 217 -

To receive Bigelow Sanford's "Looptuft" or approved equal with design insert of Bigelow Sanford's "Varsity" quality. Design as shown on page P-18.

All stairs to receive Bigelow Sanford's "Varsity" or approved equal. Treads of stairs to receive two layers of padding. An allowance of an extra 1/2 yard is to be made on each stair carpet so that it may be shifted.

ITEM #13-C - CHAMBER MUSIC HALL

Labor and material for furnishing removable carpet for Room 102 -

This covers all aisle areas according to the approved seating plan -

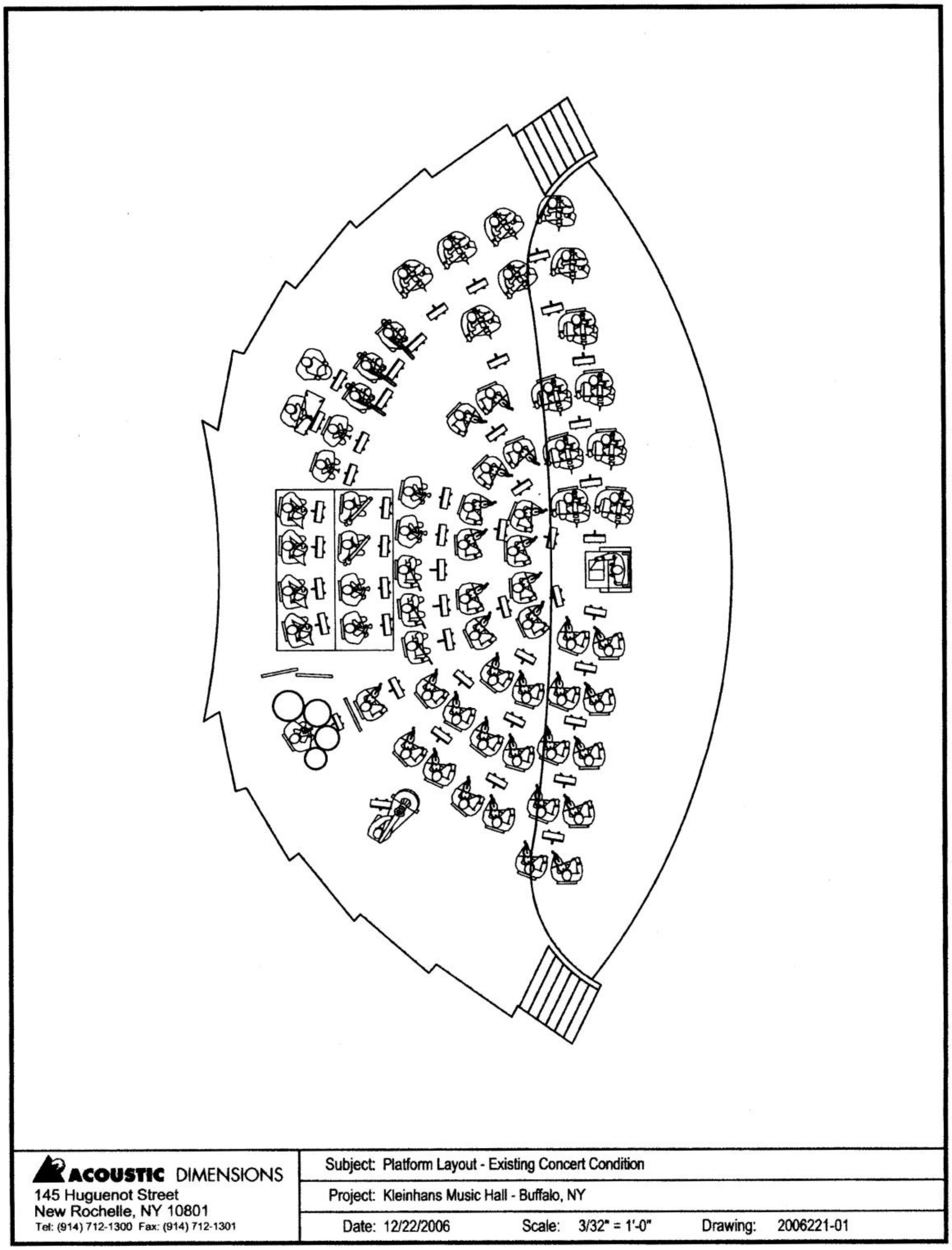
Carpet to be Bigelow Sanford's "Looptuft" or approved equal, without padding secured to the floor by the socket and pin method (equal to #523 made by H. L. Judd Wallingford Company) in a way that will hold the carpet firm and without tripping hazards. To be easily removed. All edges to be re-enforced by B.S. Lockweave 3" tape or equal.

