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The forging of modern Broadway Sound Design Techniques amid the Fires of the Rock Musicals in the Late 1960s and 1970s.

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THE FORGING OF MODERN BROADWAY SOUND DESIGN TECHNIQUES AMID THE FIRES OF THE ROCK MUSICALS IN THE LATE 1960s AND 1970s

by

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ABSTRACT

From the ancient Greek theater, through the dawn of the Renaissance, beyond the development of Shakespearean theater, to the Broadway theater boon in the 1920s, sound reinforcement within the theater remained virtually unchanged. Through Broadway's Golden Age, directors and producers relied on architectural acoustics to carry sound throughout the theaters. This is not surprising given that most of the theaters were built in the early 1900s, before the invention of any electric sound reinforcement technology. Moreover, early attempts at amplification in the 1940s yielded dismal results. Eventually, the maturation of the integrated book musical and the invasion of the rock musical in the late 1960s demanded more than architectural acoustics alone could provide. Abe Jacob, the sound designer of *Hair* and *Jesus Christ Superstar*, led the efforts to create a modern approach to sound design. Relying on his rock-and-roll touring experience and the introduction of technological advancements within the recording industry, Jacob and others forged a modern approach to sound design specifically within the framework of the Broadway musical, which helped restore the fading industry of the Broadway musical in the late 1960s.

These new approaches served well the human irony and concept musicals of the 1970s by Sondheim and other emerging composers. Sound design was critical to the successful mounting of the mega-musicals of the 1980s (*Cats*, *Les Miserables*, *Starlight Express*, *The Phantom of the Opera*, *Miss Saigon*, etc.). Now, modern day composers collaborate early in the creation process with sound designers and create original works with the power of modern sound design in mind,

such that today, sound design is a fundamental design discipline employed in every Broadway musical–from the initial show concept conversations all the way through opening night.

To my wife, Eleanor

ACKNOWLEDGMENTS

I am grateful for the support of many along this endeavor. The team at Northland Church supported me daily, offering words of encouragement and prayers. I also wish to thank Bill Platt for showing me a “better way” in the use of sound reinforcement. Dr. Scott Warfield provided tireless oversight, always balancing the call to do better work with equal amounts of encouragement–I will always be grateful. My son, Michael, as a sound professional in New York City theater, was a source of great wisdom and inspiration for this project.Thank you, Michael.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Broadway is big business. Box office receipts exceeded $1 billion each year since the 2009–2010 season.[1] According to the Broadway League's 2012–2013 biennial report, the Broadway industry contributed $11.9 billion to the New York City economy and supported 87,000 jobs.[2] These numbers exceed those of most American municipalities. As Galinda in the musical *Wicked* might say, Broadway is exceedingly "pop-u-u-lar" with the public. Its 2013–2014 attendance topped that of the ten professional New York City metropolitan sports leagues (baseball's Mets and Yankees, hockey's Rangers, Islanders and Devils, basketball's Knicks and Nets, women's basketball's Liberty, and football's Giants and Jets) *combined*.[3]

Broadway is big spectacle. The mega-musicals of the 1980s and 1990s (*Cats, Starlight Express, The Phantom of the Opera, Les Miserables, Miss Saigon*, etc.) have mushroomed into never-before-seen extravaganzas like *Spider-Man: Turn off the Dark*, whose producers spent more than $75 million dollars during its ill-fated run. A closer look at these numbers yields interesting findings pertaining to the creative discipline of sound design within the Broadway

[1] The Broadway League, "Broadway Season Statistics," last accessed April 22, 2015. http://www.broadwayleague.com/index.php?url_identifier=season-by-season-stats-1. The Broadway League is the national trade association for the Broadway industry.

[2] The Broadway League, "Broadway's Economic Contribution to New York City 2012–2013," last accessed April 22, 2015. http://www.broadwayleague.com/index.php?url_identifier=broadway-s-economic-contribution-to-new-york-city.

[3] The Broadway League, "Broadway Facts," last accessed April 22, 2015. http://www.broadwayleague.com/editor_files/Broadway-Facts.pdf.

musical budget. During the first four months of its life, *Spider-Man* spent $48 million of the $75 million eventual total, broken down as follows in Table 1.[4]

Table 1–Cost Breakdown of *Spider-Man: Turn Off The Dark*

Physical Production (sets, costumes, special effects, etc.)	$16.4 million	34.2%
Pre-production expenses (rehearsal hall, casting, theater rental, stagehands, etc.)	$13.7 million	28.5%
Creative and production fees (director, general manager, etc.)	$5.7 million	11.9%
Rehearsal salaries	$6.1 million	12.7%
Advertising	$3.1 million	6.4%
Developmental/Workshop	$2.0 million	4.2%
Other	$1.0 million	2.1%
TOTAL	**$48.0 million**	

A further breakdown (see Table 2) of the first line item, “Physical Production,” reveals just how little of the $16.4 million in “physical production” costs was spent on sound design and production.

[4] Kevin Flynn and Patrick Healy, “How the Numbers Add Up (Way Up) for ‘Spider-Man.’” *New York Times,* June 23, 2011, A1.

Table 2–Breakdown of "Physical Production" Costs from Table 1

Physical Production	Amount	% of $48 Million Total
Sets and props	$8.8 million	18.3%
Costumes, shoes, wigs, etc.	$2.6 million	5.4%
Flight rigs and machinery	$2.3 million	4.8%
Video and Lighting	$1.7 million	3.6%
Other	$0.6 million	1.3%
Sound	$0.4 million	0.8%

The $400,000 spent on sound was, in fact, the sum total that the producers of *Spider-Man* invested in sound design and sound production of the $48 million investment during its initial four months–*i.e.,* 0.8% of $48 million. The producers spent more than six times that amount on costumes, shoes, and wigs; and more than four times that amount on video and lighting. While the sound design and production budget was dwarfed by *Spider-Man*'s special effects and other dazzling production elements, sound design, according to multiple-Tony-award-winning sound designer Brian Ronan, is typically among the more moderate line items in today's Broadway musical production budget.[5]

Of all the usual creative design disciplines in a Broadway production–stage direction, choreography, lighting, costuming, sets, and sound–sound design is the most enigmatic. The sound design of a Broadway musical is unseen and often subtle. For most theatergoers, sound is simply assumed with little thought of its underlying complexity. Perhaps that is why the first

[5] Brian Ronan, interviewed by author, New York City, April 3, 2014.

Broadway sound design credit did not appear until 1961, and sound designers waited another forty-seven years when, in 2008, the Broadway League and the American Theater Wing altered the ballot to award Tonys for best sound design of a play and best sound design of a musical.[6] As Howard Sherman, then-executive director of the American Theater Wing affirmed, "This is not an award for placing a microphone somewhere. It's about the creation of an aural environment that impacts our relationship to a production, just like any other design."[7] In a surprise announcement on June 11, 2014, the Tony Awards administration committee reversed its 2008 decision and eliminated the Tony award categories for best sound design of a play and of a musical.[8] Between the June 11, 2014 announcement and July 30, 2014, over 32,000 theater professionals and patrons signed a petition to reinstate these Tony awards for best sound design of a play and of a musical.[9] While no Tony awards will be awarded for sound design in the 2015 season, the Tony Awards administration committee petitioned the Tony rules committee to review the widespread request to restore these Tony awards.[10] No timetable has been set for this review.

The Broadway League and the American Theater Wing may continue to flip-flop on the merits of sound design in a Broadway production; yet, no live musical production demands more

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[6] Mark Blankenship, "Making Noise Behind The Scenes," *New York Times*, June 1, 2008, AR13.

[7] Ibid.

[8] Philippe Bowgen, "Tony Award Administration Committee Eliminates Sound Design Categories," last accessed April 22, 2015. http://www.playbill.com/news/article/tony-award-administration-committee-eliminates-sound-design-categories-322389.

[9] John Gromada, "Reinstate the Tony Award Categories for Sound Design Now!," last accessed April 22, 2015. http://www.thepetitionsite.com/470/217/554/reinstate-the-tony-award-categories-for-sound-design-now/.

[10] Patrick Healy, "Tony Panel to Review Decision on Sound Design," *New York Times,* November 15, 2014, C2.

from its sound design than that of a Broadway musical. No other live production that incorporates live music requires its sound design to reproduce everything from a dramatic whisper one moment to a Merman-esque belt the next. The same sound design must reproduce the music of a large chorus, a single violin or other delicate acoustic instrument, and electroacoustic sounds across the full range of human hearing, including the experience of hearing them, *i.e.*, lower frequencies are more "felt" than heard. As such, sound is now a design discipline fully integrated into the creation and mounting of every Broadway production. In fact, sound design is one of the tools that many of Broadway's present-day composers presume upon when creating new works.[11]

In this thesis, I will argue that no other theatrical design discipline is more responsible for the direct communication of the essence of a Broadway musical than sound design. Sound provides *the* direct connection between the core content of the production as created by book writers, composers, and lyricists, and the theatergoers. Costume, set, and lighting designs are each secondary reflections of the story or character(s). As playwright and novelist Thornton Wilder (1987–1975) once said, "The unencumbered stage encourages the truth operative in everyone. The less seen, the more heard. The eye is the enemy of the ear in real drama."[12] Sound design shares its level of contribution with the other design disciplines for the artistic success of a Broadway show. In larger Broadway theaters and touring theaters across America, whose size

[11] Brian Ronan interview.

[12] David T. Bradley, Erica E. Ryherd, and Michelle C. Vigeant, *Acoustical design of theatres for drama performance, 1985–2010* (Melville, NY: Acoustical Society of America, 2010), 306.

can often double Broadway houses, sound design bears additional responsibility for the show's financial success. Brian Ronan notes:

> In larger venues some of the visual components of a show, its wigs, costumes, scenery, props, etc., become, literally, distant in remote seating areas. However, if the audience can hear the show in the far reaches of the theatre well they can still appreciate the show's story line and music. This allows seats to be sold in distant and visually impaired areas opening up a wider ticket base.[13]

I will trace sound design from its shared origins with the birth of the theater in ancient Greece through the expansion of sound design and sound effects in Shakespeare's theaters. I will look at the transition Broadway producers made from the exclusive use of architectural acoustics and mechanically generated sound effects during Broadway's Golden Age (commonly referred to as the era between the 1940 production of *Pal Joey* and 1964's *Fiddler on The Roof)* to electrically reinforced sound on Broadway during the 1960s. Special attention will be given to the sound design crisis created by the arrival of the rock musical on Broadway, which, I will demonstrate, served as a pivotal point in forging today's Broadway sound design techniques. First, however, it is important to understand the impact sound has on humans, specifically the connection between the ear, the brain, and human memory and emotion.

[13] Brian Ronan interview.

CHAPTER 1: MUSIC + OUR EAR/BRAIN MECHANISM = OUR HUMANITY

> Music is unusual among all human activities for both its *ubiquity* and its *antiquity*. No known human culture now or anytime in the recorded past lacked music. Some of the oldest artifacts found in human and protohuman excavation sites are musical instruments: bone flutes and animal skins stretched over tree stumps to make drums. Whenever humans come together for any reason, music is there: weddings, funerals, graduation from college, men marching off to war, stadium sporting events, a night on the town, prayer, a romantic dinner, mothers rocking their infants to sleep, and college students studying with music as a background.[14]

Daniel Levitin believes humans are obsessed with music. "Americans spend more money on music than on sex or prescription drugs. Given this voracious consumption, I would say that most Americans qualify as expert music listeners."[15] Levitin is certainly including American theatergoers as expert listeners when considering the musical portion of a Broadway musical. Abe Jacob, a veteran Broadway sound designer featured later in this thesis for his ground-breaking sound designs of *Hair* and *Jesus Christ Superstar,* captures this notion well: "Every person connected with the theatre knows two jobs: their own…and sound! Everybody is a sound expert."[16]

Science has taught us that music produces affective responses which engage the brain's emotional processing deep in the reptilian regions of the cortex.[17] Music and humanity are inextricable–you cannot have one without the other. Music matters, and the way in which we are

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[14] Daniel J. Levitin, *This is your brain on music: the science of human obsession* (New York: Plume, 2007), 5–6.

[15] Ibid., 7.

[16] David Collison, *The sound of theatre: a history* (Eastbourne, England: PLASA, 2008), 240.

[17] Daniel Levitin, *This is your brain on music: the science of human obsession,* 87.

presented music–whether it be "natural" acoustical reinforcement or electronic reinforcement–also matters. At all times, we are interested and engaged listeners. We do not choose this reality. We are born with it.

Music Preference And Human Development

The auditory system of prenatal infants is fully developed and functioning twenty weeks after conception. Alexandra Lamont discovered that one-year old children preferred music they listened to in utero over other music, even music of a similar style. In her experiment, Lamont asked expectant mothers to play a single piece of music repeatedly during the final trimester of pregnancy. And while these prenatal infants were also hearing the other sounds and noises to which their mothers' environments would have been exposed–including other pieces of music–the babies clearly showed a preference one year after birth to the pieces of music their mothers played to them in utero.

The parameters of the experiment make this a powerful finding. First, the songs chosen for the fetuses were of varying styles, including classical, reggae, Top 40, and world music. From the moment of each baby's birth through its first birthday, the mother stopped playing the chosen piece to her baby. At one year, the mother replayed–for the first time since birth–the original, in utero song, along with several other songs of similar style. Lamont, relying on the traditional head turning procedure developed in the 1960s for infants demonstrating preference, confirmed that babies preferred the song they heard in utero over every other song, including songs of very

similar styles.[18] As Levitin noted, these "results are important because they show that the prenatal and newborn brain are able to store [musical] memories and retrieve them over long periods of time."[19]

By the time we are two years old, we start to show preference for the music of our culture, if we show any musical preference at all. Those children with a preference for music initially prefer songs with simple melodies, or clearly defined themes, and predictable harmonic progressions.[20] It is not until our teen years, however, that we begin to "take on music as a real interest, even in those children who didn't express such an interest in music earlier."[21] As adults, "the music that we tend to be nostalgic about…corresponds to the music we heard during these [teen] years."[22] Levitin notes that we allow music to hold sway over us. We often surrender to the music to which we listen.

> [W]e allow ourselves to trust the composers and musicians with a part of our hearts and spirits; we let the music take us somewhere outside of ourselves. Many of us feel that great music connects us to something larger than our own existence, to other people, or to God. Even when music doesn't transport us to an emotional place that is transcendent, music can change our mood.[23]

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[18] Alexandra M. Lamont, "Infants' preferences for familiar and unfamiliar music: a socio–culture study," paper read at Society for Music Perception and Cognition, August 9, 2001, Kingston, Ontario.

[19] Daniel Levitin, *This is your brain on music: the science of human obsession,* 227.

[20] Ibid., 230.

[21] Ibid., 231.

[22] Ibid.

[23] Ibid., 242–243.

Music And The Power Of Memory

The music and memory connection is gaining scientific attention. We all have experienced the phenomenon of the "earworm." "An earworm (or Involuntary Musical Imagery) is a short snippet of music that comes unbidden into the mind and then repeats outside the will of conscious control."[24] Simply put, earworms are those phrases of music that play over and over in our head involuntarily, and we seemingly have little control to stop them. According to Finnish cognitive scientist Lassi A. Liikkanen, earworms are experienced by 90% of people at least once per week.[25]

Music is deeply embedded into human memory and can be the recall trigger for powerful human emotions even when we are listening without conscious thought or effort. "The music that you have listened to at various times in your life is cross-coded with the events of those times. That is, the music is linked to the events of the time, and those events are linked to the music."[26] As Levitin notes, we only need the proper trigger to recall any memory. It is not that the memory is not stored in the brain, it is that we don't always have the right cue to recall it. And specifically, the more unique the cue, the greater the chance we have of recalling a detailed memory event. As it relates to music, the more often we continue to hear the same song over time, the less likely we are to associate the song with a specific memory. "But as soon as we hear

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[24] Rhian Worth and Victoria Williamson, "Music to Our Ears: Interview with Victoria Williamson," *Europe's Journal of Psychology* 8, no. 2 (2012): 218.

[25] Lassi A. Liikkanen, "Musical activities predispose to involuntary musical imagery," *Psychology of Music* 40, no. 2 (2012): 236–256.

[26] Daniel Levitin, *This is your brain on music: the science of human obsession,* 166.

a song we haven't heard since a particular time in our lives, the floodgates of memory open and we are immersed in memories."[27]

Memory also plays a very important role when we are actively listening to music. "As the music is playing (particularly if you're engaged with focused attention), your brain is thinking ahead to what the different possibilities for the next note are, where the music is going, its trajectory, its intended direction, and its ultimate end point."[28] Listening to music is quite a workout for the brain. "[M]any brain regions participate in specific aspects of music processing, whether supporting perception (such as apprehending a melody) or evoking emotional reactions."[29] According to neuroscientists, we break down sounds "into the fundamental elements of loudness, pitch, contour, duration/rhythm, tempo, timbre, spatial location and reverberation."[30] Perhaps even more impressive is our ability to process each of these attributes of sound distinctly from the other. Further, "each can be varied without altering the others, allowing the scientific study of one at a time."[31]

Though invisible, sound–and music, in particular–has shown to be a powerful anthropomorphic marker for humans. As I noted at the beginning of this chapter in quoting Daniel Levitin, humankind and music are inextricable. And while musical theater is a relatively young genre, music within dramatic settings date to 5 BCE. According to Shay Thornton, "…

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[27] Ibid.

[28] Ibid., 236.

[29] Norman M. Weinberger, "Music and the Brain," *Scientific American* (November 2004): 95.

[30] Daniel Levitin, *This is your brain on music: the science of human obsession,* 15.

[31] Ibid., 17.

most plays in Greece were set up with one to three actors and a chorus that responded to what the characters did. Both the actors and the chorus sang lyrics throughout the play."[32] In like manner, today's Broadway productions feature actors and choruses speaking and singing throughout the production: through music and the spoken word, Broadway musicals cut through to the core of our humanity. The productions reflect back to us what it means to be human. Thus, sound design and sound production are powerful tools necessary to deliver the Broadway experience to the theatergoer.