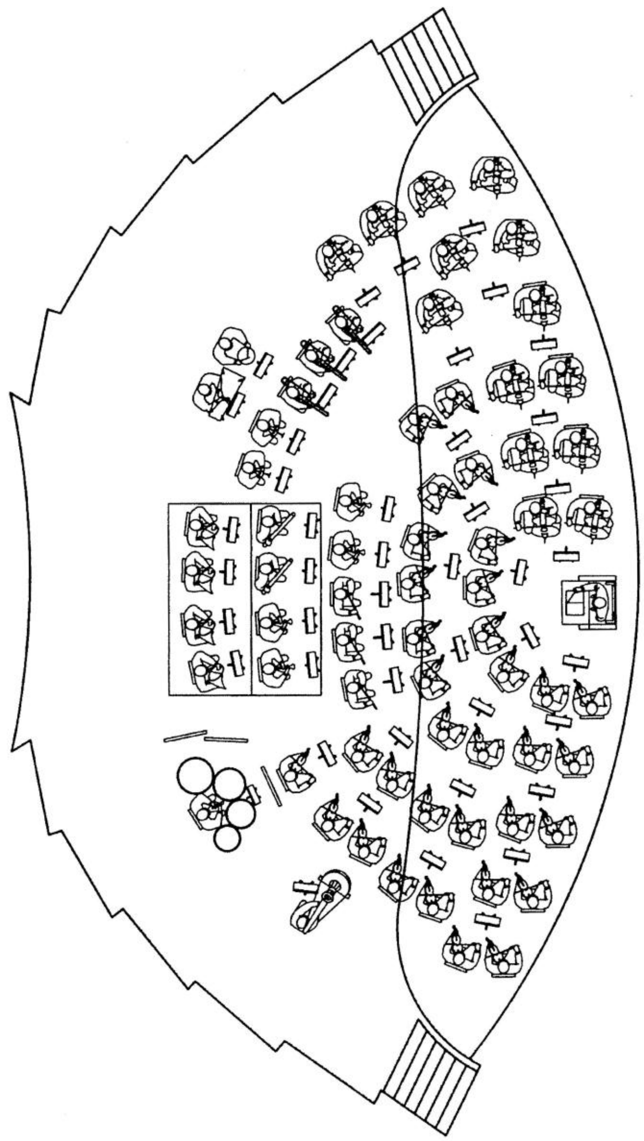
ITEM #13-D - OFFICE

Labor and material for covering floor of Rooms 129, 130 and 133 -

Bigelow Sanford's "Looptuft" or equal.

APPENDIX E


ACOUSTIC DIMENSIONS
145 Huguenot Street
New Rochelle, NY 10801
Tel: (914) 712-1300 Fax: (914) 712-1301
Subject: Platform Layout - Existing Concert Condition
Project: Kleinhans Music Hall - Buffalo, NY
Date: 12/22/2006
Scale: 3/32" = 1'-0"
Drawing: 2006221-01



ACOUSTIC DIMENSIONS 145 Huguenot Street New Rochelle, NY 10801 Tel: (914) 712-1300 Fax: (914) 712-1301	Subject: Platform Layout - Musicians Moved Downstage Project: Kleinhans Music Hall - Buffalo, NY Date: 12/22/2006 Scale: 3/32" = 1'-0" Drawing: 2006221-02

ILLUSTRATIONS

Fig. 1. Eero and Eliel Saarinen, circa 1940. (Courtesy of BPO Archives, www.music.buffalo.edu/bpo/kmh-tale.htm. Accessed 18 July 2011.)

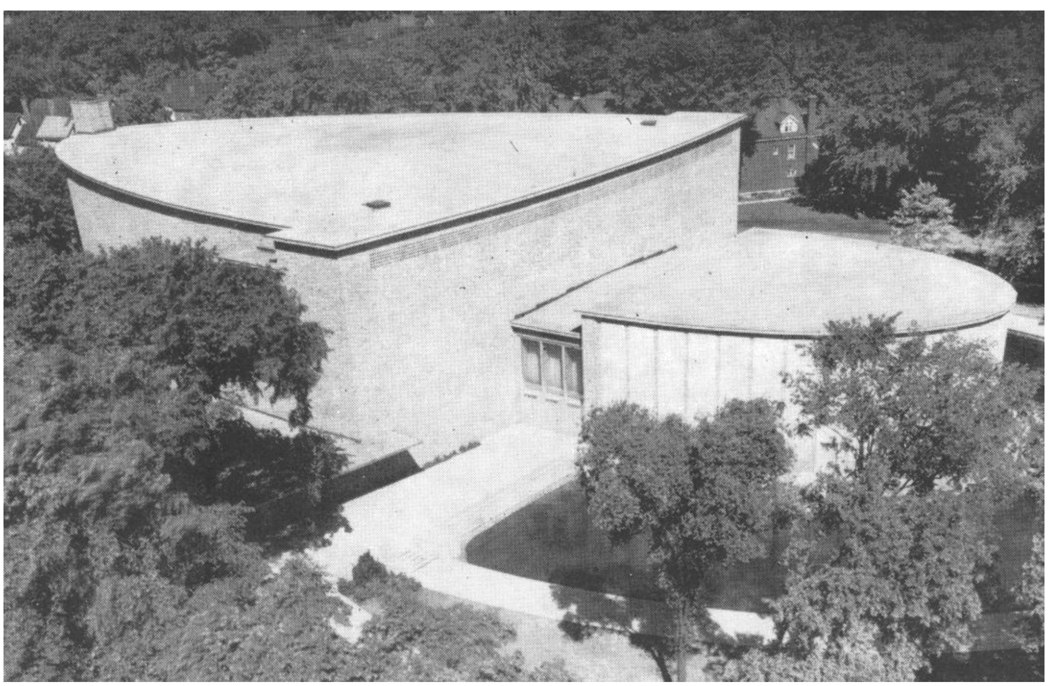


Fig. 2. Kleinhans Music Hall, bird's-eye view. (*Kleinhans Music Hall* (1953), Front Cover.)

Fig. 3. Edward L. and Mary Seaton Kleinhans (*Kleinhans Music Hall* (1953), 3.)

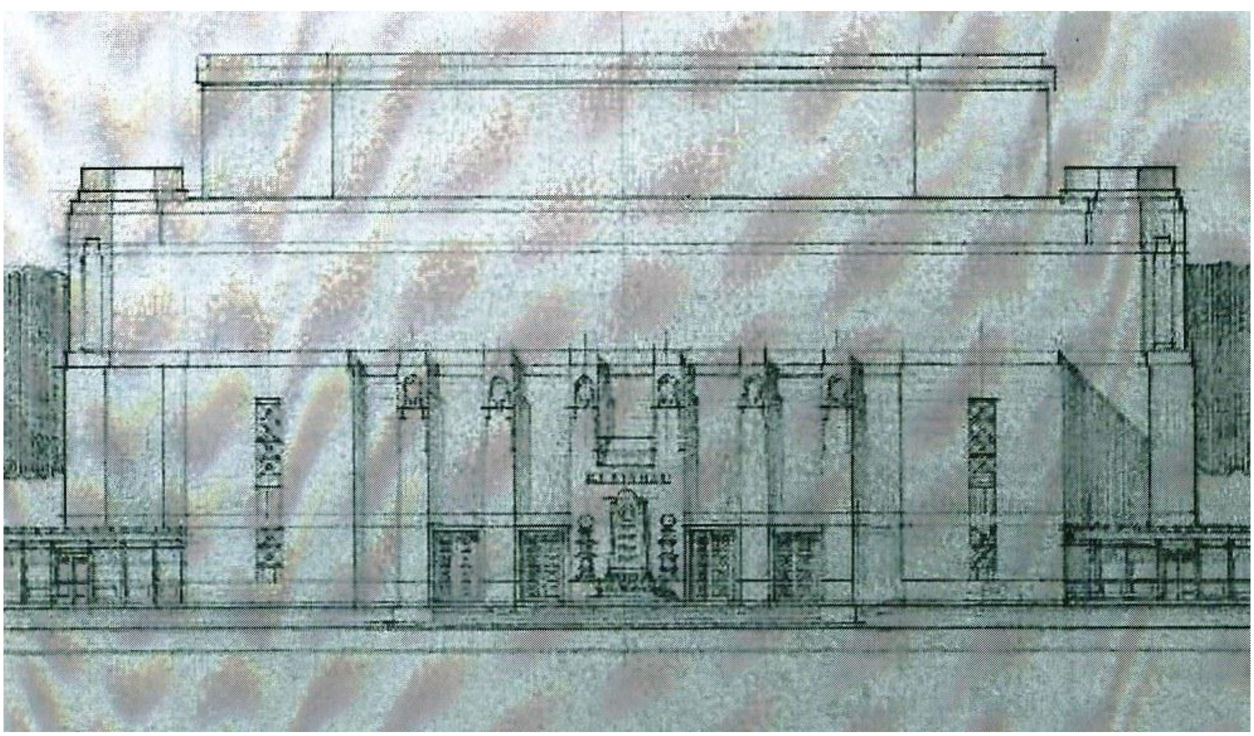


Fig. 4. Kidd and Kidd's 1938 Design for Kleinhans Music Hall, exterior.
(Kleinhans Music Hall archives.)

Fig. 5. Eliel Saarinen's Helsinki Train Station. (ARTstor. http://library.artstor.org/library/ iv2.html?parent=true#. Accessed 1 August 2011.)

Fig. 6. Eliel Saarinen's Chicago Tribune Tower, entry. (ARTstor. http://library.artstor.org/library/ iv2.html?parent=true. Accessed 1 August 2011.)