As Brian Ronan indicated, trust with the theatergoer is compromised when there is a single failure in sound (a microphone or speaker goes dead, an actor's line is missed, an unplanned sound system startle such as feedback or other noise, etc.). As listening beings, "…we (hearing people) take [sound] for granted and become impatient when it's less than nominal."[33] More importantly, perhaps, Ronan notes that a sound failure has a negative affect on the actor as they often are not aware as to why it happened, when it will happen again, or how often it will happen. Ronan notes "[i]t's their resilience and spontaneity that helps them work through technical failures and deliver the story to the audience."[34]

No other technical design discipline within the Broadway musical is more labor intensive–and thus more prone to human error–during a performance than that of the sound operator. Whereas lighting and stage scenery are controlled entirely via the aid of computer

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[32] Shay Thornton, "A Wonderful Life: Educational Study Guide," *Theatre Under The Stars*, page 2, last accessed April 22, 2015. http://web.archive.org/web/20071127051412/http://www.tuts.com/season07/wonderful_study.pdf.

[33] Brian Ronan interview.

[34] Ibid.

automation, each and every line of dialogue is manually "mixed" by the sound operator separately from the other as he/she strives to leave only one microphone open, or "on," at a time.[35] The stakes are high and everyone has an opinion on sound–everyone. And that is due to the fact that sound and music connect deeply to our human existence.

John Meyer is the founder and president of Meyer Sound Laboratories, Inc., a preeminent loudspeaker manufacturer whose products are found in virtually every professional theatrical installation throughout the world. Meyer, who holds twenty-three loudspeaker design patents, once remarked: "Sound and music are the most powerful forces exerted on the human mind." A student and scientist of sound, Meyer made the empirical observation:

> Everyone thinks that visual stimuli are powerful. How often, over the course of a lifetime, do you watch your favorite video source (movie, television show, etc.)? By comparison, how often do you listen to your favorite song or musical recording?[36]

And though modern science is beginning to map the power of music on our memory and our humanity, the basic science of sound was discovered first by the ancient Greeks, and the power of sound design was incorporated into the theater at its earliest beginnings.

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[35] I have personally observed several Broadway musicals while sitting in the front-of-house sound booth. When two (or more) actors' microphones pick up a single sound source, they do so at different times due to the physical distance between the actors. Even though milliseconds apart in time, two or more microphones picking up the same sound produce a noticeably muffled sound known as microphone phase cancellation.

[36] John Meyer, interviewed by author, Berkeley, May, 2010.

CHAPTER 2: THE HISTORY OF SOUND IN THE THEATER

The first credit for sound design of a Broadway musical was given to Jack Mann on January 11, 1961–the opening night of *Show Girl*, a lightweight musical revue starring Carol Channing.[37] As previously mentioned, however, the discipline of theatrical sound design shares its origins with the theater itself dating back to ancient Greece, where sound design was a necessary focus within the Greek's enormous theaters. According to Benjamin Hunningher, theaters in Sophocles time (495-406 BC) accommodated up to 17,000 theatergoers.[38] Figure 1 on the next page provides a plan view of a typical ancient Greek theater. A few notable measurements help to convey the massive size of these theatrical structures.

Hunningher's archeological research sets the distance from the center stage to the back row of seating at approximately 275 feet. (This compares to a current distance of ninety-three feet for Vienna's Wiener Staatsoper and ninety-six feet for Wagner's Bayreuth Festspielhaus.[39] The farthest seat from the stage in the Metropolitan Opera House in New York City is an impressive 174 feet.[40]) The distance from center stage to the first row in a typical ancient Greek theater was approximately thirty to thirty-five feet and the distance from center stage to the farthest seat hard right or left was about ninety feet.[41]

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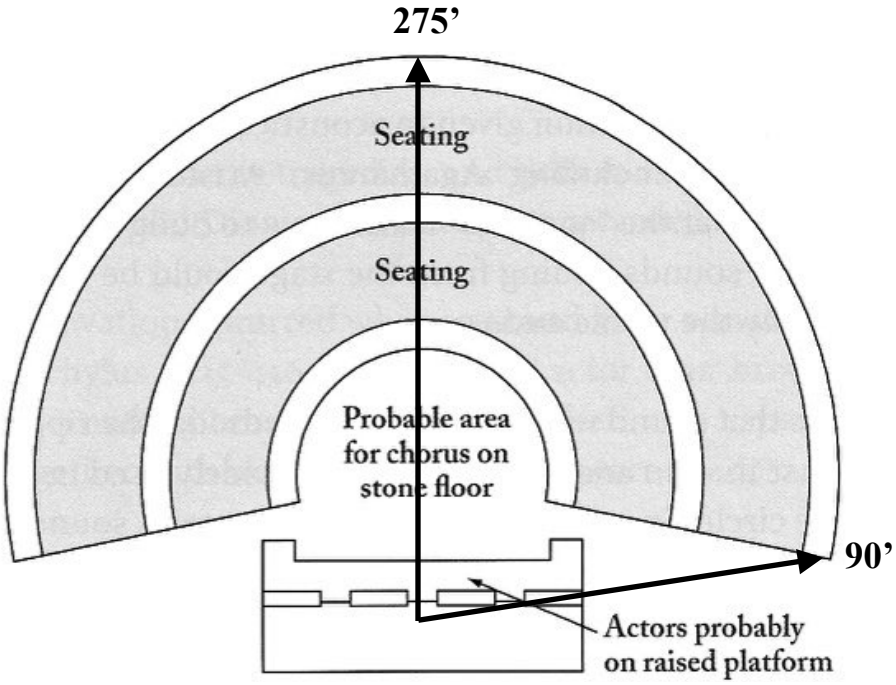
[37] Mark Blankenship, "Making Noise Behind The Scenes."

[38] Benjamin Hunningher, *Acoustics and acting in the theatre of Dionysus Eleuthereus* (Amsterdam: Noord-Hollandsche Uitgevers Maatschappij, 1956), 309–310.

[39] David Collison, *The sound of theatre: a history*, 4.

[40] Michael Barron, *Auditorium Acoustics and Architectural Design,* 2nd ed. (New York: Spon Press, 2010), 356.

[41] David Collison, *The sound of theatre: a history,* 4.



David Collison–*The sound of theatre: a history*
Figure 1–Typical layout of Sophoclean (495–406 BC) Theater (measurements added for clarification).

Ernest A. Gardner, an English archeologist from the early 1900s, noted "…it cannot be supposed that the democratic audience of Athens would have tolerated any performance which was not audible throughout the building."[42] According to veteran West End sound designer David Collison, Aristotle was preoccupied with acoustics, making the significant discovery "that sound waves do not behave in the same way as light, since they are not confined to straight lines."[43] Aristotle, noting that sound travels in the shape of a conical wave, is responsible for the

[42] Ernest A. Gardner, *Ancient Athens* (London: The Macmillan Company, 1902), 438.

[43] David Collison, *The sound of theatre: a history,* 3.

steep rake of the audience seating within ancient Greek theaters. Further, Aristotle discovered the importance of sound absorption and reflection and how both could be harnessed to enhance sound within the theater. Specifically, Aristotle experimented with different materials for the stage floor, settling on hard, flat sand over a mixture of straw, chaff and sand, to achieve greater clarity from the chorus.[44] It is worth noting here that virtually nothing has changed in today's discipline of architectural acoustics.

> The discipline of architectural acoustics can generally be divided into two sub-fields: *noise control* and *room acoustics*...Room acoustics focuses on the characterization and optimization of the acoustical conditions within a built environment…we…focus on the actor as the source and the audience member as the receiver.[45]

The Roman architect Vitruvius's important work, *De architectura*, was completed in the first century BC and served as a detailed manifesto for ancient theater construction. Vitruvius' contribution to the science of sound and his detailed findings for application within the theater are impressive. "When these matters are arranged with great care and skill, particular attention must be bestowed on the choice of a place where the voice falls smoothly, and reaches the ear distinctly without an echo. Some places are naturally unfavourable to the diffusion of the voice."[46] Vitruvius' work includes many theories of sound which are still applied in today's theatrical acoustic design.[47] He documented several architecturally-formed unwanted reflections,

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[44] Ibid.

[45] David T. Bradley, Erica E. Ryherd, and Michelle C. Vigeant, *Acoustical design of theatres for drama performance, 1985–2010* (Melville, NY: Acoustical Society of America, 2010), 306.

[46] Marcus Vitruvius Pollio, *De architectura* (Book V), translated by Joseph Gwilt (London: Priestley and Weale, 1826), last accessed April 22, 2015. http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Vitruvius/5*.html, under "Chapter 8."

[47] David Collison, *The sound of theatre: a history*, 3.

or dissonant places, where vocal intelligibility was reduced. Similarly, Vitruvious documented favorable reflections, or consonant places, where vocal clarity was enhanced and even amplified by architectural reflections.[48] This topic of helpful (consonant) and harmful (dissonant) reflections is expanded in Chapter 4 (the "Haas" effect).

Sound In The Ancient Greek Theater

Early innovations in ancient Greek theater sound design made impressive use of Aristotle's and Vitruvius' work. The upstage back wall was the first architectural addition to ancient Greek theaters. When playwrights supplemented the standard Greek chorus with individual characters, the upstage back wall (noted by Vitruvius' as a consonant reflection) served to project dialogue effectively into the theater space.[49] Ancient sound amplifiers which consisted of sympathetically tuned bronze vases, were placed strategically throughout the massive theaters' seating areas to help carry dialogue to the farthest seats.[50] As recently as 2006,

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[48] Vitruvius, *De architecutra* (Book V), last accessed April 22, 2015. http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Vitruvius/5*.html, under "Chapter 8." A sonic reflection here is a secondary or tertiary sound that is generated by the original sound hitting another hard surface, *e.g.,* a wall, a floor, a ceiling, etc.

[49] David Collison, *The sound of theatre: a history*, 5.

[50] Vitruvius, *De architecutra* (Book V), last accessed April 22, 2015. http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Vitruvius/5*.html, under "Chapter 8."
Vitruvius' specifications here are impressive. "…the brazen vases are to be made with mathematical proportions, depending on the size of the theatre…Then, between the seats of the theatre, cavities having been prepared, they are disposed therein in musical order, but so as not to touch the wall in any part, but to have a clear space round them and over their top: they are fixed in an inverted position, and on the side towards the scene are supported by wedges not less than half a foot high: and openings are left towards the cavities on the lower beds of the steps, each two feet long, and half a foot wide…By the adoption of this plan, the voice which issues from the scene, expanding as from a centre, and striking against the cavity of each vase, will sound with increased clearness and harmony, from its unison with one or other of them…Hence, he who carefully attends to these rules, to the nature of the voice, and to the taste of the audience, will easily learn the method of designing theatres with the greatest perfection."

Rob Goodman undertook the task to reproduce these vases and study their efficacy to aid in sound amplification. Goodman concluded, "There is now a large amount of evidence to support the concept. Other resonating vases have been found throughout history and some are still in use. There is no doubt that Vitruvius was the source…."[51]

And while the science of sound was being employed impressively by the ancient Greeks, they were also keenly aware of the power of sound to intensify the dramaturgical experience. Thunder, wind, animal noises, door hinges, and other theatrical sound effects were used extensively in ancient theater settings.[52] The Greek mathematician and engineer, Heron of Alexandria, designed a thunder machine in the first century AD (see Figure 2).[53] "The cord on the right released the bronze balls at the top. The balls fell through the baffles onto the stretched skin at the bottom."[54]

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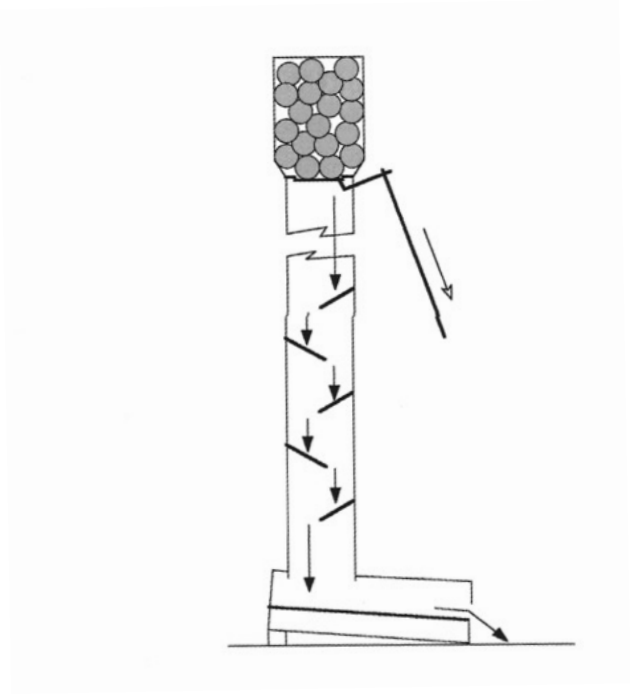
[51] Rob Goodman, "The enigma of Vitruvian resonating vases and the relevance of the concept for today," *Working papers in Art & Design* no. 4 (2006).

[52] David Collison, *The sound of theatre: a history*, 8–9.

[53] Robert S. Brumbaugh, *Ancient Greek gadgets and machines,* (New York: Crowell, 1966), 28.

[54] David Collison, *The sound of theatre: a history*, 8.



David Collison–*The sound of theatre: a history*
Figure 2–Heron of Alexandria Thunder Machine.

It is legitimate to conclude that, apart from the writing of scripts and the directing of the actors in their delivery of dialogue, sound was *the* primary design discipline in ancient Greek theater. The theaters' massive sizes would have rendered costuming ineffective for all but the initial rows bordering the stage. Likewise, stage movement would not be read deeply into the audience areas. Given the lack of electricity, lighting would have been limited to sun, moon, and shadows. Sound design in ancient Greece was a discipline of supreme focus which concerned itself with the science of acoustics to properly reinforce and project the voices of the actors and choruses, and the creation and implementation of sound effects to assist in a play's dramaturgical efforts. Sound design in today's Broadway musicals is concerned with the very same issues–the

accurate reinforcement and projection of the voices and music and the creation and implementation of sound effects.

Sound In The Mediaeval Theater

Very little is known about theater from the collapse of the Roman Empire through the Dark Ages. Theater emerged again in Mediaeval Europe with the dramatic tellings of the story of the Christian God. "Much of the drama that has survived was written to teach…people…the stories of the Bible…as well as to inculcate Christian doctrine and encourage good moral behavior."[55] Biblical themes such as heaven and hell, God speaking forth the Ten Commandments, the appearance of angels, the eternal inferno, etc. demanded more powerful sound effects and, with the ability to add explosions via the use of gunpowder, sound effects grew more elaborate during the Mediaeval ages.[56]

Sound Effects Explode In The Renaissance Theater

It was the Renaissance that birthed the modern theater. Italy rediscovered the theatrical achievements of the ancient Greeks and Romans during the fifteenth and sixteenth centuries. Vitruvius' work was also discovered in manuscript form and published in Italy in 1480.[57] Using his work, the:

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[55] Peter Meredith, "Mediaeval drama in Europe" in *The Cambridge Guide to Theatre*, 2nd ed., ed. Martin Banham (Cambridge: Cambridge University Press, 2008), 696.

[56] David Collison, *The sound of theatre: a history*, 10–11.

[57] Ibid., 14.

> Italians designed a new kind of theatre; a rectangular building with a roof, with a semi-circle of seats facing a flat-fronted stage area, complete with a proscenium and scenery. The first modern theater (as far as we know) was built in Ferrara (in northern Italy)…at the very end of the 1400s.[58]

Italian architects designed magnificent theaters to support Italy's interest in its newly developed art forms of opera and ballet. As Phyllis Hartnoll, editor of *The Oxford Companion to the Theatre,* noted, "…we must concede that…Italy deserves her reputation as the cradle of the modern theatre."[59]

The Italians' development of indoor theater soon spread throughout Europe and was seminal in the construction of permanent theaters in London.[60] The Globe, built in 1599 and rebuilt in 1613 following a 1612 fire, was the hub for most of William Shakespeare's works. According to James Brock, the audiences of Shakespeare and his playwright contemporaries would have demanded the heavy use of sound effects.[61] Such expectation is confirmed by an apology written into the prologue of *The Two Merry Milkmaids,* a play written by one of Shakespeare's contemporaries:

> This Day we entreat All that are hither come, To expect no noyse or Guns, Trumpet, no Drum, Nor Sword and Targuet; but to heare Sence and Words, Fitting the matter, that the Scene affords. So that the Stage being reform'd, and

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[58] Ibid.

[59] Phyllis Hartnoll, *The theatre: a concise history,* 3rd ed., updated by Enoch Brater (London: Thames and Hudson, 1998), 60.

[60] Ibid.

[61] James W. Brock, "A Study of the Use of Sound Effects In Elizabethan Drama" (PhD dissertation, Northwestern University, 1951). Such "sound amplification" controversies existed long before Broadway's Golden Age.

> free From the lowd Clamors it was wont to bee, Turmoye'd with Battailes; you
> I hope will cease Your dayly Tumults, and with us wish Peace…[62]

Off-stage sound effects were as prevalent in Shakespeare's Elizabethan drama as they are today; and, according to Brock, would have been used extensively throughout any production for:

1. Scene establishment and atmosphere creation. Plays opened with thunder or, to suggest the serene, a bird song. Bells and cock-crows suggested time of day. Music was used to suggest the somber and/or the festive.

2. Suggestion of actual happenings. Clock strikes, pistol shots, arriving horses, etc., as suggested by the script, would have been reproduced offstage.

3. Symbolism. Off-stage sound effects were not only used to create the illusion of literal happenings in the play action, but were often used for their powers of suggestion. For example, the action of the gods was often accompanied by thunder. Drums would be used to support an army marching towards battle. Horns would be blown to set a hunting scene, etc.

4. Drama enhancement. Musicians would join actors on stage to create spectacular processions, enhancing both sound (volume) and the crowd size (more people). Dramatic speeches would climax with horn fanfare or gunfire.

5. Linking of scenes. To keep time and place constant between scenes, sound effects would bridge the close of one scene and the beginning of the next. Or, to suggest a different place and time, opposing sound effects would be used.