DIAGRAM OF HALL—SHOWING INTERIOR ARRANGEMENT

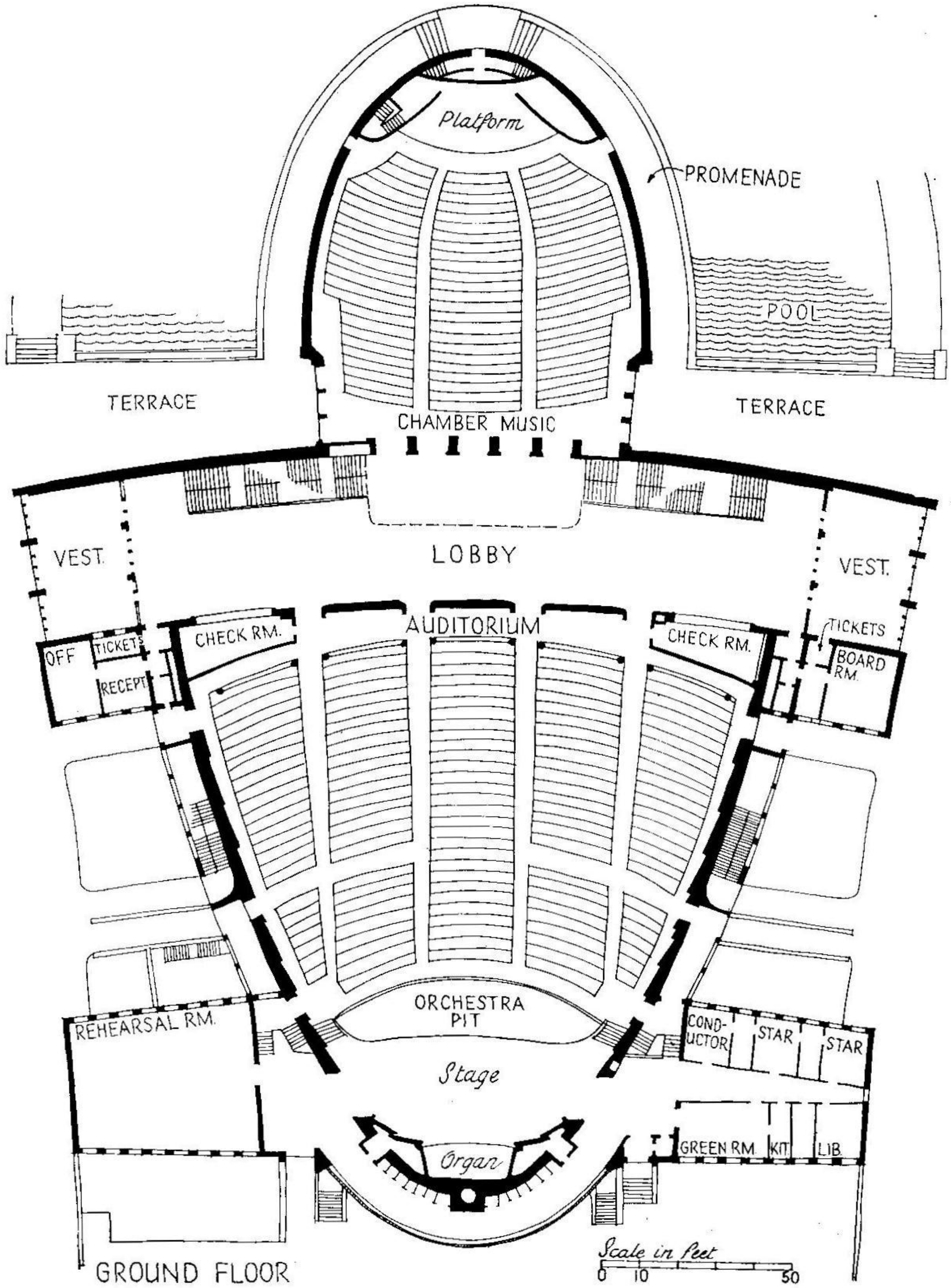


Fig. 7. Kleinhans Music Hall, plan. (*Kleinhans Music Hall* (1953), 32.)

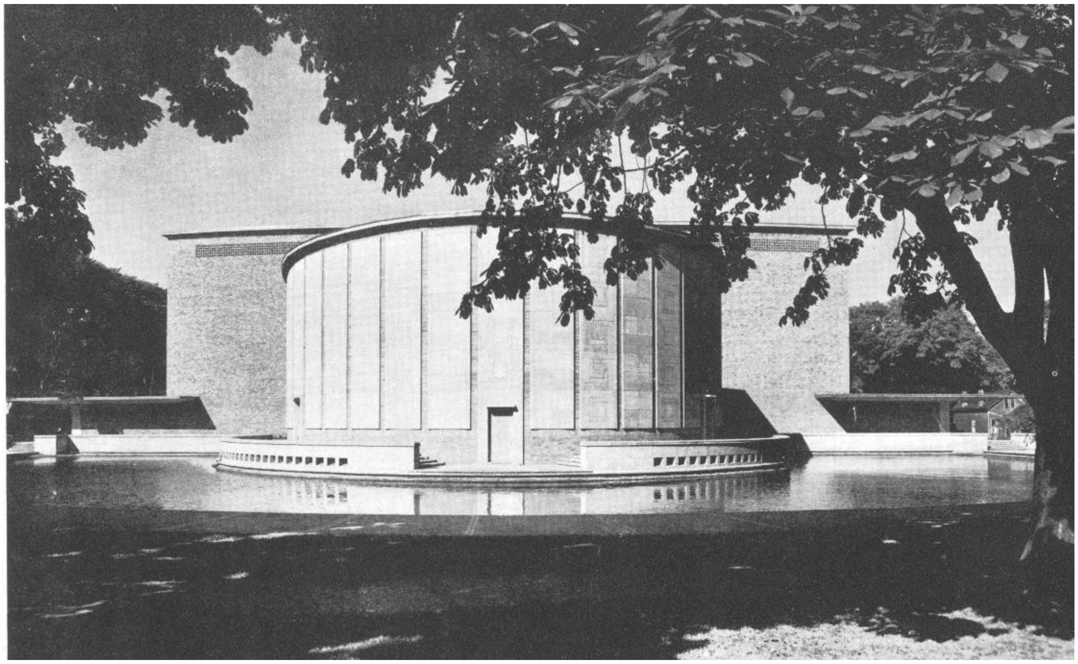


Fig. 8. Kleinhans Music Hall, Chamber Music Hall with reflecting pool. (*Kleinhans Music Hall* (1953), 26.)

Fig. 9. Kleinhans Music Hall, Main Auditorium, set for an orchestral concert. (BuffaloNews.com, "Celebrating a Musical Marvel." http://www.buffalonews.com/city/article258291.ece Accessed 1 August 2011.)

Fig. 10. Mary Seaton Room, view from the stage (set for a quartet.) Note enormous floor to ceiling doors to lobby, and small doors (left and right) contained within. (*Buffalo as an Architectural Museum*, http://www.buffaloah.com/a/sym/klein/misc/source/2.html Accessed 4 August 2011.)

Fig. 11. Kleinhans Music Hall, Livingston Hall. (*Kleinhans Music Hall* (1953), 30.)

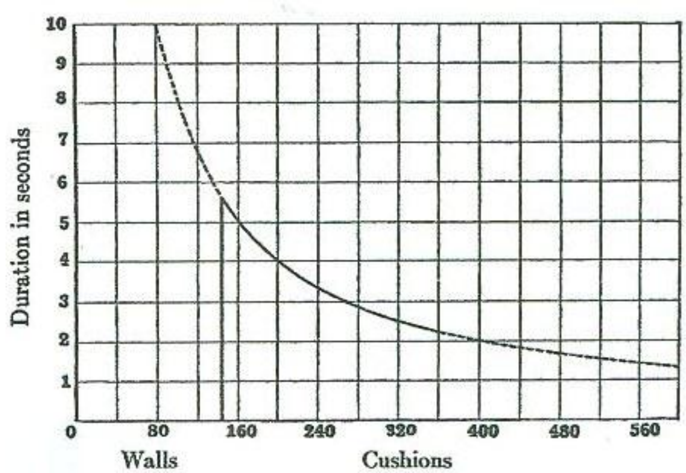


FIG. 6. Curve 5 plotted as part of its corresponding rectangular hyperbola. The solid part was determined experimentally; the displacement of this to the right measures the absorbing power of the walls of the room.