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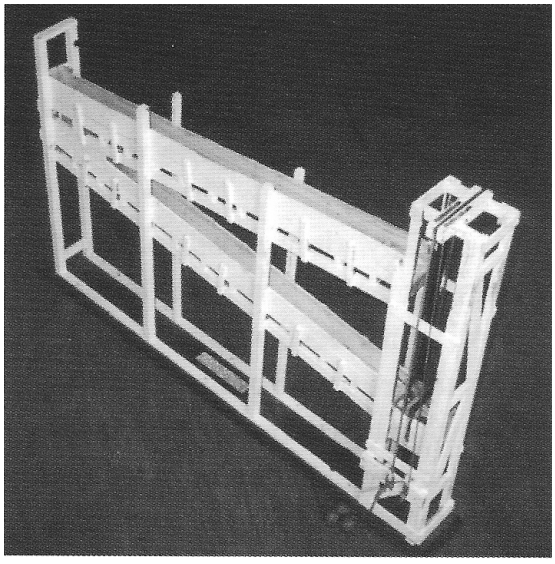
[62] David Collison, *The sound of theatre: a history*, 15.

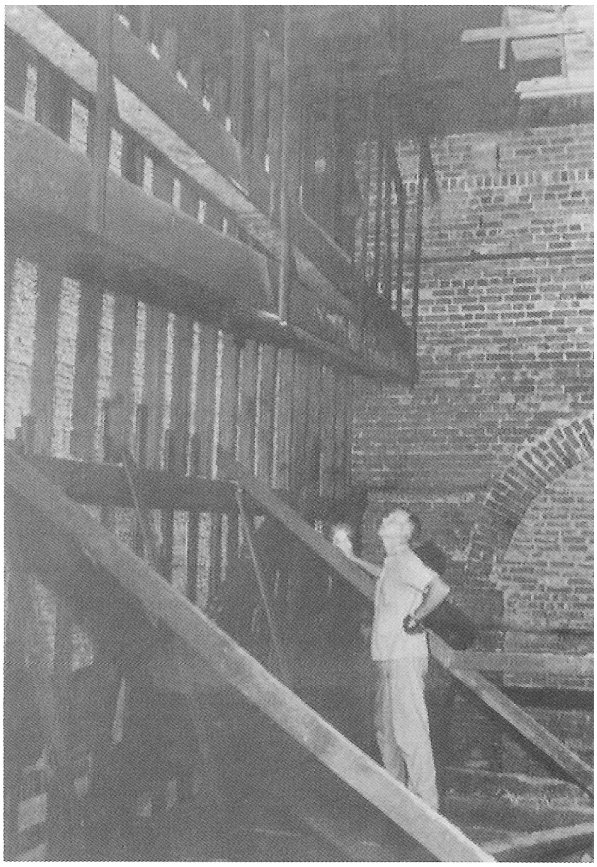
6. To start and finish a performance. Music and or scene-specific sound effects were often used to mark the start or end of a play, especially in theaters without curtains.[63]

The creation and use of mechanical sound effects grew with the theater over the next 150 years as it expanded throughout Europe and into the United States. Of course, advances in mechanics and machines by way of the Industrial Revolution made their way into the theater and more elaborate machinery was invented. Figure 3 and Figure 4 show just how large a typical thunder run, just one of many standard sound effects in any theater, had become and how much real estate theater owners were willing to devote to such effects.



David Collison–*The sound of theatre: a history*
Figure 3–Model of a zig-zag thunder run showing the pulley-operated lift to transport the cannon balls to the top of the tower.

[63] James W. Brock, "A Study of the Use of Sound Effects In Elizabethan Drama."



David Collison–*The sound of theatre: a history*
Figure 4–Zig-zag thunder run on wall of the stage house in Thalian Hall (built in 1858), Wilmington, NC.

In 1821, the electric motor was invented by Michael Faraday. Electricity ushered in new methods by which dramatists and theater directors could reproduce sound effects, *e.g.,* the use of a phonograph, which was invented by Thomas Edison in 1877.[64] The invention of the modern condenser microphone in 1917 and the moving-coil direct radiator loudspeaker in 1924 allowed these effects, along with the voice of the actors and the sound of the musical instruments in the

[64] David Collison, *The sound of theatre: a history*, 71.

orchestra, to be reinforced electronically.[65] In Chapter Three, I discuss the effects of electricity and its impact on the modern Broadway musical. Broadway got its start and operated for the first hundred years without the use of electronic sound reinforcement. Instead, architects took great care to design acoustically balanced theaters that would project the voice of the actor, the music, and the sound effects. No single architect had more impact on Broadway theaters than Herbert J. Krapp.

Herbert J. Krapp–Broadway's Architect

In 1920s America, the Broadway theater business was exploding. New theaters were being built at breakneck pace. Thirty-four of the forty Broadway theaters standing today were built between 1903 and 1928. Many others built during this same period have been demolished. However, given the poor-quality of electric sound reinforcement systems available during the 1920s, theater owners, producers, directors, and show writers relied heavily on architectural acoustics for sound reinforcement. No architect shaped Broadway's acoustics more than Herbert J. Krapp, who designed more than forty Broadway theaters in his lifetime, including fifteen

[65] Ibid., 80, 82.

Broadway theaters in operation today.[66] Each of the fifteen theaters has been granted landmark status by the New York City Landmarks Preservation Commission.[67]

Herbert J. Krapp was born in New York City on February 21, 1886.[68] With nothing more than a high school education and a knack for drawing, Krapp was invited in 1903 into a two-year apprenticeship with the prestigious architectural firm of Herts and Tallant. "Both of his employers were products of the prestigious Ecole des–Beaux-arts in Paris, the most influential architectural training institution of the era."[69] After completing his formal apprenticeship, Krapp continued to seek instruction and freelance work from "…other theater specialists, gaining a broad and thorough knowledge of the intricate mechanics of theater design in such areas as acoustics, stage-house construction, auditorium layout, entrance and egress planning and fire prevention and safety."[70]

Herts and Tallant dissolved their partnership in 1911 and Krapp, having established his credibility via his work on the Lyceum Theatre, the New Amsterdam Theatre, the Longacre Theatres, and others in the burgeoning Times Square theater district, immediately gained the

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[66] The fifteen theaters designed by Krapp in operation today are the Ambassador Theatre, Brooks Atkinson Theatre, Ethel Barrymore Theatre, Bernard B. Jacobs Theatre, Broadhurst Theatre, Samuel J. Friedman Theatre, John Golden Theatre, Helen Hayes Theatre (redesign), Imperial Theatre, Majestic Theatre, Eugene O'Neill Theatre, Richard Rodgers Theatre, Gerald Schoenfeld Theatre, Neil Simon Theatre, and the Winter Garden Theatre (redesign). Information was gathered by individual theater websites (where available), IBDB.com and other sources.

[67] William Morrison, "Herbert J. Krapp: Architect to the Shuberts" in *The passing show: newsletter of the Shubert Archive* 16, no. 1 (1993): 19.

[68] Ibid., 2.

[69] Ibid.

[70] William Morrison, "Interlude: Herbert J. Krapp and the Architecture of Theatres" in *The Shuberts present 100 years of American theater,* edited by Maryann Chach, Reagan Fletcher, Mark E. Swartz, and Syvia Wang (New York:Abrams, 2001), 203.

attention of Sam, Lee, and Jacob Shubert, the Shubert Brothers.[71] The Shuberts commissioned Krapp for two new theaters, the Broadhurst and Plymouth Theatres, which both opened in 1917 within two weeks of each other. Thus began a forty-six year partnership that would last through the death of the final Shubert brother, Jacob, in 1963, after which Krapp retired to Florida.[72]

Although little information is available regarding Krapp's acoustical design goals or techniques, "…hundreds of theatre professionals have gone on record as viewing his theatres as architectural treasures, unmatched for their visual and acoustic properties and for the intimacy they foster between actors and audiences."[73] According to William Morrison, Krapp's buildings are most appreciated from the inside. The Shuberts allotted little money to street facades. Krapp's buildings are "models of efficient and flexible playhouse design, ideally suited for the presentation of plays and musicals, factors that account for their continued viability and sought-after status three-quarters of a century after their constructions.[74]

Morrison states:

> Much more can be done [regarding the designs and work of Krapp]. The Shubert Archive contains hundreds of plans and drawings by Krapp for theatres, both built and proposed, as well as drawings for countless alterations to existing houses, ranging from designs for new marquee canopies and advertising signage to full-scale reconfigurations of auditorium interiors. Also in the Archive are plans by Krapp for hotels, apartment houses, retail stores, health spas, and even a skating rink, as well as voluminous correspondence between the architect and his clients, financial statements, design

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[71] Ibid., 202.

[72] Ibid., 203.

[73] William Morrison, "Herbert J. Krapp: Architect to the Shuberts" in *The passing show: newsletter of the Shubert Archive,* 19.

[74] William Morrison, "Interlude: Herbert J. Krapp and the Architecture of Theatres" in *The Shuberts present 100 years of American theater,* edited by Maryann Chach, Reagan Fletcher, Mark E. Swartz, and Syvia Wang, 202.

prospectuses, photographs of completed works, and even drawings executed by Krapp as a student. Taken as a whole, the Archive's collection represents a uniquely wide and comprehensive documentation of the career of this important but little-known designer.[75]

[75] William Morrison, “Herbert J. Krapp: Architect to the Shuberts” in *The passing show: newsletter of the Shubert Archive,* 2.

CHAPTER 3: SOUND DESIGN EVOLVES IN THE BROADWAY THEATER DURING THE TWENTIETH CENTURY

Electronic Sound Reinforcement Struggles To Make It To Broadway

During Broadway's Golden Age, sound design was limited to the firing of mechanical sound effects, and the somewhat imprecise efforts of actors and musical directors to balance voices and orchestras within the architectural acoustics at hand. Virtually nothing had changed in theatrical sound design for over 2,000 years. And though microphones, loudspeakers, and amplifiers were invented in the late 1920s, they would not become common on Broadway until the 1960s.[76] While electrical sound was a revolution in Hollywood, "[p]rogress [in the theatre] was relatively slow because there was no tradition of electric sound in the theatre and no department to foster its cause."[77] Paradoxically, the first permanent installation of a theatrical sound system was completed in 1940 for the playback of sound effects at the New York Metropolitan's Opera House.[78] Though no one can say precisely when, Broadway eventually employed electric sound, using turntables and loudspeakers to generate sound effects within a performance.[79] Since stagehands who produced the mechanical sound effects were prevented by union rules from handling anything electric, the stagecraft union further slowed the progress of

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[76] David Collison, *The sound of theatre: a history*, 109 and 117.

[77] Ibid., 108.

[78] Ibid.

[79] According to David Collison, the first playback of a pre-recorded sound took place in the late 1800s, during a London production of *The Judge*, which called for the playback of a baby's cry on a phonograph. David Collison, *The sound of theatre: a history*, 65.

modern Broadway sound design when, sometime during the mid-1950s, they placed sound under the care of the chief electrician.

> Making matters worse, because the chief electrician's main concern was for the lighting, the responsibility for operating the sound equipment usually fell to the most junior, or the most ineffectual, member of the electrical team. Quite often, one or another of the lighting board operators would perform sound cues between lighting operations.[80]

Sound Reinforcement Debuts On Broadway

The Earl Carroll Vanities, which opened at the St. James Theatre January 13, 1940, is believed to have been the first Broadway production to use microphones.[81] However, the microphone's debut on Broadway flopped. According to *New York Times* reviewer Brooks Atkinson, "The microphones, which nearly make this 'Vanities' a menace, could be yanked out and tossed in the alley, which would not be a bad idea at that."[82] It would be another twenty years before electronic sound reinforcement would return to the Broadway stage. By the 1960s, according to Collison, "Many producers had acknowledged the need for sound reinforcement… And although it was not a natural sound, people were able to hear the performers more easily, so they accepted it."[83] Broadway dramaturgical expression was evolving, and architectural acoustics were not sufficient to handle such changes.

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[80] David Collison, *The sound of theatre: a history*, 109.

[81] Ibid.

[82] Brooks Atkinson, "Earl Carroll's 'Vanities' Comes East From Hollywood With Some Of Those Girls," *New York Times*, January 15, 1940, 18.

[83] David Collison, *The sound of theatre: a history,* 117.

West Side Story (1957) was among the first productions to place microphones equidistantly along the front edge of the stage, and the foot microphone, also known as the shotgun microphone, became the standard microphone used in Broadway musicals in the late 1950s and 1960s.[84] Shotgun microphones are highly directional with a very narrow area of sensitivity, rejecting most any noise source that is not on axis with the microphone element at the tip of the unit. See Figure 5.[85]

The Sennheiser MKH 805 shotgun microphone–www.countant.org

Figure 5–A picture of a Sennheiser MKH 805 shotgun microphone in a mounting stand. The microphone is approximately 17 inches long and weighs 12.5 ounces.

Stephen Sondheim's dense lyrics and Bernstein's complex score (accompanied by a very large orchestra) pushed the limits of architectural acoustics of the Winter Garden.[86] Herbert J.

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[84] Ibid.

[85] "The Sennheiser MKH 805 Shotgun Microphone," *S. O. Coutant,* last accessed April 22, 2015. http://www.coutant.org/mkh805/. This site is devoted to several broadcast and recording microphones and was created and is maintained by S.O. Coutant, a retired professor performing and communication arts professor from Pasadena City College.

[86] The original orchestra consisted of thirty-one musicians, as follows: five woodwinds, seven brass, five percussion, one keyboard, one guitar, and twelve strings. "*West Side Story* Frequently Asked Questions," last accessed April 22, 2015. http://www.westsidestory.com/site/level2/archives/fact/faq.html#12.

Krapp's renovation of the Winter Garden Theatre in 1922 would have been undertaken to serve the theatrical needs of the day–the light fare of the musical revue. Neither Krapp nor the Shuberts, the owners of the Winter Garden, could have contemplated anything as complex as *West Side Story* in their 1922 renovation.

West Side Story's "Tonight Quintet" from act one serves as an excellent example of how sound reinforcement is needed to connect the story and musical material to the theatergoer. In this scene, the Jets gang, the Sharks gang, Anita, Tony, and Maria are each anticipating the rumble set for later that night. Bernstein masterfully weaves each of the five perspectives, all supported by distinct musical themes, into a dramatic and musical pastiche that lays bare the extreme love, hate, and racism explored in the production. In this YouTube example of a recent NYU student performance, the sound design appears to mimic the original Broadway design, relying on shotgun microphones attached equidistant to the lip of the stage.[87] The stage direction confines each performer or group downstage, directly on top of one of the shotgun microphones, presumably to ensure that the performance can be heard. By way of contrast, this YouTube clip of the 2009 Broadway revival of the "Tonight Quintet" demonstrates how, with today's sound design techniques and technologies, the entire stage can be used to heighten the dramatic impact of this powerful scene.[88] In 2009 Broadway, each performer would have been individually miked

[87] "*West Side Story*–'Tonight Quintet'–Tisch New Theatre–NYU," YouTube, last accessed April 22, 2015. https://www.youtube.com/watch?v=DsTQXnwB4sY.

[88] "*West Side Story*–'Tonight Quintet,'" 2009 Broadway revival, YouTube, last accessed April 22 2015. https://www.youtube.com/watch?v=Rhn5qB3JYqg.

with recording studio quality microphones, raising the intelligibility factor significantly over what could be achieved using today's shotgun mikes (as seen in the NYU production clip).

Brooks Atkinson, in his review of *West Side Story*'s 1957 premiere, made no mention of the quality of the sound. Perhaps the brilliance of the score, the writing, the dance and stage direction, and the cast performances transcended the unnatural sound of the shotgun microphones. A few years later, productions in the early 1960s were not as fortunate. Critics would become quick to point out the poor quality of Broadway's initial electric sound reinforcement.

As Dan Dietz noted, John Chapman, in his *New York Daily News* review of Jerry Herman's 1961 production of *Milk and Honey* pondered "…why the annoyingly artificial aid of mikes and giant loudspeakers" was necessary, given that the principals Robert Weede and Mimi Benzell were top-notch *New York Metropolitan Opera* singers."[89] Similarly, when chronicling 1962's *Eddie Fisher at the Winter Garden,* Dietz writes that "Norman Nadel, in the *New York World-Telegram and Sun* blasted Fisher, saying his amplification probably sounded better on Tenth Avenue than in the front row seats of the Winter Garden."[90]

George Abbott's Broadway career is legendary, spanning an impressive ninety-three years (1913–2006). Abbott is credited with the astonishing number of 116 Broadway shows as director, book writer, choreographer, producer, and/or performer. His fifty-three Broadway credits as director include *On The Town* (1944)*, Call Me Madam* (1950)*, Wonderful Town* (1953), *Pajama*

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[89] Dan Dietz, *The complete book of 1960s Broadway musicals* (Lanham, MD: Rowman & Littlefield, 2014), 93.

[90] Ibid., 141.

Game (1954), *Damn Yankees* (1955), *A Funny Thing Happened On The Way To The Forum* (1962), and many others.[91] Abbott was equally renowned as a "show doctor" and was frequently called upon to serve Broadway creative teams in mounting their shows. According to David Collison, Abbott resisted using any form of amplification when directing 1962's *Forum.* He simply did not like the inferior sound quality produced by the available technology. Sondheim's farcical romp is awash in one-liners and rash comedy, however. His use of double entendre and his exploitation of a vast lyrical vocabulary are critical elements to the show's success. Each lyric must be intelligible to the theatergoer. Abbott would not allow amplification in *Forum*'s New Haven try-out and, according to Collison, "…nobody could hear a thing. By the time they got to New York the show was miked."[92]

"Comedy Tonight," *Forum*'s opening number*,* illustrates Sondheim's mastery of word play, wit, and humor–hallmarks of his contribution to the American Musical Theater genre. The loss of even an occasional syllable would be detrimental to the theatergoer's overall comprehension of the show. The section below occurs towards the end of the opening song. Sondheim, using Rossini's crescendo techniques, begins shortening the phrases with the character Eurronius (below), halving the phrases again starting with Philia, with a final halving of the phrase into a single bar sung by Prologus (final line) before the entire company enters to sing the final chorus of the tune.

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[91] "George Abbott," *Internet Broadway Database*, last accessed April 22, 2015. http://ibdb.com/person.php?id=5770.

[92] David Collison, *The sound of theatre: a history,* 117.

Miles:	Nothing that's grim.
Domina:	Nothing that's Greek.
Prologus:	She plays Medea later this week.
ALL:	Stunning surprises!
	Cunning disguises!
	Hundreds of actors out of sight!
Eurronius:	Pantaloons and tunics!
Senex:	Courtesans and eunuchs!
Domina:	Funerals and chases!
Lycus:	Baritones and basses!
Philia:	Panderers!
Hero:	Philanderers!
Hysterium:	Cupidity!
Miles:	Timidity!
Lycus:	Mistakes!
Erroneous:	Fakes!
Phili:	Rhymes!
Domina:	Crimes!
Prologus:	Tumblers! Grumblers! Bumblers! Fumblers!
ALL:	No royal curse, no Trojan horse,
	And a happy ending, of course!
	Goodness and badness,
	Panic is madness–
	This time it all turns out all right!
	Tragedy tomorrow
	Comedy tonight![93]

No doubt–each line must be fully heard by the theatergoer. It is interesting to compare the tempo of the original "Comedy Night" led by Zero Mostel in 1962 with Nathan Lane's version in *Forum*'s 1996 Broadway revival. Mostel's version, heard here on Spotify, is sung at approximately 106 beats per minute.[94] Lane's version, heard here on YouTube, is faster at

[93] Burt Shevelove, Larry Gelbart and Stephen Sondheim, *A funny thing happened on the way to the forum : a musical comedy based on the plays of Plautus* (New York: Dodd, Mead, 1983), 21–22.

[94] "Comedy Tonight," from *A Funny Thing Happened On The Way To The Forum* (Original Broadway Cast)*, Spotify,* last accessed April 22, 2015. open.spotify.com/track/41xOlm3Kl620klE0J2MB7p.

approximately 120 beats per minute.[95] By 1996, theatrical sound design techniques and related sound equipment had both progressed to deliver much higher intelligibility than that which was available in 1962, arguably giving *Forum* a more lively and energetic opening.

The greatest contribution to sound design during this era, however, had nothing to do with microphones, loudspeakers, technology, or sound system design techniques. Jack Mann, an early pioneer in Broadway's burgeoning theatrical sound design industry, was asked to investigate trouble in 1961's *Show Girl,* starring Carol Channing. Upon arriving at the Eugene O'Neill Theatre, "Jack was surprised to discover that the sound control desk (an Altec five channel mixer) was placed backstage, between two lighting switchboards, facing the back wall of the stage."[96] Up to this point, no one had considered that the sound operator might create a better theatrical experience if he or she could actually hear the sound produced by the systems under his or her control. So without technical modifications of any kind, Mann simply relocated the sound control desk into the seating area, providing the operator direct feedback from the speakers he or she was operating. The producers were immediately smitten with the results, despite the revenue loss from the seat removal, and the theatrical "front-of-house" audio booth has been a fixture in the house seating area of every Broadway show since.[97]

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[95] "Comedy Tonight," from *A Funny Thing Happened On The Way To The Forum* (1996 Broadway Revival), *YouTube,* last accessed April 22, 2015. https://www.youtube.com/watch?v=SuxzTarpusI.

[96] David Collison, *The sound of theatre: a history,* 120–121.

[97] Ibid., 121. Mann went on to an illustrious career designing thirty-four shows on Broadway, including Sondheim's early works, *Company, Follies, A Little Night Music,* the first revival of *Gypsy*, *Pacific Overtures,* and, *Sweeney Todd.*

Despite these notable achievements, the progress of sound design during Broadway's Golden Age languished. Producers were reluctant to adopt the sound quality of emerging sound reinforcement technology, preferring the sonic aesthetic of architectural acoustics over the then-current microphones and loudspeakers. Furthermore, the discipline of sound design was just coming into being. Technology, design techniques, best practices, etc. were being improvised on the spot, often causing more problems than they solved. Sound design was simply not seen as an aesthetic priority in helping directors and producers create better Broadway musicals. Eventually, Broadway's story lines and music demanded higher quality sound to achieve their dramaturgical goals. By the early 1970s, the crises created by the failed sound designs of the early rock musicals *Hair* and *Jesus Christ Superstar* paved the way for Abe Jacob to change the sound of the Broadway musical for good, a point discussed more fully in Chapter Four.

According to the Broadway League, forty theaters operate on Broadway today.[98] All but three–the Gershwin Theatre (opened in 1972), the Minskoff Theatre (1973), and the Marquis Theatre (1986)–were designed and built to utilize architectural acoustics for the reinforcement of voice and music in theatrical productions.[99] No doubt many of these acoustic-based theaters (non-sound reinforced) produced masterworks of the American Musical theater genre, especially during Broadway's Golden Age, where electric sound reinforcement was virtually non-existent. Brian Ronan, winner of two Tony awards for his sound designs of both *The Book of Morman* and

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[98] The Broadway League, "Broadway Theaters in NYC," last accessed April 22, 2015. http://www.broadwayleague.com/index.php?url_identifier=broadway-theatres-in-nyc-1.

[99] David Chase, interviewed by author, New York City, April 3, 2014. Chase has twenty-six Broadway credits as musical director, musical supervisor, and dance arranger.

Beautiful: The Carol King Musical, recounted the anecdotal remarks he heard from former theater ushers who remembered when theatergoers would purchase mezzanine or balcony seats over the far more expensive orchestra seats. If the patrons enjoyed the show, legend has it, they would stop by the box office afterward and purchase tickets for orchestra seats at a future performance. Ronan notes this was standard practice for local theatergoers so they might hear what they missed while sitting in the mezzanine or balcony at their first viewing.[100] The power and dramaturgical impact of the latter period of Broadway's Golden Age integrated book musicals were being thwarted by the reliance on natural acoustics alone to amplify the book, music, and lyrics.

Broadway Is In Need Of A Savior

By the late 1960s, Broadway was in a steep decline as producers failed to attract a new generation of audiences. Scott Warfield notes, "Beginning with a strike in 1960 that raised labour costs significantly, Broadway experienced a series of disastrous seasons that reached its nadir in 1967 with the fewest new shows produced in Broadway's recorded history."[101] Drama critic Steven Suskin confirms "…(Broadway) saw one disappointing musical after another from former hit-makers like Rodgers, Lerner, Styne, Bock, Strouse, Herman, Kander, and

[100] Brian Ronan, interview.

[101] Scott Warfield, "From Hair to Rent: Is 'Rock' a Four-Letter Word on Broadway?" in *The Cambridge Companion to the Musical*, 2nd ed., ed. William A. Everett and Paul R. Laird (Cambridge: Cambridge University Press, 2008), 236.

Coleman."[102] The baby-boomer generation was not interested in their parents' Broadway musicals. They were not listening to the songs of Tin Pan Alley. They were more interested in the aesthetic of rock music–the songs and sounds of Elvis Presley and the Beatles. According to Elizabeth Wollman, "When rock and roll emerged in the mid-1950s, most musical theater writers dismissed it as a loud, vulgar fad."[103] Frank Sinatra expressed far more than a benign lack of respect for rock music as reported in a January 12, 1958 *New York Times* article:

> Rock 'n roll smells phony and false. It is sung, played and written for the most part by cretinous goons and by means of its almost imbecilic reiteration, and sly, lewd, in plain fact, dirty lyrics…It manages to be the martial music of every side-burned delinquent on the face of the earth.[104]

The first Broadway shows to incorporate any reference to rock music did so, according to Wollman, "…due to a perceived necessity rather than out of any real admiration or respect [for the genre].[105]" Broadway needed a lifeline and the rock musical was waiting in the wings. As I will demonstrate in Chapter Four, the sound design techniques forged in the fires of mounting *Hair* in 1968 and *Jesus Christ Superstar* in 1971 marked historic technical and design achievements for Broadway musical sound design. These new techniques created powerful aural

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[102] Steven Suskin, *Second act trouble: Behind the scenes at Broadway's big musical bombs* (New York: Applause Theatre & Cinema Books, 2006), 133.

[103] Elizabeth Wollman, "Rock musical," *Grove Music Online,* ed. Deane Root, last accessed April 22, 2015. http://www.oxfordmusiconline.com.ezproxy.net.ucf.edu/subscriber/article/grove/music/A2263085?q=rock+musical&search=quick&pos=1&_start=1#firsthit.

[104] Gertrude Samuels, "Why They Rock 'n Roll–And Should They? The Big Beat is more insistent than ever and the younger generation is all shook up. A reporter attempts to explain What It All Means. Why They Rock 'n' Roll," *New York Times*, July 12, 1958, SM16.

[105] Elizabeth Wollman, "Rock musical," *Grove Music Online,* last accessed March 29, 2015.

experiences for theatergoers that were "…instrumental in attracting new audiences and enabling the work of Broadway's new hit-makers."[106]

[106] Richard K. Thomas, *USITT presents the designs of Abe Jacob* (Syracuse, NY: United States Institute for Theatre Technology in cooperation with Broadway Press, 2008), 27.

CHAPTER 4: THE ROCK MUSICAL JOLTS BROADWAY

> After the mid '50s, the historical alliance between American popular song and show music failed to assimilate rock and roll and its successors, despite the efforts of such shows as *Bye Bye Birdie*. Eventually the success of *Hair* as a Broadway musical suggested a possibility for reconciliation, at least on the musical front. But this loosely structured, highly amplified, and gratuitously underclothed assault on the military draft, the Vietnam War, the work ethic, and "the Establishment" and its norms for behavior and dress, thumbed its nose at everything about the idealized America that *Oklahoma!* had exalted.[107]

Hair

Hair arrived on Broadway in April of 1968. Subtitled 'An American Tribal Love-Rock Musical,' *Hair "*...was…a rambling diatribe against all authority figures and a glorification of drugs, free love, racial tolerance, respect for the individual and environmentalism."[108] *Hair* explored the hippie themes of anti-war (Vietnam), sexual repression, protest, racism, psychedelic drugs, etc., all of which were headline themes within the culture of the late 1960s America. Theatrically, *Hair*'s medium contained its message. Director Tom O'Horgan admits that, in his approach to directing *Hair*,

> …manner tends to be more important than matter, since primary emphasis is placed not on story, character, or idea but on picturesque physical activity (writhing, pantomimes, subtextual business, human pyramids, and sexual semiexhibitionism), tableaux, bold anti-illusionistic devices, frantic light effects, amplified music and sound, and gimmickry of various sorts.[109]

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[107] Kim H. Kowalke, "Theorizing the Golden Age Musical: Genre, Structure, Syntax," in *A Music–Theoretical Matrix: Essays in Honor of Allen Forte (Part V)*, ed. David Carson Berry, *Gamut 6/2* (2013): 133–184.

[108] Scott Warfield, "From Hair to Rent: Is 'Rock' a Four-Letter Word on Broadway?", 237.

[109] Barbara Lee Horn, *The Age of Hair: Evolution and Impact of Broadway's First Rock Musical* (New York: Greenwood Press, 1991), 52.

While experimental theater was alive and well off-Broadway and off-off-Broadway in the late 1960s, Broadway had never experienced anything like *Hair.* It was literally caught with its pants down, remembering *Hair*'s first act closes with a nude scene. *Hair* was a contradiction to the rest of 1968 Broadway with its tamer, gentler book musicals such as *Hello Dolly!, Fiddler on the Roof, George M!, I Do! I Do!, Mame,* and *Man of La Mancha.*[110]

Though *Hair*'s orchestrations were a mix of acoustic and electronic instruments (the nine-member opening night orchestra consisted of electric piano, two electric guitars, electric bass, drums, percussion, clarinet/saxophone and two trumpets), *Hair* was rock and roll in both music *and* book.[111] With *Hair,* shotgun microphones–the standard of the day–were abandoned for in-your-face, hand-held microphones. Tossed out with the shotgun microphone was its more forgiving sound created by the acoustic space between the sound source (actor) and the microphone input element.[112] Moreover the accompanying musicians and their amplifiers were featured directly on the Biltmore's stage where they communed, up-stage in a hollowed-out bus; and–a first for Broadway–they were all miked and amplified through the sound system.[113] As

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[110] *Cabaret*, which ran from 1966 through 1969, certainly pushed the boundaries of the Broadway musical, exploring Nazisim and abortion. However, it was set sixty years earlier in pre-war Germany, which, in 1968, was relegated to the annals of history.

[111] Barbara Lee Horn, *The Age of Hair: Evolution and Impact of Broadway's First Rock Musical,* 63. The Broadway orchestra was enlarged to nine musicians from five in *Hair*'s off-Broadway performance at the Public Theater.

[112] Several yards of open space–*i.e.,* air–would have existed between the actor and the shotgun microphone attached to the stage lip. The shotgun microphone picked up the sound after it travelled through several cubic yards of open space, which added natural reverberation, additional warmth from the roll-off of higher, more strident frequencies (high frequencies travel only inches before they disperse), and some natural compression (louder vocal passages are quieter at the microphone element than they are when measured at the sound source, or mouth in this case). The handheld microphone, on the other hand, reproduces the sound at its source–raw, with no space for natural reverberation, high frequency roll-off, or compression.

[113] Thomas S. Hischak, *The Oxford Companion to the American Musical: Theatre, Film, and Television* (Oxford: Oxford University Press, 2008), 314.

music director and composer Galt MacDermot noted, "[The Biltmore] was a bigger theatre [than the off-Broadway Public Theater, from which *Hair* transferred], we had to make more noise."[114] And make more noise they did. "With eight large loudspeakers and an emphasis on amplification, the decibel level was considerably above the norm for Broadway audiences."[115]

No doubt the visual impact of large loudspeakers, hand-held microphones, guitar amps on stage, etc. added to the *perceived* sound pressure level of the show. Rather than mask the sound equipment into or behind the scenery, O'Horgan incorporated as much of the sound system into the show as possible. According to Richard Thomas, "Choreographing the [mikes and] mike cables [from performer to performer] became a major stylistic device in *Hair*."[116] Figures 6 and 7, pictures from the original Broadway run of *Hair,* show the hand-held microphones and their conspicuous cords.

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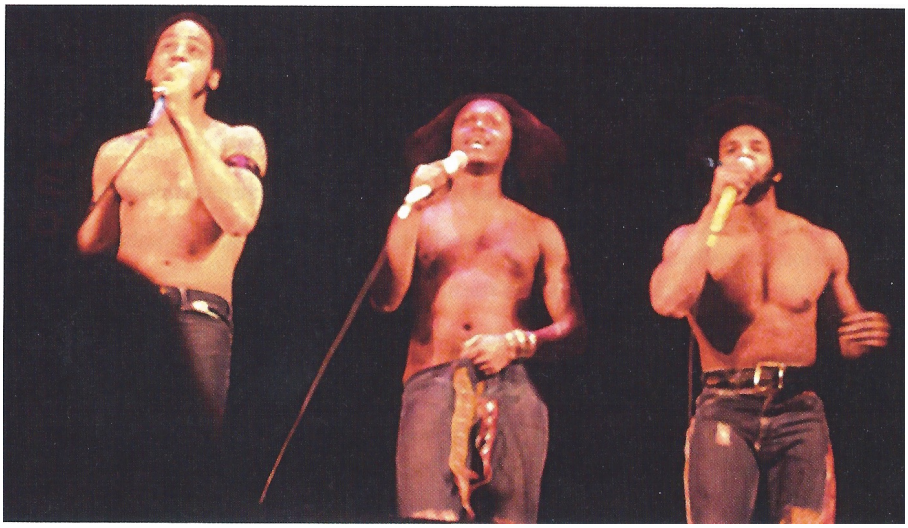
[114] Barbara Lee Horn, *The Age of Hair: Evolution and Impact of Broadway's First Rock Musical*, 63.

[115] Ibid.

[116] Richard K. Thomas, *USITT presents the designs of Abe Jacob*, 28.



Richard K. Thomas–*USITT presents the designs of Abe Jacob*

Figure 6–Microphones and their cords were incorporated into the choreography of *Hair*.

Richard K. Thomas–*USITT presents the designs of Abe Jacob*

Figure 7–Stage right scaffolding in *Hair* shows blue (on the left) and white (on the right) corded microphones in their color-coded holsters.

Broadway musical sound design, virtually unchanged since the arrival of the phonograph used to replay electronic sound effects, was ill-prepared to meet *Hair's* sound design challenges. Amplified musicians, hand-held microphones, and higher decibel levels did not combine to produce a favorable sound.[117] Michael Butler, *Hair's* producer, was very unhappy with the sound of the show. "When we opened on Broadway, the electrician's union gave us somebody who was tone deaf to run the sound system."[118] Nevertheless, *Hair* enjoyed substantial box office acclaim, running five years and 1,750 performances on Broadway alone. Butler capitalized on his Broadway success and expanded his franchise rapidly to fourteen national–and several international–companies running concurrently with its Broadway production.[119] Rather than send out tours, Butler created several sit-down (open-ended) productions in major cities, each with a new cast, known as a "tribe."[120]

With the growing commercial success, Butler decided to tackle the problem of bad sound. *Hair* needed more than a sound operator with a good ear. *Hair* needed a rock-and-roll sound system capable of reproducing rock-and-roll sound pressure levels. As Thomas notes, "What *Hair* really required was the kind of system that [Abe] Jacob pioneered for rock-and-roll."[121] In February of 1970, Michael Butler hired Abe Jacob to design the sound system for *Hair's* Boston tribe, "Wampanoag." *Hair*'s Boston opening launched the sound design career of Abe Jacob,

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[117] Although opening reviews were generally favorable with regard to the show, they curiously left out any mention of the large and very present sound system.

[118] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 27.

[119] Barbara Lee Horn, *The Age of Hair: Evolution and Impact of Broadway's First Rock Musical,* xiv.

[120] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 28.