Fig. 12. Wallace Sabine's hyperbola: Reverberation Time plotted against the Number of Seat Cushions, with extrapolations to the left and right. Note the time decreases as the seat cushions increase. (Source: Thompson, *The Soundscape of Modernity* (2002), 38.)

Fig. 13. Boston Symphony Hall, interior. (*Wired*. http://www.wired.com/science/discoveries/news/2008/10/dayintech_1015# Accessed 1 August 2011.)

Fig. 14. Paul E. Sabine. ("Architectural Acoustics: Its Past and Its Possibilities." *Journal of the Acoustical Society of America*, 11 (July 1939): 21.)

Fig. 15. Charles C. Potwin. ("Charles C. Potwin," *Journal of the Acoustical Society of America* 13 (January 1942): 318.)

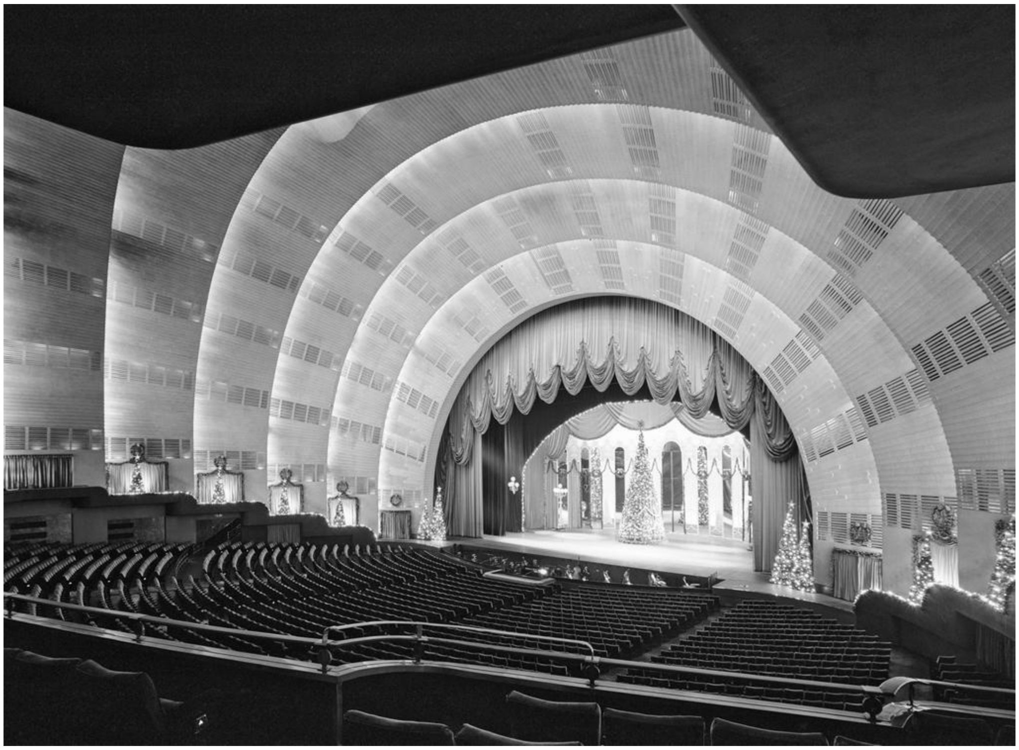


Fig. 16. Radio City Music Hall. (ARTstor. http://library.artstor.org/library/iv2.html?parent=true Accessed 1 August 2011.)

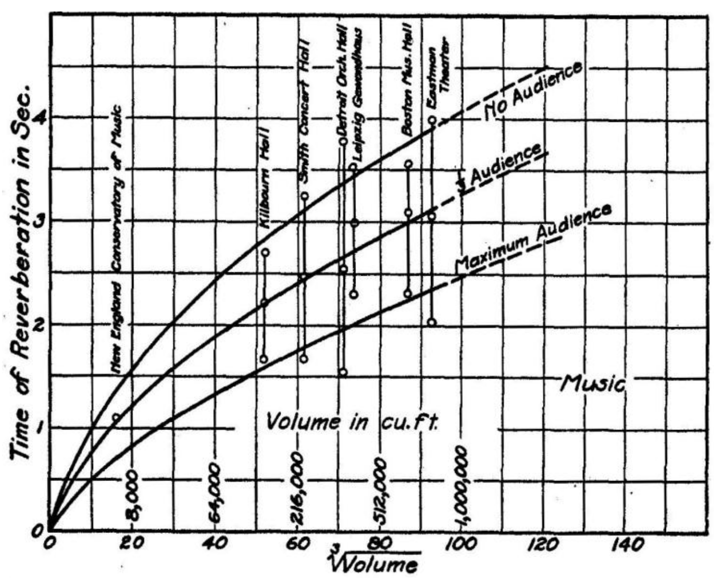


FIG. 12. — Acceptable Time of Reverberation for Concert Halls of Different Volume.

Fig. 17. Floyd Watson's recommended Reverberation Time Graph. (Watson, *Acoustics of Buildings*, 1923).