[121] Ibid.

who would go on to influence and shape the future of Broadway sound design more than anyone else in history, and later earn him the moniker the "Godfather of Theatre Sound."[122]

Abe Jacob Makes His Broadway Debut And A Star Is Born

Abe Jacob (b. 1944 in Tucson, AZ) was a sound engineer for major rock-and-roll touring artists of the 1960s including the Mamas and the Papas, Jimi Hendrix, and Peter, Paul, and Mary. Moreover, Jacob was involved in theater, performing on stage as a child actor through his college days. He even made a brief appearance the 1951 film *The Last Outpost,* which starred Ronald Reagan and was shot on the set of Old Tucson studios, twelve miles west of downtown Tucson.[123] His theatrical sensibilities and his rock and roll sound experience were a perfect fit for Butler's *Hair.* His design of Boston's Wampanoag production was an immediate success, and the associated improvements in sound quality were obvious to everyone associated with the show. Jules Fisher (b. 1937 in Norristown, PA), *Hair*'s lighting designer, has 114 Broadway lighting design credits.[124] Already a seasoned designer when he designed *Hair* (his twenty-ninth Broadway show), Fisher said of Jacob:

> Abe…came in and said, "hey, we can add better speakers, we can put microphones behind the borders upstage, behind the legs upstage, so as actors move upstage there

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[122] Ibid., 101.

[123] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 11.

[124] Jules Fisher is still active in his design career. His most recent Broadway credit is for his lighting design of the 2014 revival of *Side Show.*

> could be other microphones that could pick up what they were singing or saying." Jacob brought a lot [of these never-before used techniques] to the theatre.[125]

Further, Abe individually miked the band instruments (sometimes with multiple mikes, *e.g.,* drum set) with the same methods he would have used when touring with the Mamas and the Papas and Jimi Hendrix. To aid in *Hair*'s theatricality, Abe added the shotgun mikes back to the stage lip. The original sound designer, Robert Kiernan, removed the shotgun mikes because they picked up too much sound from the onstage band. To counter the negative effects of the band's sound pressure levels, Abe simply turned the shotgun mikes off when they were not being used to reinforce an actor on stage. Incidentally, this technique–turning on only the mike in use–is still being used today as a fundamental sound mixing technique by every Broadway sound operator.[126]

Boston's *Hair* and the many national and international productions that followed provided a significant learning ground where Jacob could "…explore what worked and didn't when rock-and-roll combined with theatrical performance."[127] Many of Jacob's solutions not only worked for rock-and-roll musicals, they were eventually adopted as best practices of musical theater sound design, in general. Two are worthy of mention here: 1) Jacob's successful elimination of the acoustic shadow under the balcony (see Figure 8 on page 48); and, 2) Jacob's techniques for propagating high-quality amplified sound to the remote seating areas in the

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[125] Richard K. Thomas, *USITT presents the designs of Abe Jacob*, 28.

[126] See footnote 35.

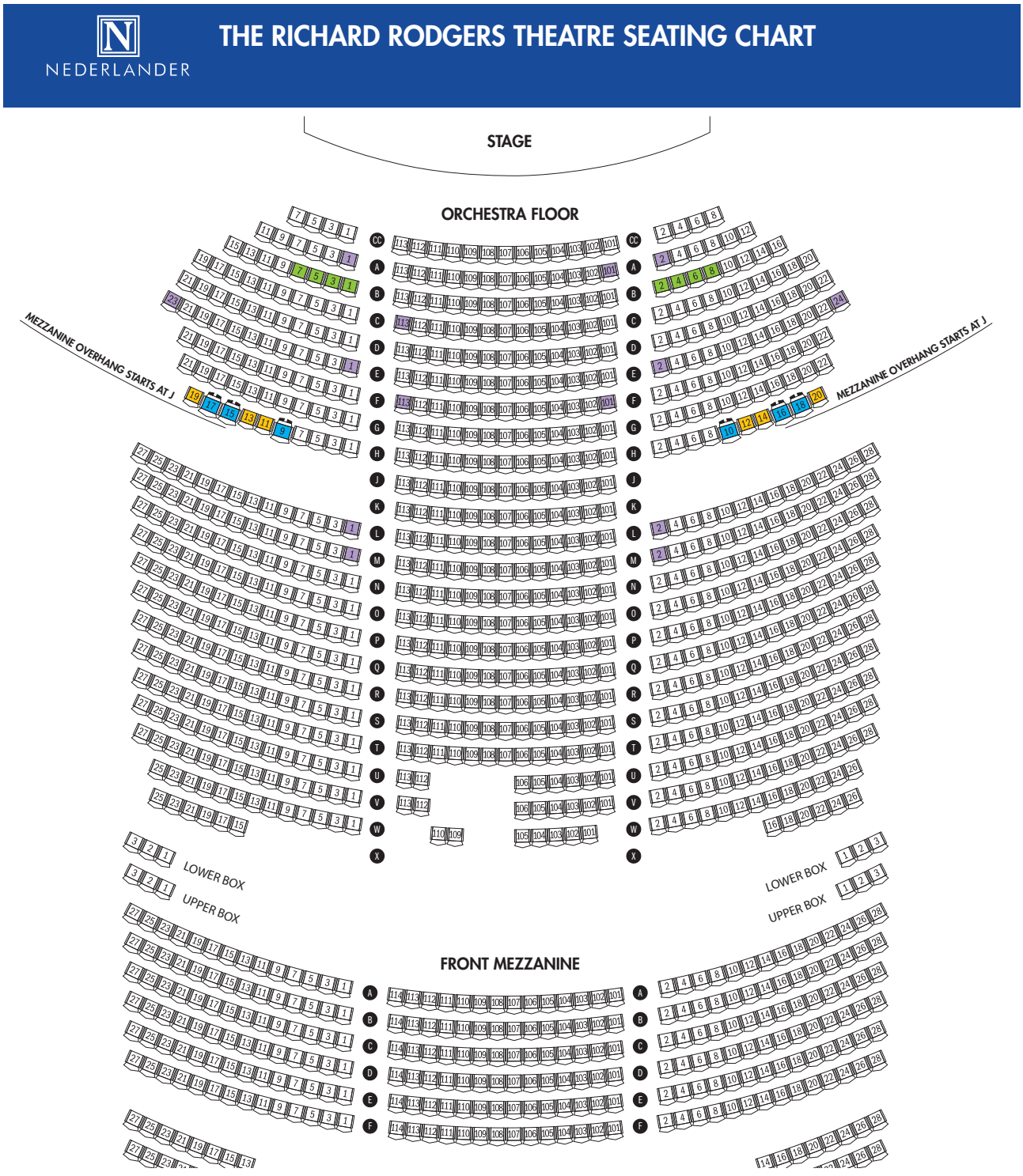
[127] Richard K. Thomas, *USITT presents the designs of Abe Jacob*, 29.

mezzanine and balcony.[128] If a show were to be amplified, then every seat would need to benefit from a competent sound system design. The techniques used in solving both issues are related; yet, each is unique to the extent they warrant separate discussion.

Jacob Removes The Acoustic Shadow From Under-Balcony Seating

Virtually every theater anywhere–including Boston's Wilbur Theater, where *Hair* opened in 1970–has orchestra seating directly under the balcony overhang. This architectural design technique maximizes seating in a given cubic space and minimizes the distance from stage to all the seats. See Figure 8 on the next page. The balcony overhang, however, often physically blocks the sound coming from the primary loudspeaker system located far stage right and far stage left at the proscenium line. To fill in sound that was being blocked by the overhang, Jacob hung small speakers along the underside of the balcony. However, the sound from the under-balcony speaker system would arrive at the listener's ear before the sound from the main loudspeaker system arrived, creating an unwanted echo, and thereby shift the sound image from the stage to somewhere overhead for the under-balcony theatergoers. Jacob turned to science to solve this problem. He employed the principles of the "Haas effect" to pioneer a new sound design technique, and successfully filled in the acoustic shadow caused by the balcony overhang.

[128] Ibid., 30.



Partial seating plan of the Richard Rodgers Theatre courtesy of www.richardrodgerstheatre.com.

Figure 8–The mezzanine overhang of the Richard Rodgers Theatre covers the majority of the orchestra seating, beginning at row "J" and continuing through the last row "X."

The "Haas" Effect

Helmut Haas, in his 1949 doctoral thesis, proved the psychoacoustic phenomenon that humans determine the physical location of the origin of a sound based upon the earliest arrival of that sound at the ear.[129] Further, Haas proved that other iterations of the same sound source, *e.g.,* a secondary reflection of the sound source off of a wall, are not "heard" by the brain, even if they are up to 10 dB louder than the original.[130] This effect, whereby the brain ignores or does not "hear" subsequent iterations of the original sound, holds true for all subsequent iterations which arrive to the ear within thirty-five milliseconds, or .035 seconds, of the first.[131] Beyond thirty-five milliseconds, we begin to "hear" subsequent sound iterations as a new sound source–a discrete echo–and localize it distinctly from the original source.

Jacob applied Haas' findings by attempting to delay the sound produced by the under-balcony speakers so that it would arrive at the under-balcony seats the same time as, or no more than thirty-five milliseconds behind, the sound arriving from the stage. This, he hypothesized, would deliver amplified sound to the under-balcony seating–within the parameters of the Haas effect–and preserve the illusion that the sound was emanating from the source, the stage. Though initially unsuccessful due to the lack of available sound signal delay technology, Jacob

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[129] Helmut Hass, "Über den Einfluss eines Einfachechos auf die Hörsamkeit von Sprache;" translated into English by Dr. Ing. K.P.R. Ehrenberg, Building Research Station, Watford, Herts., England Library Communication no. 363, December, 1949; reproduced in the United States as "The Influence of a Single Echo on the Audibility of Speech," *Journal of Audio Engineering Society* no. 20 (Mar. 1972): 145-159.

[130] There are numerous sources that provide relative decibel comparisons. According to the "Intensity and the Decibel Scale" page at the Physics Classroom web site, ten decibels represents the difference between "a normal conversation" at sixty decibels and "busy street traffic" at seventy decibels. Last accessed April 22, 2015. http://www.physicsclassroom.com/class/sound/Lesson-2/Intensity-and-the-Decibel-Scale.

[131] Sound basically travels one foot per millisecond.

persevered and, according to Thomas, was the first to develop "…a technique that has become common practice in today's theatre."[132] In 1977's *The Act*, Jacob finally perfected his under-balcony technique with the use of a newly-developed digital delay unit that provided the necessary processing power to delay the sound signal to much longer lengths than previously available. With the use of the digital delay unit, Jacob successfully delayed the under-balcony speakers in *The Act* to deliver quality sound reinforcement directly to under-balcony seating.[133] Applying the principles of the Haas effect, Jacob added this sound via loudspeakers that, despite being physically over and in front of the heads of the under-balcony theatergoers, created the illusion that the sound from these overhead speakers was originating from stage.[134]

Jacob Delivers Natural, Amplified Sound To Remote Seating

Hair's many national and international companies provided Abe Jacob a touring research and development laboratory in which to experiment extensively with theater sound. In addition to successfully removing the balcony's acoustic shadow, Jacob established a method to successfully deliver amplified sound to the farthest seating areas in the mezzanine and balcony, today referred to as "balcony delays."

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[132] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 31.

[133] With this under-balcony, delayed loudspeaker technique, Abe Jacob was able to influence every major loudspeaker manufacturer to create a new product line to meet this need. This practice continued well into the 21st century. In the last few years, the line array speaker has virtually eliminated the need for delay speakers in a Broadway theater.

[134] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 59.

Early reinforced Broadway sound design techniques in the 1950s and 1960s depended upon the on-stage loudspeaker system to reach remote seating areas. Loudspeakers were stacked on the stage deck such that the higher speakers were aimed at the mezzanine and balcony seating areas. However, in order to ensure adequate amplified sound at the distant seating areas, the on-stage loudspeaker system would have to be pushed to sound pressure levels that would have been painful for the first several rows of orchestra seating. Figuring too little sound pressure in the balcony and mezzanine seating was less of an evil than too much sound pressure in the orchestra seating, Broadway musical sound designers were forced to ignore the remote seating areas. The issue was not caused by an inadequate loudspeakers or sonic material (vocal, dialogue, music) that was being produced too softly. The problem was one of the laws of physics–the inverse square law.

Sound pressure levels decrease inversely proportionate to the increase in the distance in through which they travel. This physical phenomenon has been known for hundreds of years. Abe Jacob put this law of physics to use in order to fill the remote balcony and mezzanine seats with quality, amplified sound. It is helpful at this point to outline the basics of the inverse square law in order to create the context for discussing Jacob's solution[135]

[135] It is important to note that the inverse square law would also have been used alongside the Haas effect to perfect the under-balcony techniques. Likewise, both the Haas effect and the inverse square law would have been used to perfect techniques for balcony and/or mezzanine delays.

The Inverse Square Law

The inverse square law holds that sound pressure levels are inversely proportionate to the distance sound travels. Specifically, sound pressure levels decrease six decibels (dB) with each doubling of the distance sound is required to travel. For purposes of illustration, assume a stage whisper arrives at the first row of seats ten feet from the source (actor and/or loudspeaker) at a 70 dB sound pressure level. The following table illustrates the implications of the inverse square law on this 70 dB sound source over several distances.

Table 3–Example of the Inverse Square Law

Distance From Source	**Sound Pressure Level (dB)**
Ten feet	70
Twenty feet	64
Forty feet	58
Eighty feet	52

To give some context to the table above, it might be helpful to look at New York's Richard Rodgers Theater. Most recently housing the Broadway musical production of *If/Then,* the Richard Rodgers is a medium-sized Broadway house with 1,400 seats. According to *If/Then*'s assistant sound designer, Mike Tracey, the distance from the farthest downstage point to the farthest seat in the Richard Rodgers is eighty feet.[136] For purposes of this discussion, Table 3 represents the impact of the inverse square law on sound in the Richard Rodgers Theatre.

[136] Mike Tracey, phone interview with author, February 15, 2015.

To bring this into a "real-world" scenario, Tracey stated that today's Broadway sound designers build sound systems to provide nearly even sound pressure, tolerating variances no greater than +/- 3 dB across a theater's entire seating area. "Anything beyond those limits," Tracey said, "will result in sound that is too loud in some seats and unintelligible in others."[137] Additional speakers will be added to reach seating areas that fall outside these tolerances and those speakers will be delayed using the findings and guidelines of the Haas effect. Their volume levels will be determined according to the guiding principles of the inverse square law. This method will produce even sound pressure levels to nearly every seat and, ensure that the sound will be "heard" by the brain as originating from the stage. Looking back at Table 3 with the knowledge of today's design tolerances not to exceed +/- 3dB in any seat, it is readily apparent just how difficult it must have been to get adequate sound to the mezzanine and balcony seats in the Richard Rodgers with sound pressure level decreases of 12–18dB, according to the inverse square law.

Abe Jacob provided the necessary solution. First, Jacob hung delay speakers along the theater ceiling directly in front of the balcony seats. The speakers were small enough to preserve adequate sight lines. With the aid of digital delay units and armed with the laws of physics–the "Haas" effect and the inverse square law–Jacob delivered amplified sound pressure to the balcony that was "heard" as though it was coming from the stage, *i.e.,* "imaged" to the stage. As Jacob remembered, "The concept was to keep it as natural as possible, you didn't want to run a

[137] Ibid.

lot of energy from your proscenium speakers to the rear of the orchestra or the balcony floors" because it would be too loud for the first rows of orchestra seating.[138] Jacob's design of the Boston *Hair* was so successful that Butler charged him with the design of all future productions as well as the redesign of the Broadway production.

Jesus Christ Superstar

Hair's success quickly attracted several new rock-and-roll musicals to Broadway, though none was as highly anticipated as the 1971 arrival of *Jesus Christ Superstar*. As Horn reports, "Creators Andrew Lloyd Webber and Tim Rice freely admit their decision to write a rock show came immediately after they attended a performance of *Hair* at the Biltmore. Unable to get the show on the boards, they recorded the album to promote it…" [139] Decca released the concept album in September of 1970 and it "…became a smash hit, topping the American album charts three times, and became the biggest selling double album of all time."[140]

As such, *Jesus Christ Superstar* was dubbed by *Variety* as "the biggest all-media parlay in show business history."[141] The producers of *Jesus Christ Superstar* were quick to hire *Hair*'s director, Tom O'Horgan, to direct the production.[142] Along with O'Horgan, *Hair*'s lighting and

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[138] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 29.

[139] Barbara Lee Horn, *The Age of Hair: Evolution and Impact of Broadway's First Rock Musical*, 130.

[140] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 32.

[141] Ellis Nassour and Richard Broderick, *Rock opera; the creation of Jesus Christ Superstar, from record album to Broadway show and motion picture* (New York: Hawthorn Books, 1973), 1.

[142] "Conceived for the stage" is also credited to Tom O'Horgan.

set designers, Jules Fischer and Robin Wagner, were hired to mount the production. As Richard Thomas notes, "Curiously, Abe Jacob, who had so successfully solved the sound problems in *Hair,* was not included."[143] Given the popularity of its recording-studio-based concept album and the fact that the entire production was sung–a "rock opera"–sound design, it would seem, would warrant supreme attention from the producers. First attempts at sound design were abject failures.

Jesus Christ Superstar Is Plagued By Poor Sound Design

The task of transferring the sound, power, and fan devotion of the popular concept album to the live Broadway stage proved to be too big a challenge for Taplin Productions, who is credited as the original sound designer.[144] *Jesus Christ Superstar* was Taplin's first and only Broadway sound design credit. Problems escalated through the technical rehearsal period to the extent that the producer, Robert Stigwood, was forced to cancel the first three public previews in late September of 1971. As director O'Horgan said to Mel Gussow in a *New York Times* interview prior to opening, "There's a new sound system every night."[145] The chart-topping concept album, *Jesus Christ Superstar,* was in jeopardy of not opening as a stage musical.[146] See Figure 9 on the next page.

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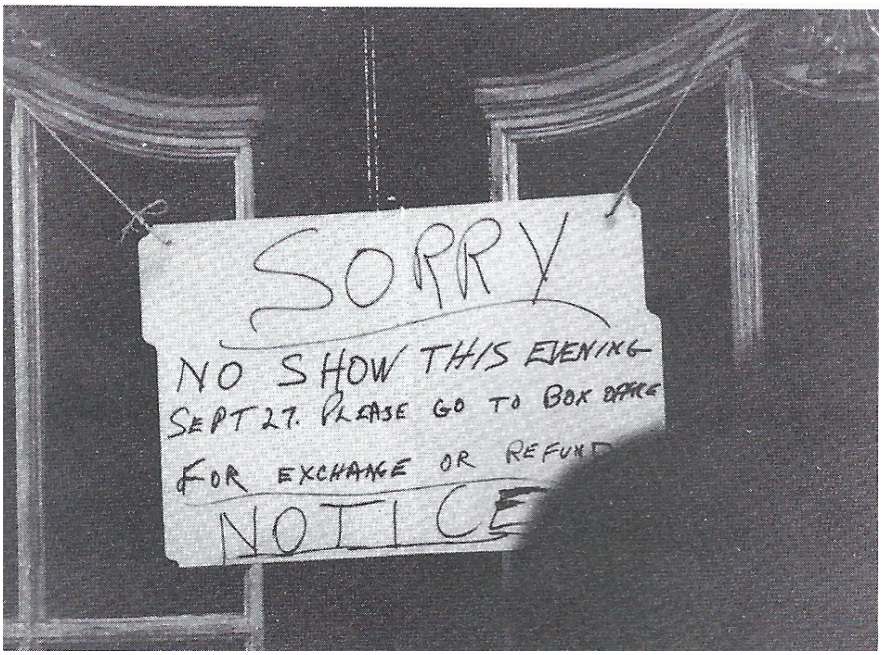
[143] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 32.

[144] According to IBDB.com,

[145] Mel Gussow, "'Superstar.' a Hit Before Opening," *New York Times,* October 12, 1971, 48.

[146] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 32.



David Collison–*The sound of theatre: a history*

Figure 9–Sign outside the Mark Hellinger Theatre announcing the cancellation of the second scheduled preview of *Jesus Christ Superstar* on September 27, 1971.

Abe Jacob serendipitously dropped by the Mark Hellinger Theatre on Tuesday, September 28th. Jacob had just finished a Three Dog Night concert in Atlanta and had the week off, so he headed to New York City to catch the second preview of *Jesus Christ Superstar* and to pay a social visit to Fischer and Wagner, his colleagues from *Hair.* Instead, as he approached the Mark Hellinger Theatre, he saw the sign announcing the cancellation of the evening's performance–the second cancellation in a row. Jacob went ahead into the theater to pay a visit to his friends. Upon entering the theater, Jacob was spotted by director Tom O'Horgan who recognized Jacob from *Hair*. With producer Robert Stigwood's blessing, O'Horgan immediately

arranged for Jacob to take over as the replacement sound designer.[147] Jacob proved to be a critical and successful addition to the design team. "They didn't have a show until I came in to give them sound. I was able to give them the fourth preview, I guess, after being there for two days."[148]

Jacob Raises *Jesus Christ Superstar* From The Dead

Abe Jacob walked into a myriad of poor sound design choices, any one of which was capable of stopping a show. *Jesus Christ Superstar* had slim chances of ever playing before a live audience for that reason. Jacob's first duty was to sit with O'Horgan throughout a complete run of the show for the sake of devising a plan to fix the deeply flawed sound design. During the Wednesday afternoon rehearsal, which was supposed to be a third public matinee preview, Jacob spotted an obvious problem–the use of multiple wireless microphones. Wireless microphone technology in 1971 had not evolved to meet the rigors of theatrical use. In *Hair,* Jacob had successfully used *one* wireless mike. Multiple wireless microphones operating in the same theatrical space would never work.[149]

Jacob turned to O'Horgan during the Wednesday rehearsal, asking "…Tom, remember how we used to use the hand microphones in *Hair.* Can it work here?"[150] O'Horgan immediately

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[147] Ibid.

[148] Ibid., 33.

[149] Ibid. 32–33.

[150] Ibid., 33.

began re-choreographing the show around microphones and microphone cables. Set designer Robin Wagner transformed the mikes and cables into grapevines. Over the next few hours, the cast followed O'Horgan diligently as he transformed the staging from wireless microphones to staging that accommodated wired microphones. This first of many Jacob changes allowed the Wednesday evening preview–the first public, staged performance–to play as scheduled. *Jesus Christ Superstar* would survive. *Jesus Christ Superstar* opened October 12, 1971 and ran 711 performances before closing on July 1, 1973. The buzz generated from the concert album sold lots of tickets, including all the scheduled preview performances and the first three months of the official run.[151] New York City news reviews, however, were mediocre. Clive Barnes, in his *New York Times* review, compared *Jesus Christ Superstar* to the Empire State Building, "Not at all uninteresting, but somewhat unsurprising and of minimal artistic value."[152] Barnes said Lloyd Webber's music "…is extraordinarily eclectic…pleasant…although unmemorable."[153] *New York Times*' Walter Kerr, certainly unaware of the greater evil of the initial use of wireless microphones, did not like the conspicuous microphones and their cords, noting "Microphones are used throughout, which means the company seems to be trailing umbilical cords wherever they go and when Christ asks if his cup may not be taken away from him one imagines he is referring to that omnipresent nuisance he's got in his hands."[154] It is interesting to note his dislike of the

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[151] Ellis Nassour and Richard Broderick. *Rock opera; the creation of Jesus Christ Superstar, from record album to Broadway show and motion picture,* 119–120.

[152] Clive Barnes, "Theater: Christ's Passion Transported to the Stage in Guise of Serious Pop," *New York Times,* October 13, 1971, 40.

[153] Ibid.

[154] Walter Kerr, "A Critic Likes the Opera, Loathes the Production: Kerr on 'Superstar.'" *New York Times,* October 24, 1971, D1.

visual of the microphones with cords, especially given Kerr made no mention of the sound or sonic quality of the system. Dick Brukenfield, in *The Village Voice*, specifically criticized the sound system, writing "…I missed half the words, partly due to the theater's sound system…"[155] Later in the review, Brukenfield labeled *Jesus Christ Superstar* a "…psuedo musical…" due to the power and control of record companies.[156] Nevertheless, according to Nassour and Broderick, "As the theatergoers flowed out of the Hellinger [on opening night], it was evident that Broadway had a hit on its hands."[157]

Jacob Continues To Innovate

As previews ground on, Jacob began tackling challenges created by the original sound design. Unlike *Hair*, where Jacob's creative and psychoacoustic talents yielded brand-new solutions to the problems of the acoustic shadow under the balcony and getting reinforced sound to distant seating, *Jesus Christ Superstar*'s challenges were solved more with common sense and bits of ingenuity. Below is a listing and discussion of the two other major issues (the first was the replacement of the wireless microphones with wired mikes) Jacob resolved in his sound redesign of the original Broadway production of *Jesus Christ Superstar.*

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[155] Dick Brukenfield, "From the Archives...The Voice Reviews Jesus Christ Superstar, 1971," *The Village Voice*, last accessed April 22, 2015. http://www.villagevoice.com/2009-09-08/theater/from-the-archives-the-voice-reviews-jesus-christ-superstar-1971/.

[156] Ibid.

[157] Ellis Nassour and Richard Broderick. *Rock opera; the creation of Jesus Christ Superstar, from record album to Broadway show and motion picture,* 130.

1. **Proper loudspeaker selection.** The original sound design specified a high-end, home stereo speaker manufactured by James B. Lansing. Known as the Ranger Paragon, Jacob commented "It was a great sounding speaker if you're in a living room [averaging 960 cubic feet]. If you're trying to fill up a theatre, it left a lot to be desired."[158] Tracey estimated the cubic volume of the Richard Rodgers Theatre to be approximately 165,000 cubic feet.[159] Figure 10 is a picture of the Ranger Paragon.

© 2010 Michael W. Pretzer[160]

Figure 10–Picture of the Ranger Paragon Loudspeaker (9' wide by 3' high). Note the attempt to create a stereo image with both a left and right horn source.

[158] Ibid.

[159] Tracey interview. Richard Rodger Theatre's average dimensions are 42 feet high (highest seat), 56 feet wide, and 80 feet deep. The Mark Hellinger Theatre seated approximately 1,505 as compared to the Rodgers 1,400.

[160] Michael W. Pretzer, "JBL D44000 Paragon," *Flickr,* last accessed April 22, 2015. http://www.flickr.com/photos/magnum151/5233013987/in/photostream/.

Jacob ordered up a loudspeaker he had used in live concert settings which was capable of filling large spaces, to replace the Ranger Paragons. Jacob specified four concert loudspeakers, McCune Sound Service's JM3's, to replace the two Ranger Paragon, home stereo speakers. He flew two JM3's over the proscenium to deliver reinforced sound to the balcony and portions of the rear orchestra seating. To help pull the image back to the stage, Jacob placed the other two JM3's on the stage deck, stage left and stage right.[161] As with Jacob's under-balcony and over-balcony delay techniques, he continued to insist that the image of the sound align with its acoustic source which, for a musical, is the stage.[162]

2. **Redesign of the orchestra pit.** Presumably to replicate the concept album's studio sound with which fans had become familiar, the original sound designer completely filled the orchestra pit with dampening material and acoustically-treated baffles.[163] In addition, the designer covered the overhead opening of the pit with perspex (a plexiglass like substance) leaving a hole in the center. The conductor would enter the pit, take his position upon the podium with his head visible to the audience. He would take his customary bow and, upon turning to face the orchestra, he would grab a dome-shaped piece of perspex which he used to cover his head. The entire pit and its musicians were now completely acoustically isolated

[161] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 33. Interestingly, the JM3 was designed by John Meyer for McCune. John Meyer eventually founded what has become the preeminent loudspeaker manufacturer in the world, Meyer Sound Laboratories, Inc.

[162] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 33.

[163] Ibid.

from the rest of the theater.[164] This technique was grossly misguided, resulting in several sound problems.

Jacob noted that the first and most significant problem of this isolation technique was:

> …you had no [acoustic] space around any of the instruments, or the microphones [as in a professionally designed recording studio]; and so the sound of a trumpet doesn't sound like a trumpet when the mike is right in the bell of the instrument.[165]

Moreover, there was no plan to ventilate the build up of heat in the completely enclosed orchestra pit. Thus, the instruments' tunings were volatile and the musicians were uncomfortably hot, evermore so as the evening wore on. Both conditions negatively affected the sound of the orchestra. Practically speaking, the conductor was completely cut-off from the music on stage. In fact, during rehearsals, the conductor would only know to stop the orchestra when the stage manager walked out across the top of the enclosed orchestra pit and, with a stick in hand, tapped firmly on the dome covering the conductor's head.[166] Jacob eventually succeeded in getting the orchestra pit uncovered and the sonic benefits–not to mention the improvement in personal comfort–were acknowledged by all.

Jacob Establishes The Role Of Sound Designer On Broadway

Jacob's pioneering work in the sound designs of both *Hair* and *Jesus Christ Superstar* caught the attention of Broadway producers, directors, and writers. As Thomas notes, "[Jacob's]

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[164] David Collison, *The sound of theatre: a history,* 211.

[165] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 33.

[166] David Collison, *The sound of theatre: a history,* 211.

impact on sound…and the theatre would not escape notice."[167] Nassour and Broderick drew notice of the impact that the sound of *Jesus Christ Superstar*'s live stage production had on the theater:

> The turnabout that this O'Horgan–Stigwood version of the rock opera brought is interesting. In the late 1950s when stereophonic sound was being touted, the pitch by record companies was that stereo brought the listener into the middle of the music as in a live performance. Now, here was a live performance opting for recorded sound… *Superstar* flaunts the use of sophisticated sound equipment in attempting to create the feel and the tricks of "record" sound for the theater.[168]

Recognizing the potential dramaturgical power and impact of a well-designed aural environment for the theater, Jacob solved several, prevailing sound issues during his work on *Hair* and *Jesus Christ Superstar.* Jacob is responsible for sound becoming "a hot commodity on Broadway, and when Bob Fosse heard *Jesus Christ Superstar*, he talked producer Stuart Ostrow into hiring Abe Jacob for their new musical, *The Adventures of Pippin*."[169] Jacob's work on *Pippin* marked the first time a sound designer or sound professional of any sort was included from the beginning of the creative process in mounting a Broadway musical.[170] According to Richard Thomas, "The idea was unheard of at the time. Up until then, sound had always been added at the end of the process. By then it was typically too late to solve problems that did not compromise either the sound or the visual design."[171]

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[167] Richard K. Thomas, *USITT presents the designs of Abe Jacob,*34.

[168] Ellis Nassour and Richard Broderick, *Rock opera; the creation of Jesus Christ Superstar, from record album to Broadway show and motion picture,* 130.

[169] Richard K. Thomas, *USITT presents the designs of Abe Jacob,* 46.

[170] Ibid.

[171] Ibid.

Abe Jacob (see Figure 10 on next page) alone is responsible for the veneration and inclusion of sound designers in the theatrical design unions, and today, he works tirelessly to educate the next generation of Broadway sound designers and sound engineers via the annual "Broadway Sound Master Classes." His influence as a sound designer is deeply embedded in today's Broadway musicals. According to Brian Ronan, "…with special acknowledgment to Jack Mann [mentioned earlier as the first person to receive an official sound design credit for Carol Channing's 1961 *Showgirl*] and his pioneering efforts to bring electric sound reinforcement to certain landmark musicals , *e.g. Company, Follies, A Little Night Music, etc.,*…today's designers are all direct descendants of Abe."[172]

[172] Brian Ronan, interview.

Figure 11–Abe Jacob in front of Digico's SD8 mixing console. Digico is the leading console manufacturer for today's professional theater applications.

CHAPTER 5: THE RECORDING STUDIO ARRIVES ON BROADWAY

Abe Jacob combined his high-level concert touring experiences with his theatrical sensibilities to legitimize Broadway sound design, and to educate producers and directors concerning sound design's powerful capabilities in helping achieve a production's overall dramaturgical goals. During the late 1950s through the end of the 1960s, advances in recording studio technology also captured the ears of Broadway's producers and directors. Several powerful technologies emerged and changed forever the sonic quality of recorded albums, tapes, and live concert performances. A partial list of these include: 1) the first modern, hand-held microphone; 2) the minicomputer; 3) the cassette tape; 4) the electret microphone in 1964 (which provided the technological basis for today's high quality, miniature microphones, usually hidden in actors' hair lines, taped on cheek bones or eyeglasses, etc.); 4) the Beatles use of multi-track recording in 1965 (only four tracks, but vastly improved sonic quality); 5) special amplifiers, known as the "slave amplifier," which could be chained together to produce significant sound pressure levels needed for large concert stadiums; 6) the Moog Synthesizer and its vast library of new sounds; 7) the Dolby Noise Reduction system which forever changed the quality of all sound recordings; and, 8) the graphic equalizer, providing separate boost or cut equalization for each third of an octave over the human sound hearing spectrum (generally understood to be 20 hertz to 20,000 hertz).[173]

[173] For reference, a typical, modern piano's lowest note–A0–is 27.5 hertz while its highest note–C8–is 4,186.01 hertz, assuming the standard tuning of A4=440 hertz.

Burt Bacharach Expands To Broadway

Burt Bacharach is a prodigious song writer having won six Grammy Awards and two Academy Awards. *Promises, Promises* was Bacharach's first Broadway musical. When it opened on December 1, 1968, it was the first Broadway musical to directly employ state-of-the-art recording studio technology and techniques in its sound design.[174] Bacharach's Grammy-award-winning engineer, Phil Ramone, brought his studio techniques into the theater in order to recreate the sonic excellence of the recording studio. Ramone changed the seating of the orchestra personnel to mimic that of a recording studio, with more isolation from one another. The four female backup singers, whose vocal arrangements were an integral part of the orchestrations, stood in circular clusters around one or more microphones, a typical studio recording technique.[175] Ramone also applied absorption and reflective material around the physical space of the orchestra pit to allow for more precise acoustic control and processing by the sound operator.[176] Additionally, Bacharach and Ramone were the first to install a much higher quality recording studio mixing console in the theater, standard fare in today's Broadway musicals, though today's consoles are more specifically adapted for theatrical use.[177] Bacharach, sparing no expense in attempting to perfect the sonic quality of his show, installed the famed German EMT echo plate (Elektromesstechnik), which, due to its enormous size, is believed to still reside in the

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[174] John S. Wilson "The New Sound Of 'Promises,'" *New York Times*, February 16, 1969, D28. Interestingly, the cast album won the Grammy Award while the Tony for "Best Musical" went to *1776.*

[175] Ibid.

[176] Ibid.

[177] David Collison, *The sound of theatre: a history*, 208.

Shubert Theatre's basement.[178] The EMT echo plate was *the* sonic standard for creating the highest quality vocal reverberations and other sound effects used in the world's finest recording studios of the day. Incidentally, Abe Jacob took advantage of the EMT echo plate in his 1975 sound design of *A Chorus Line*.[179]

Bacharach and Ramone were intent on producing the sonic quality equivalent to that achieved in the top studio recordings of the day. And while not totally successful, as I will discuss later, they laid important ground work to raise the overall sonic quality of the Broadway musical. Perhaps it will be helpful at this point to compare and contrast the sound processing of a lead vocal recorded in the studio with one sung live on a Broadway stage.

A vocal track recorded to tape in a recording studio and a vocal sung live on stage are different in many ways; but, the critical difference for purposes of this discussion is that the vocal printed to tape is fixed in every way. It *never* changes unless it is re-recorded. Then, the result is a new, fixed vocal. A live vocal performance on Broadway does not benefit from such consistency. It changes note-to-note and night-to-night. In fact, that is one of the great distinctions of a Broadway show. However, such variances make it impossible to achieve the same vocal quality as can be obtained within a recording studio environment.

In a studio, the vocal track goes through the process of post-production whereby it is further processed after the final, raw vocal version is committed to tape (or hard drive today). Working on a final vocal track, the studio engineer enhances the sound of the vocal through the

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[178] Ibid.