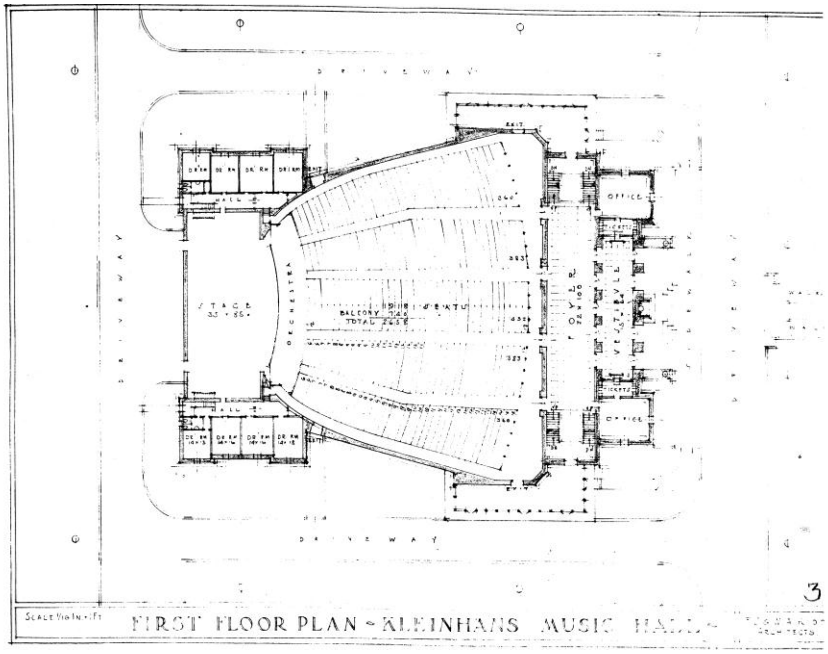


Fig. 18. Kidd and Kidd, Plan. Note the fan-shaped auditorium design. (Kleinhans Music Hall archives.)

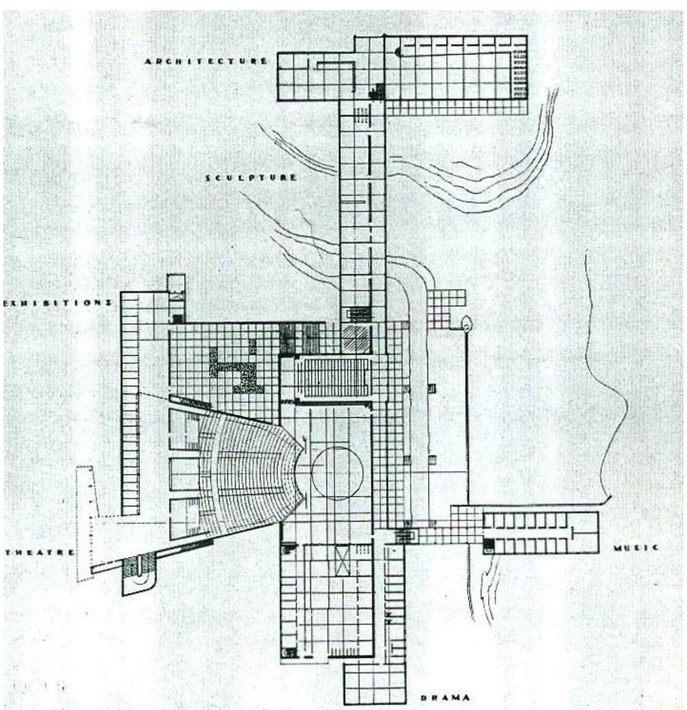


Fig. 19. Eero Saarinen, Theater Project for College of Williams and Mary, Plan. Note the fan-shaped auditorium on the left. ("Winners of National Theater Competition Are Announced." *Architectural Record* 85 (April 1939): 62.)

Fig. 20. Esther Link. (“Esther Links Plays Big Part in Music Hall Construction.” *Buffalo Evening News*, 10 October 1940.)

Fig. 21. Edward Letchworth. (Kleinhans Music Hall (1953), 6)

Fig. 22. Leopold Stokowski, 1928. (ARTstor. http://library.artstor.org/library/iv2.html?parent=true Accessed 2 August 2011.)

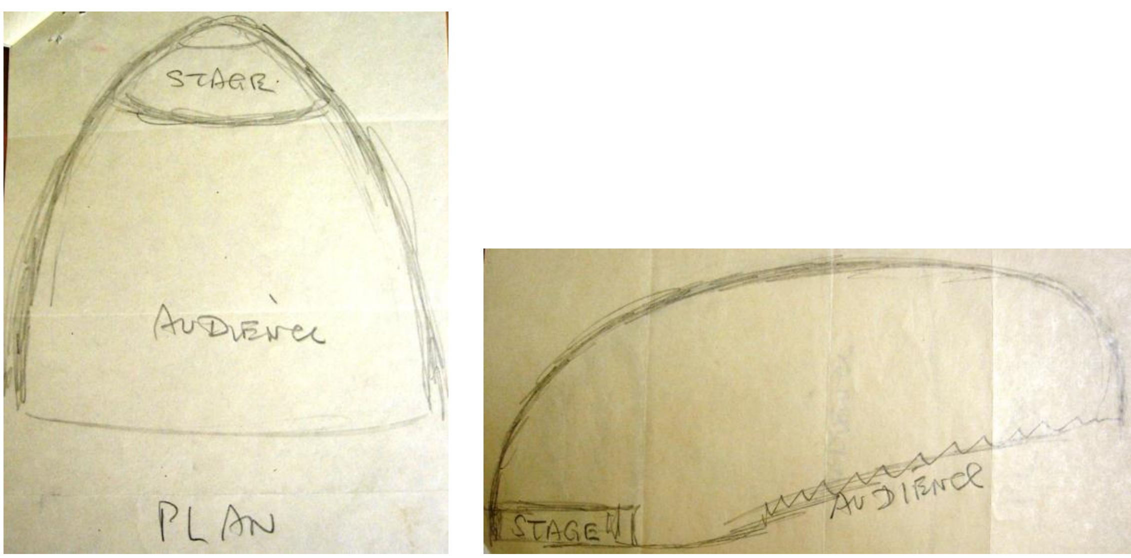


Fig. 23. Stokowski Sketches for Kleinhans Music Hall, Plan and Elevation. (Kleinhans Music Hall archives.)