[179] Ibid.

aid of several pieces of machinery; 1) equalization (the boosting or cutting of certain sound frequencies to achieve an even frequency response throughout the vocal performance); 2) reverberation (the addition of warmth and spatial presence to make up for the fact that the voice is recorded millimeters from the microphone); 3) compression (the balancing of the louder sections with the quieter sections so as not to have too large of a dynamic range, a distraction to the listener when played back on most consumer playback gear); 4) vocal delay to add presence to the overall sound (especially in ballads, where there is a lot of available sonic space); and, 5) a chorus effect to help "fatten" the vocal.[180]

In a Broadway setting, every note of each vocal performance is different from night to night in amplitude, phrasing, and style choices (*e.g.,* scooping into notes, speaking certain words instead of singing them, etc.). In addition, unless the music is being played to a click track, the tempo varies. All of these factors limit the choices Broadway sound operators have regarding their use of recording studio effects and processing on live vocals within a Broadway musical performance. For instance, a vocal delay might be chosen to give the lead vocal a fuller sound in

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[180] Specifically, a vocal delay unit is set in time to create a duplicate of the original, lead vocal, only a few milliseconds later (remember the Haas effect). The two vocals–the original and the delayed vocal–are then combined to achieve a richer, fuller sound. There is hardly any vocal recording today that does not use a vocal delay. It is almost never perceptible as a distinct sound, but can offer subtle enhancements to most any lead vocal. In the studio, where everything is recorded to click tracks, the delays can also follow the same click tracks and be changed with tempo changes as needed. Such techniques are impossible in a live Broadway musical.

A chorus is a modulation effect used to create a richer, thicker sound and add subtle movement. The effect roughly simulates the slight variations in pitch and timing that occur when multiple performers sing or play the same part. "What Is A Chorus Effect?" last accessed March 29, 2015. http://testtone.com/fundamentals/what-chorus-effect.

Until recently, only studio engineers understood the total impact post production can have on a recorded vocal. With today's internet, many "raw" vocal tracks are now available for listening. In many cases, the benefits of post-production are immediately obvious. Karen Carpenter of the pop-group the Carpenters possessed extraordinary vocal talent. Several of her unprocessed vocals can be heard here. Her vocal performance on these isolated tracks is excellent–a rare exception to most all other vocalists. Karen's unprocessed vocal tracks stand in stark contrast to Mariah Carey's 2014 live performance of her hit "All I Want For Christmas Is You" heard here. This performance does not reconcile to the fact that Mariah Carey is the best selling female recording artist of all time.

the studio. However, with a constantly changing "live" tempo, a delay effect may degrade the quality of the vocal rather than enhance it. Reverberation adds significant beauty to any vocal. If an actor suddenly speaks a word that is usually sung *e.g.,* for dramatic purposes, a reverberation sound on that spoken word might interrupt the dramatic moment significantly.

All of this is not to say that recording studio effects are unusable. They are used successfully in a different, more restrained manner than might be used in the recording studio. They cannot be imported wholesale into the theater. Perhaps this is why Phil Ramone, Bacharach's studio engineer and sound consultant on *Promises, Promises*, struggled. Ramone had no theatrical sound experience. Although initial reviews of *Promises, Promises* were charitable, comments concerning sound and sound design were absent. There is evidence to suggest Bacharach and Ramone were not entirely successful in their cutting-edge endeavors, however. Fordham professor Gene Phillips, in a 1969 letter to the *New York Times* editor, wrote:

> Favorable reviews of *Promises, Promises* were obviously not written by critics seeing the show from the balcony, where the lyrics of several songs were audible, but unintelligible…Most of the ensembles sound like muffled messages from outer space…I noticed that people around me in the balcony progressively lost interest in the…show.[181]

Nevertheless, Bacharach and Ramone's work on *Promises, Promises* is fundamental to modern Broadway musical sound designs. Today, every Broadway musical employs the same state-of-the-art technologies used in recording studios, including the five discussed previously– equalization, reverberation, compression, vocal delay, and chorus. Every piece of audio gear used within the sonic signal chain of a Broadway musical is recording-studio quality–the

[181] Gene D. Phillips, "Muffled," *New York Times*, June 29, 1969, D20.

microphone, the cable (if not wireless), the pre-amplifier (boosts the level of the low voltage mic signal to avoid noise and other audio artifacts over long cable runs), the digital input for the microphone which then runs to the mixing console, the mixing console to the loudspeaker processing gear (equalization, loudspeaker delays, etc.) to the amplifiers (now usually built into the loudspeaker cabinets), and finally to the loudspeaker, which converts the acoustical energy to moving air that reaches the seating areas as sound. Further, today's musicals make use of surround sound systems, governed by complex digital algorithms, whereby dozens of small speakers surround the seating areas to add not only special sound effects, *e.g.*, a gunshot appears to come from somewhere other than the stage, but also a sense of being transported elsewhere spatially, as experienced in the opening procession of *The Lion King.* As the animals process from the back of the theater to the front, the very real sound of an African stampede wraps over and around the audience, and moves in time with the action from the back of house to its eventual home on stage.

Human Irony Musicals Of Sondheim (And Others) Demand New Sound Design Techniques

Jack Mann's sound design for Stephen Sondheim's *Company* (1970) also laid important ground work in the nascent theatrical sound design industry. Sondheim's lyrics are creative gems that can be difficult to discern in the midst of complex melodies, complex vocal arrangements, and complex orchestrations. Rather than simplify lyrics and melodies, or arrangements and orchestrations, Sondheim worked with sound designers and musical directors to mike individual

instruments he felt would enhance the communication of his lyrics and song *e.g.*, Sondheim specifically asked that the flute and clarinet be individually miked in *Company* to help give a slight lift to the vocal melody in certain numbers. He also made use of off-stage microphones to augment the sound of the chorus, thereby enhancing the intelligibility of his lyrics and songs. Specifically, when certain company members were not required on stage, Sondheim had them gather around vocal microphones offstage to sing along with the onstage chorus. The near proximity of the off-stage voices to the off-stage vocal microphones increased the overall vocal intelligibility.[182] Sondheim is also responsible for the addition of overhead, long-range microphones to the standard foot-microphones of the late 1950s and 1960s, a move that also increased *Company's* intelligibility throughout the theater. Sondheim worked closely with scenic designer Boris Aronson to conceal these long-range microphones in fixed scenery pieces upstage.

As the first American musical to be airlifted to London–cast, sets, costumes, *etc.*–*Company* marked "…the start of studio recording techniques being brought into the (London) theatre."[183] The only discipline not imported from the US production was sound design. The producers hired David Collison, a London-based sound designer, and eventual author of *The sound of theatre: a history*. Specifically, *Company* introduced the London sound designers to the first professional mixing desk, the US-made Bozak column loudspeakers (Bozak is now defunct), the brand-new US-made Electro-voice 644 long-range shotgun microphones, etc. In

[182] Richard K. Thomas, *USITT presents the designs of Abe Jacob*, 207. For the most part, vocal intelligibility is inversely proportional to the distance from the microphone element.

[183] David Collison, *The sound of theatre: a history*, 206–207.

addition, the London production individually miked the same instruments and backstage vocalists (just as in the US).[184] Given the soon-to-arrive British invasion in the United States, Sondheim's and *Company's* contributions toward the advancement of theatrical sound design in the UK are notable.

There are several examples in *Company* which demonstrate the importance of a well-designed sound system. In act one's scene featuring "Have I Got A Girl For You," Bobby is overwhelmed by his well-meaning circle of friends trying to set him up for a dinner date with a would-be mate. Here is a clip of the song from the 2006 Broadway revival on *YouTube*.[185] The song opens with the following lyrics, many sung on top of one another, from all parts of the stage, in a frenetic, patter fashion:

Jenny:	Bobby, (continues *ad lib*. until "All")
Peter:	Bobby, (continues *ad lib*. until "All")
Amy:	Bobby baby, (continues *ad lib*. until "All")
Paul:	Bobby bubi, (continues *ad lib*. until "All")
All but Robert:	Robby,
Susan:	Robert, darling (continues *ad lib*. until "All")
All but Robert:	Bobby, we've been trying to reach you,
Sarah:	Angel, I've got something to tell you...
Amy and Paul:	Bobby, it's important or I wouldn't call...
All but Robert:	Whatcha doin' Thursday?
Jenny and David:	Bobby, look, I know how you hate it and all...
All but Robert:	But this is something special...
	Not that you don't know a lot of lovely girls, but
	Bobby, come on over for dinner!
	There's someone we want you to meet!
	Bobby, come on over for dinner!

[184] Ibid., 207.

[185] "Company–Have I Got A Girl For You," *YouTube,* last accessed April 22, 2015. https://www.youtube.com/watch?v=QadzUu0RRB8&list=PL5B7D01EA892E424E&index=8.

This girl from the office...
My niece from Ohio...
It'll just be the four of us...
You'll looooooooooooooooooove her![186]

"I'm Not Getting Married Today," also from *Company,* is a great example of Stephen Sondheim's lyrical prowess. Each lyric is packed with meaning and the song's frenzied tempo creates an unforgettable theatrical moment. Sondheim further complicates the performance of this song by setting it in a low tessitura, though his orchestrator, Jonathan Tunick, brilliantly sets the strings within the vocal range of the song which helps drive the tempo, while leaving room for the voice, and more importantly, the lyrics to he heard. Madeline Kahn delivers a prodigious performance in this concert version of the song hosted on YouTube.[187]

The Sound Of Broadway Today

Today's Broadway sound designers are direct beneficiaries of the groundbreaking work on Broadway in the late 1960s and early 70s, especially as pioneered by Abe Jacob. In addition to Jacob, Brian Ronan also credits the following:

> In the 1980s, Otts Munderloh got producers to invest more in the sound departments' budgets, and then the British invasion of Martin Levan (*Cats*, *Phantom*) and Andrew Bruce (*Les Miz*, *Miss Saigon*) really ramped up what we expected in terms of quality.[188]

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[186] Ibid.

[187] "Getting Married Today"–Sondheim : A Celebration At Carnegie Hall (1992) - Madeline Kahn," *YouTube,* last accessed April 22, 2015. https://www.youtube.com/watch?v=-u1DO5ESgYA. It is interesting to note that the production used hand-held microphones in this concert production. While a distraction theatrically, every word is intelligible.

[188] Brian Ronan, interview.

Technological advances continue at an exponential rate, affording sound designers even more precise tools necessary to create the powerful aural experiences that today's Broadway audiences and producers demand. The studio-quality, miniature body-worn microphone has effectively replaced the shotgun or foot microphone. The pairing of dependable wireless technology with the miniature body microphone directly facilitated the production of the mega-musical (*Cats, Starlight Express, The Phantom of the Opera, Les Miserables, Miss Saigon,* etc.) with their complex and athletic staging requirements.

Line array speakers (see Figure 12 on next page) are specified for almost every Broadway musical today. Their unique technology allows several speaker elements to combine to operate as a single speaker from a single point source in the theater, providing very even sound pressure levels to the seats the line array is programmed to cover (as stated earlier, sound design goals are +/- 3dB throughout the entire seating area). Line arrays can steer the sound to very specific areas–more so than any other loudspeaker technology–and perhaps more importantly, keep sound off walls and other surfaces which may cause unwanted, or as Vitruvius called them 2,000 years ago, dissonant reflections. According to Meyer Sound Laboratories,

> A line array is a group of radiating elements [enclosed in speaker cabinets] arrayed in a straight line, closely spaced and operating with equal amplitude and in phase. Described by Olson in his 1957 classic text, *Acoustical Engineering*…line arrays afford very directional vertical coverage and thus project sound effectively.[189]

[189] "A Line Array Theory Q&A," *Meyer Sound Laboratories, Inc.,* last accessed on April 22, 2015. http://www.meyersound.com/support/papers/line_array_theory.htm.

Today, according to Brian Ronan, Broadway sound designers use line-array speaker technology to achieve:

> …wider areas of coverage from a single source, cutting down on what can often be the problematic use of multiple conventional speakers to cover a given section of the theatre…[which] has greatly improved intelligibility. Cutting down on multiple source amplification [and the negative effects of multiple sources arriving at different times to the same seat] has greatly improved intelligibility.[190]

The typical line array system (Figure 5 below) used in a theatrical setting–again, the boxes combine to operate as a single speaker with regard to amplitude and frequency response–allows the back row of the mezzanine (the top boxes) and the front row of the orchestra (the bottom boxes) to be covered by a single array. Employed effectively, line arrays, as Brian Ronan indicated above, reduce the number of additional speaker sources that must be added to fill in sound holes within the theater.

Courtesy of Meyer Sound Laboratories, Inc.
Figure 12–Meyer Sound's Lyon line-array loudspeaker system.

[190] Brian Ronan, interview.

From an electronically reinforced sound vs. architectural acoustics perspective, Brian Ronan notes of today's Broadway musical sound designs:

> Most Broadway [sound] designers know how to use and have access to state of the art equipment. I believe that a production can decide what kind of sound it's going for and apply it. It's true that, in most cases, the tools to overcome the challenges that classic theatrical architecture presents to sound designers on contemporary musicals are available. There may be reasons that architecture wins–budget, speaker placement due to scenic requirements, sightline considerations, etc. All factor in to what a designer can and can't do in trying to overcome architectural challenges. But given a decent scenario and adequate time, a good designer has the option to choose what quality or volume they're going for.[191]

Sound designers also help compensate for the ever shrinking Broadway choruses and orchestras or perhaps, it could be argued, today's sound design techniques allow for smaller choruses and orchestras. Though carefully staged and directed to appear as a single ensemble, Broadway choruses were historically a combination of separate, but equal talent–singers and dancers. Today's casting requires a single performer to do both. Thus, singing and vocal projection suffer. Consequently, stage directors and musical directors rely more heavily on sound reinforcement technology to make up the gap.[192]

A review of today's sound equipment list on a typical Broadway musical, especially when compared to the equipment list Abe Jacob used on his early musicals, reveals just how sophisticated the sound design of modern Broadway musicals has become. Appendix A lists the equipment specified in Abe Jacob's sound design of *Pippin* in 1972. Appendix B lists the

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[191] Ibid.

[192] David Chase, interview.

equipment specified by Brian Ronan's sound design of Sting's 2014 musical *The Last Ship.* The contrast between the two is striking. See Table 4.

Table 4–Equipment List Comparison between *Pippin* (1972) and Sting's *The Last Ship* (2014).

Gear	***Pippin* (1972)**	***The Last Ship* (2014)**
Microphones and other sound input devices	41	183
Available input channels on mixing console	30	253
Loudspeakers	2	122
Processing Gear (reverbs, delays, e.q's, etc.)	1	9
Computers	0	6

Table 4 clearly proves that a lot more "stuff" is involved in sound design within the Broadway musical today than was available forty years ago. Yet, theatergoers still do not "see" sound. There is some irony that the breakthrough shows for modern Broadway sound design, *Hair* and *Jesus Christ Superstar,* brought microphones front and center stage when today, sound designers hide them discreetly in hair lines and elsewhere on the head. Forty years ago, Broadway sound was an appendage to the electrician's union. Today, most Broadway shows operate with three full-time audio technicians running each live performance.

Undoubtedly, we all have experienced the power of a great musical moment–and sound is at the core of that moment. But perhaps we, as humans, are the ones who are developing most, as listeners. And such development begets further technical advances that further our capacity to

hear and to engage music as beings emotionally moved by sound. Don Ihde believes this to be so. “Our capacities for listening are changed by technological culture…We have learned to listen farther,…extended our range of hearing…[and] made technologically produced sound pervasive.”[193]

[193] Don Ihde, *Listening and voice: a phenomenology of sound* (Athens: Ohio University Press, 1976), 4.

CONCLUSIONS

Cleon Throckmorton was a scenic designer in New York from the mid-1920s through the mid-1940s.[194] Even he–a scenic designer–was keenly tuned in to the power of sound within theatrical productions. He once remarked, "This board, you may say, is a tree, this muslin a wall and that spotlight the tropical sunlight–and the public will imagine it. But a dog's bark must sound like a bark, and a train like a train!"[195] Today's creators of Broadway shows are presuming upon the techniques of skilled sound designers. Complicated human emotions and conditions communicated via complex lyrics, melodies, and orchestrations could not be fully explored were it not for the ability to reproduce it all in an environment of pristine sound. The Pulitzer Prize-winning *Next To Normal* (2009) provides an excellent example for such a requirement. *Next To Normal* deals with a modern family whose wife and mother, Diana, suffers from bipolar 1 disorder with psychotic features. In a pivotal scene illustrating the progression of the disorder, Diana and her husband, Dan, are grappling with the impact of the disorder on their relationship. As the scene reaches its climax, Gabe, the son who has been dead for sixteen years, enters as a comforting illusion conjured by Diana's illness. All of this is portrayed within the context of the songs "You Don't Know" and "I Am The One." The multiple lines of lyrics, the rock- and pop-oriented orchestrations, and the intense emotional blanket under which it is performed combine to create an extraordinarily powerful theatrical moment. The scene, as broadcast on the 2009

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[194] Playbill Vault, "Cleon Throckmorton: Designer, Director, Producer," last accessed April 22, 2015. http://www.playbillvault.com/Person/Detail/2334/Cleon-Throckmorton.

[195] Cleon Throckmorton, *Catalog of the theatre: scenery, lighting, hardware, painting, costume, make-up* (New York: Cleon Throckmorton, 1933), 6.

Tony awards telecast, can be viewed here on *YouTube*.[196] It is difficult to imagine this scene performed without the aid of studio-quality, miniature wireless microphones (for dramaturgical purposes), processed by the highest quality digital equalizers (to bring separation and distinction to each voice), mixed on a state-of-the art console to compensate for the smallest variations in sound pressure from the actors, amplified by an expertly designed loudspeaker system.

Sound design, in the ancient Greek theater and the modern Broadway musical, is ultimately successful when it points to something other than itself–that is, some greater *truth* or *human ideal* as captured and portrayed within a story. David Collison notes:

> But whether you were throwing rocks into copper jars in the ancient Greek theatre, rolling cannon balls around the roof of an auditorium in the 1800s, or a 21st century audio engineer producing a whole range of amazing noises from a little black box, we were all striving for the same thing–to assist the telling of the story, to heighten the drama, and to help create a world that is believable.[197]

[196] "Next To Normal," from June 7, 2009 Tony awards television broadcast, last accessed April 22, 2015. https://www.youtube.com/watch?v=yx9z1Fdz1j8.

[197] David Collison, *The sound of theatre: a history*, 259.