FRANCO AUTORI

Fig. 24. Franco Autori, Music Director, Buffalo Philharmonic Orchestra (1936-1945). (Courtesy of the Buffalo Philharmonic Archives, http://www.music.buffalo.edu/bpo/mus-dirs.htm Accessed 1 August 2011.)

Fig. 25. Boston Symphony Hall and Orchestra, with Serge Koussevitzky in 1930. Note the risers to the left and right. (Philadelphia Orchestra Home Page – Leopold Stokowski. http://www.stokowski.org/Boston_Symphony_Musicians_List.htm Accessed: 11 May 2011.)

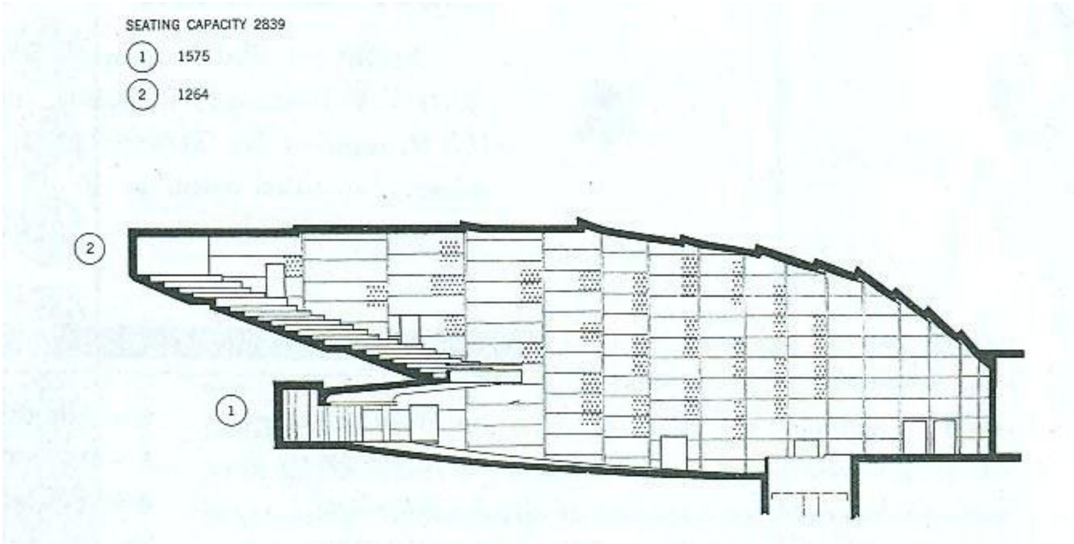
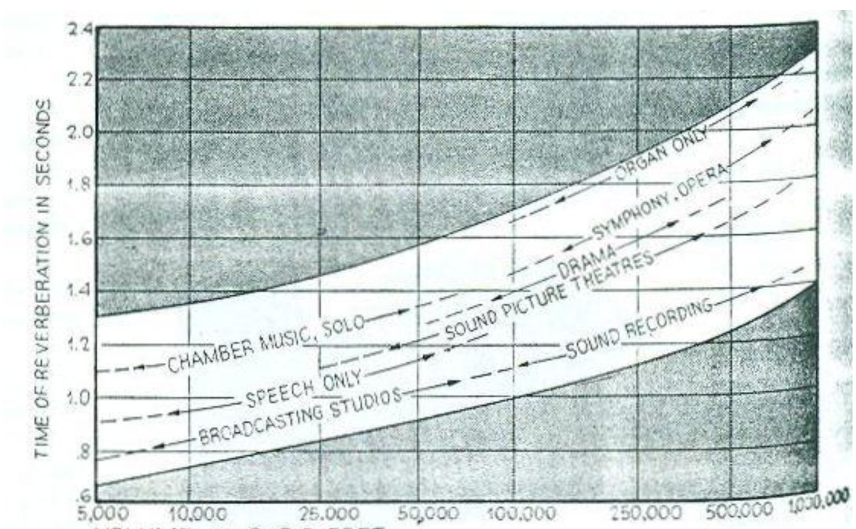


Fig. 26. Kleinhans Music Hall, Main Auditorium Section. Note how the balcony tilts upward, above the main floor. (Beranek, *Concert Halls and Opera Houses* (2004, 1996), 53.)



Desirable times of reverberation for various kinds of sound presentation in various size rooms, frequency 512 c.p.s. (average). Times should be reasonably uniform for other frequencies, especially in broadcasting, sound recording, and lecture rooms, increasing slightly at low frequencies with increase in room volume.

Fig. 27. Potwin's Recommended Reverberation Times Graph.
("Architectural Acoustics: 2." *The Architectural Forum* 71 (September 1939): 204.)

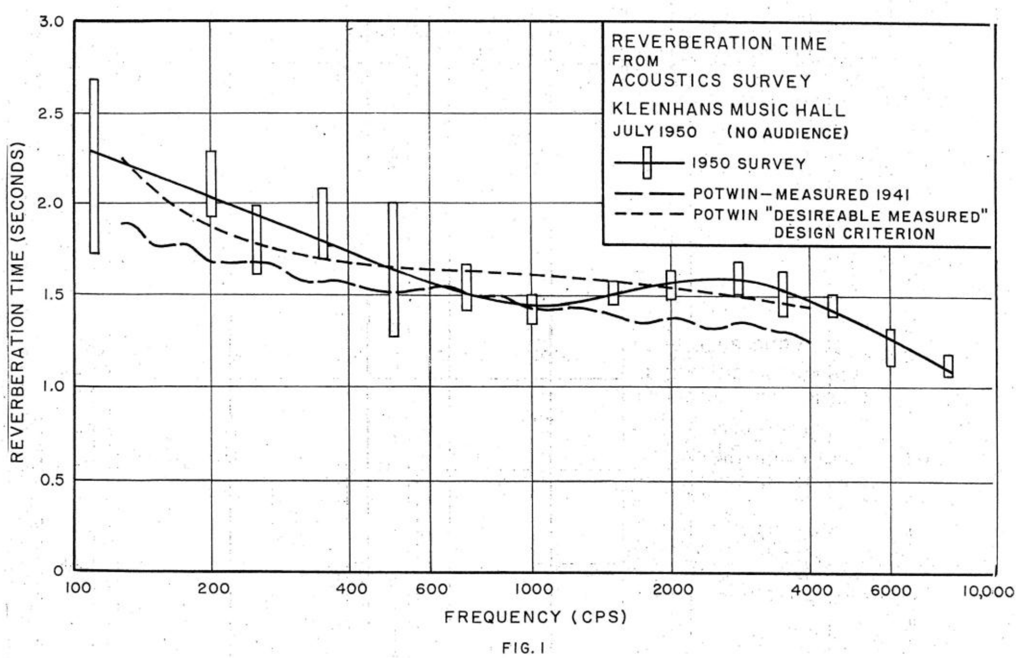


Fig. 28. Reverberation Time Graph, MIT Study (1950). (Kleinhans Music Hall archives.)

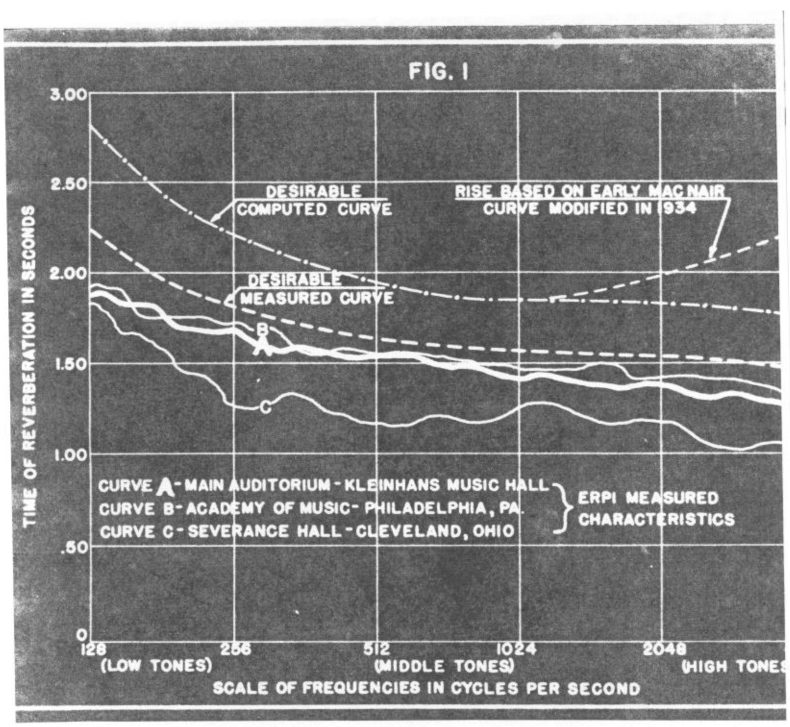


Fig. 29. Reverberation Time Graph, Charles Potwin Report. (Kleinhans Music Hall archives.)

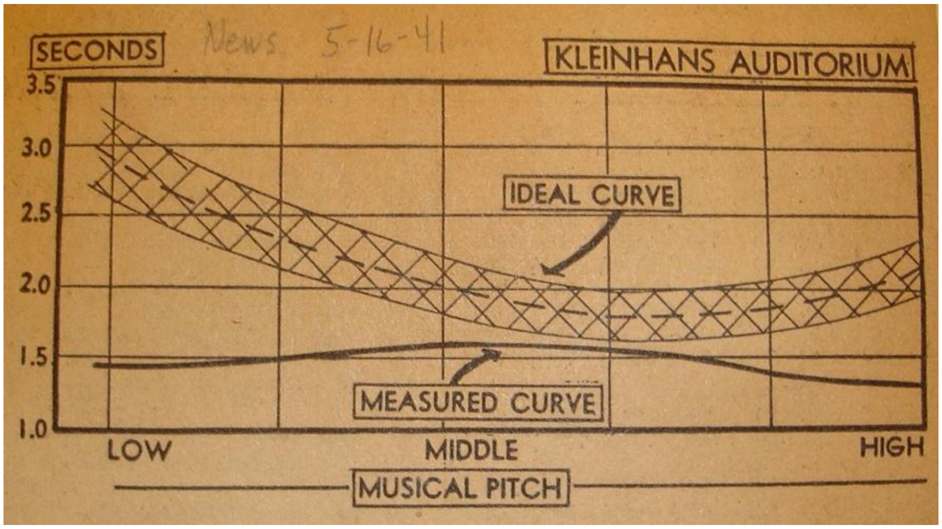


Fig. 30. Reverberation Time Graph, Grant Hector's Study of Kleinhans Music Hall ("Acoustical Expert Measures Quality of Two New Halls," *Buffalo Evening News*, 16 May 1941.)

Miss Kerr says that her investigation
so far indicates that Mr. Eames brought
the carpet specifications from Saarinen.
She thinks she can locate the original
from the Kidds.

Fig. 31. Typewritten Note Found in Carpet Specifications.
(Kleinhans Music Hall archives.)

Fig. 32. Charles Eames and Eero Saarinen. (Photo courtesy of Cranbrook Archives. http://www.cranbrookart.edu/Pages/History.html Accessed 18 July 2011.)

Fig. 33. Meyerson Symphony Center, Dallas. (CBS DFW.com
http://dfw.cbslocal.com/top-lists/best-concert-halls-theaters-in-dallas/
Accessed 2 August 2011.)

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