APPENDIX A: SOUND EQUIPMENT LIST FOR BROADWAY'S 1972 PRODUCTION OF *PIPPIN* AS DESIGNED BY ABE JACOB

Below is Abe Jacob's equipment list specified to support his sound design of the 1972 production of *Pippin*.[198]

- 3–Sony ECM microphones
- 2–Shure 55S microphones
- 9–Shure SM54 microphones
- 1–Shure SM53 microphone
- 6–Shure 546 microphones
- 4–Electro-Voice RE15 microphones
- 7–Sennheiser MKH 805 microphones
- 5–Neumann KM84 microphones
- 3–Direct Boxes
- 10–Baby boom arms and microphone stands
- 8–short microphone stands
- 6–goose necks
- 9–regular microphone stands
- 5–Altec 1567A mixers
- 1–Altec 1592A mixer
- 1–Shure reverb mixer
- 2–Altec 1604 loudspeakers

[198] Richard K. Thomas, *USITT presents the designs of Abe Jacob*, 46.

APPENDIX B: SOUND EQUIPMENT LIST FOR BROADWAY'S 2014 PRODUCTION OF STING'S *THE LAST SHIP* AS DESIGNED BY BRIAN RONAN

Below is Brian Ronan's equipment list specified to support his sound design of the 2014 production of Sting's *The Last Ship.*[199]

Mixers

- 1–DigiCo SD7T Control Surface w/ Dual engines
- 1–DigiCo SD10-24 Control Surface
- 3–DigiCo SD Racks w/ opticore
- 3–100 Meter Opticore Cable
- 5–5 meter Opticore Cable
- 16–DigiCo A to D mic/line input cards
- 14–DigiCo D to A line output cards
- 4–DigiCo AES Output Card
- 1–DigiCo SD7 Script Dolly
- 4–Aviom A-16D Pro Net Distributor
- 20–Aviom A360 personal mixers
- 20–A360 Aviom Stand mounts
- 1–ATI 8MX2 8 Channel Rack Mount Mixer
- 4–Fostex RM-2 Stereo Rack Monitor
- 3–Sonifex RB-DA6 Headphone Distribution

Computers

- 2–Mac Mini w/OSX 10.9, i7 2.6ghz, 16gb Ram, 500gb Solid State Hard Drive
- 2–Mac Mini w/ Windows
- 1–Windows Machine for Sennheiser Software
- 1–Apple iPad 2 16gb
- 2–DigiCo MADI USB 2.0 Interface
- 2–RME MADI Bridge
- 3–Rack Mount 24 Port Gigabit Switch
- 2–Rack Mount 16 Port Gigabit Switch
- 6–8 Port Gigabit Switch
- 1–Asus RT-N664 Wireless Router
- 2–Gefen CAT5 USB Extender
- 3–Apple Displayport to VGA Adaptors
- 4–Apple USB to Ethernet Adaptors
- 6–USB Panel Mounts
- 4–MIDI Panel Mounts
- 3–DVI Panel Mounts

[199] Courtesy of Brian Ronan.

- 5–6-port USB Hubs
- 3–Dell 24" Monitors
- 6–19" Pelco
- 2–EVGA UVPlus+ USB to DVI Adaptor
- 2–Gefen EXT-DVI-24IDL
- 4–VGA A/B Switch
- 2–Geffen DVI Detectives
- 4–Logitech Marble Mouse for Qlab/LA-8 (compatible w/KVM Switcher)
- 4–Standard Keyboards for Qlab/LA-8 (compatible w/KVM Switcher)
- 2–Kensington Pro Trackballs
- 2–Apple Thin Keyboards
- 2–Long view KVM Extenders/Receivers
- 1–Startech 4-Port Cat5 VGA Video Splitter/Distribution (for RF View)
- 4–Startech STUTPRCL Long Range Receiver (for RF View)
- 1–L'Acoustics Soundvision prediction software license
- 1–Microsoft Office
- 1–Smaart software v.7
- 2–QLab ProMidi Sound Effect Software v.3
- 1–Roland Quad Capture for use with SMAART 7
- 4–Edirol USB-ONE MIDI to USB Interface
- 4–MIDI Solutions Quadra Merge MIDI Mergers
- 4–MIDI Solutions Quadra Thru
- 2–MIDI Power Supplies
- 2–MIDI Soultions Dual Footswitch Controller
- 2–2-Button Go/Stop Box (For use with Dual Footswitch Controller)
- 4–6' DVI Cable
- 4–12' DVI Cable
- 4–6' VGA Cable
- 4–12' VGA Cable
- 8–APC 1500 Rack Mount UPS

Production

- 1–HP Color Laserjet printer w/ Network Hardware
- 1–24' DVI Monitor
- 1–27" Apple Cinema Display (Displayport or Thunderbolt)
- 2–Apple full size keyboard THIN
- 1–Kensington K64325 Expert Mouse Pro
- 1–Logitech Trackball
- 1–8 Port Gigabit Switch
- 2–Sennheiser SKP500-G2 Transmitter/Receivers

- 1–Pop Phase Checker
- 6–Motorola Walkies w/6 bay charger
- 6–Motorola Walkies
- 6–Single Bay Chargers
- 6–Motorola Fist Mic
- 10–Clear Com RM 440
- 6–CC-26 Light Weight Headsets
- 10–Sennheiser HMD-46 Headset
- 2–Sennheiser SK5212 Transmitters for wardrobe/hair
- 1–Asus RT-N664 Wireless Router
- 1–Tripplite 3' plugging strip Sound Tech table
- 30–Sennheiser MKE-2 to SK50 Beige Microphones
- 12 Sennheiser MKE-2 to SK50 black microphones (rental stock)

Wireless

- 20–Sennheiser 3532 Receivers
- 2–SKM 5000 (combo)
- 40–Sennheiser SK5212 Transmitters
- 4–Masque PWS Ground Plane Antennas
- 2–Spudnik Antennas for use with Wireless Telex
- 1–Monitoring System for 50 channels of RF
- 3–Masque RS96-MM Remote Stations
- 1–Startek 4-Port Cat5 VGA Video Splitter/Distribution
- 4–Startech STUTPRCL Long Range Receivers
- 1–Keyboard and mouse for RF extension
- 4–Shure PSM 1000 Rx/TX IEM
- 6–Sennheiser MKE-2 to SK50 beige microphones
- 6–Sennheiser MKE-2 to SK50 black microphones
- 30–Sennheiser MKE-1 to SK50 beige microphones (Paintable)
- 12–Sennheiser MKE-1 to SK50 black microphones
- 4–DPA 4061 to SK50 brown microphones
- 2–DPA 4061 to SK50 beige microphones
- 6–Countryman B-3 to SK50 beige microphones
- 8–3' Female XLR to LEMO
- 12–Spare transmit antennas
- 6–Sennheiser MKE-2 black inlet caps
- 12–Rubber antenna tips
- 25–Beige Ratpack X-Mit Belts
- 2–100' RG-213
- 2–75' RG-213

- 6–50' RG-213
- 8–25' RG-213
- 96–Powerex AA rechargeable batteries
- 8–Powerex chargers

Playback

- 2–Tascam SS-CDR2000 Solid State Recordera

Processing

- 1–Klark Teknik DN6051 Precision Mic
- 2–TC Electronics S-6000 w/ remote
- 2–TC Electonics Remore CPU for S-6000
- 2–Grace m802 preamps
- 2–Grace m802 remote

Microphones

- 3–AKG 414 w/ windscreens
- 10–Neumann KM 184
- 3–Neumann KM 185
- 4–Neumann U87
- 4–Windscreens for Neumann U87
- 4–Pop Filters for Neumann U87
- 3–Neumann U89
- 8–Sennheiser MKH40
- 7–Sennheiser MKH800
- 3–Royer R-121
- 4–Shure SM58
- 8–Shure SM57
- 4–Shure Beta 56a
- 3–Shure Beta 52a
- 4–Shure 565SD
- 3–Shure SM91 w/inline preamp
- 2–Shure SM98 w/inline preamp
- 6–Shure 404 PTT mics w/ hanging clip
- 3–Crown PCC 160
- 2–Crown GLM 100
- 8–Avalon DI’s
- 6–Radial JDI MK3
- 2–Radial JD6 6Ch DI Boxes
- 1–Opus DI-1000
- 6–Mic Mute On/Off foot switches w/ 48v and LED

- 2–Roland RT-10K Trigger
- 2–Alesis DM-10 Trigger Interface
- 2–DPA 4021
- 8–DPA 4061
- 8–DPA MHS6001 Microphone Holder
- 8–DPA DAD6001 Adapter

Microphone Accessories

- 35–Atlas MS12C w/ bases
- 20-–Atlas TS-8 Banquet Stands w/large bases
- 20-AKG KM238 side clamps
- 8–Atlas MS25E base with long straight and transducer
- 4–13” goosenecks
- 6–6” goosenecks
- 35–telescoping booms
- 6–Atlas AD5 coupling
- 6–Atlas 6” nipple
- 24–Atlas AD-11 female flange
- 24–Atlas AD-12 male flange
- 10–Atlas AD-14 90 degree nipple
- 4–BC-1 clamp
- 15–LP claws
- 20–K&M KM 240-5
- 12–Ultimate clamps
- 8–Mega clamps
- 6–Tall tripod mic stands (1247)
- 6–Medium tripod mic stands (1283)
- 4–Atlas TM1 stereo bar
- 50–Atlas L0-2B lock-on accessory
- 1–Kelly Concepts-SHU Flatz isolation system
- 6–KM216 female to male thread adaptor
- 6–KM216 5/8" to 3/8" thread adaptor

Loudspeakers

- 2–Meyer UPQ-1P w/hardware
- 8–Meyer UPM1-P w/ hanging hardware
- 6–Meyer UPA1-P w/ hanging hardware
- 2–Meyer UPJ-1P w/ hanging hardware
- 18–Meyer UPjr w/ hanging hardware
- 8–Meyer M1D’s

- 10–Meyer MM-4 w/ hanging hardware
- 4–MeyerUM-1 horn w/ hanging hardware
- 20–L'Acoustics Kara
- 38–L'Acoustics dvDosc
- 6–L'Acoustics SB18 Subs
- 50–d&b E3 w/ hanging hardware
- 10–d&b E5 w/ hanging hardware
- 2–d&b B-2 subwoofers
- 40–EAW JF80 w/ hanging hardware
- 6–Anchor AN1000 w/ hanging hardware
- 8–Genelec 8030 w/ mic stand adapter
- 4–Anchor AN-Mini portable sound system w/batteries and charger
- 24–Galaxy HotSpots

Amplifiers/Processors

- 2–d&b D12
- 17–d&b D6
- 16–L'Acoustics LA-8
- 12–Lab Gruppen FP2400 4 Channel amp
- 4–Meyer M1a processor
- 2–Meyer MM4-CEU processor
- 3–Meyer Galileo processors

Communication

- 4–ClearCom MS440 4-Channel Main Station
- 8–ClearCom RM440 4-Channel Remote Station
- 10–ClearCom RS 502 Stereo BeltPack w/6pin Y
- 4–RS 502 Stereo Beltpack w/6 Pin Y with program
- 10–RS 501 BP
- 2–Masque Spot Com box
- 4–Headset Mic Mute boxes with lighted switch
- 6–Clearcom RM-702 dual channel rack mount unit
- 6–Clearcom KB-702 dual channel speaker station w/enclosure
- 4–Beyer DT108 headsets
- 30–Sennheiser HMD 460 double-muff headsets
- 16–CC-26 lightweight headsets
- 12–HS-6 w/ hanging clips
- 3–Telex BTR 825 dual channel wireless system w/four remotes (12 total)
- 1–Antenna distribution system for Telex BTR 825 system w/dual RX/TX distribution
- 4–Antennas for Telex BTR825 distribution

- 2–Clearcom IF4W4 4-wire interface
- 8–4-wire terminal block to Telex RG 4-wire
- 6–15' headset extension cables
- 8–Clearcom terminators

Video Distribution

- 1–Vadio WallView HD-20 Cat5 w/camera control system
- 1–Panasonic AG-DVX100B
- 1–.7x wide angle convertor for AG-DVX100B
- 10–Panasonic WV-CP504
- 10–Vitek VTC-IRE30/2810
- 2–Sony EVID90 PTZ cameras
- 10–Panasonic 2.9-6mm lens for CP-504
- 4–Panasonic 8x zoom lens for CP-504
- 10–IR lens covers for Panasonic lenses
- 16–Bogen 3028 camera mounts
- 5–Infrared remote repeaters over Cat5
- 3–USB to RS-232 adaptors
- 3–RS-232 over Cat5 extenders
- 3–RS-232 to male VISCA mini-DIN 8-pin
- 10–Advanced LED technology Clarius short range LED illuminator
- 3–Vitek VT-IR2/110 infrared illuminator 200' 65 degree (7646)
- 1–BlackMagic mini convertor SDI to analog
- 3–BlackMagic mini convertor analog to SDI
- 1–Kramer VM-20HD 1X10 dual-link HD-SDI distribution system
- 2–Kramer VM-22HD 1X2 dual-link HD-SDI distribution system
- 10–Kramer VM1010
- 6–Kramer PIP-4 4 composite video picture-in-picture inserter
- 4–Kramer VM-42 composite video switcher
- 6–Kramer 4x1 VB video switcher
- 2–Kramer VS-801xlm composite video switcher
- 2–Kramer/Ocean Matrix OMX-9032 16x1 switcher
- 4–Video hum bucker
- 10–ETS SDS887 video distribution hub
- 30–Foresight TTP414V 4-channel video transceiver RJ45 Balun
- 14–Foresight TPP016-RJ45 16 Port Transceiver Hub
- 8–9" b/w monitors with hanging hardware
- 8–19" Pelco monitors
- 4–19" Pelco rack-mountable monitors
- 6–Marshall Triple 5" LCD Monitors
- 6–Dual mount 8" flat panel monitors

- 20–Delvcam Pro56 monitors
- 20–Delvcam Delv-SM swivel mount adapter
- 10–Panasonic PLCD8C 8" LCD monitors
- 5–Marshall V-LCD17H-2HD 17" Rackmount LCD Monitor with Dual HD-SDI
- 2–Marshall V-MD241 MD-HDSDIx2 dual link HD-SDI 24” monitors
- 10–K&M Vesa 75/ Vessa 100 microphone stand mount for small LCD
- 2–Ergotron LX desk LCD arm w/short poll
- 2–Ergotron LX desk LCD arm w/tall poll
- 2–Ergotron LX dual side-by-side arm
- 4–Chief universal monitor wall mount
- 2–Chief height-adjustable static dual arm monitor desk mount
- 2–Low-latency flat panel monitor for balcony rail
- 2–20" CRT b/w monitors w/hanging hardware
- 1–DMX blackout circuit
- 1–Delvcam 7" LCD field pack with battery and charger
- TBD–dual link SDI cables

Paging

- 1–TOA M912MK2 mixer/amp
- 3–L-01 line inputs
- 5–M-01 mic input
- 10–TOA CS-64 70v dressing room speakers w/volume control

Microphone Cable

- 15–100' XLR
- 25–50’XLR
- 40–25' XLR
- 40–15' XLR
- 40–10' XLR
- 40–5' XLR
- 20–3' XLR
- 20–2’ XLR
- 20–1’XLR

AES/EBU Digital Cable

- 10–<5' AES XLR
- 10–5' AES XLR
- 10–10' AES XLR
- 10–15' AES XLR

Siamese Cable

- 10–200’
- 10–150’
- 10–100’
- 15–50’
- 15–25'
- 15–15'
- 15–10’

CAT-5 Cable

- 15–Dual ethercon to ethernet panel mount
- 15–250’
- 8–200'
- 28–150’
- 25–100’
- 45–50’
- 20–25’

BNC Video Cable

- 20–1' RG-59
- 12–2' RG-59
- 12–5' RG-59
- 20–10' RG-59
- 12–25' RG-59
- 20–50' RG-59
- 20–100' RG-59
- 15–150' RG-59
- 4–250' RG-59
- 10–BNC terminators

AC-Edison Electric Cable

- 4–250’
- 15–150'
- 15–100'
- 15–50'
- 15–25'
- 10–10’
- 6–Triplights (8 edisons/1 rack space)
- 15–Waber strips
- 6–25' edison-quad
- 5–Furman PLUGLOCK

Edison to Quad Electric Cable

- 4–50’
- 4–25’

AC Twist 5-wire, 30 amp

- 4–100’
- 4–150’
- 4–10’
- 8–25’
- 6–5’
- 5–5-wire to powercon
- 4–5-wire to powercon hanging distribution
- 5–5-wire to edison panels
- 3–5-wire to PD3 panels
- 6–5-wire to L5-30 panels (LA-8s)

Power Distribution

- 1–Complete Motion Labs PD system
- 1–PD 60 Powercon 18 L21-30 (6222)
- 1–100' feeder
- 1–50' feeder
- 1–25' feeder
- 1–10’ feeder
- 1–set Cam-Lok tails
- 2–Cam-Lok F-F turnarounds
- 2–Cam-Lok M-M turnarounds

Power Conditioning

- 4–250’
- 4–200’
- 16–150’
- 20–100’
- 30–50’
- 25–25’
- 20–15’
- 20–10’
- 10–<5’
- 50–powercon barrels
- 4–powercon “Y”
- 4–Female edison to powercon grey
- 40– Powercon to 4 edison distros

- 6–1U rack-mount powercon distros, 1 blue front/8 white front
- 4–1U rack-mount powercon distros 1 blue front/8 grey rear
- 30–1U rack-mount powercon distros 1 blue front/edison rear

Custom

- 8–5-channel, 6-way XLR rack mount panels

Adaptors

- 12–1/4" to 1/4" Whirlwind instrument cable
- 10–6' 1/4" to 1/8 " headphone cables
- 10–1/4" male to 1/8 " female headphone adapters
- 10–6' 1/4" headphone extension cables
- 10–female XLR to MIDI
- 10–male XLR to MIDI
- 25–RCA male to female BNC
- 25–RCA female to female BNC
- 25–BNC “T"
- 10–Nuetrik NL4 to bare wire
- 15–XLR female to 2 XLR male "Y"
- 15–XLR-M to 2 XLR-F "Y"
- 20–Male TRS 1/4” to male XLR pin 2+
- 10–male-TRS 1/4” to female Pin 2+
- 6–speaker twist parallel "Y"
- 3–complete set patch cables
- 10–1/4” male TS to XLR male pin 2+
- 10–1/4” male TS to XLR female pin 2+
- 5–RCA male to female XLR pin 2+
- 5–RCA male to male XLR pin 2+
- 13–NL4 A/B to 2 NL4 "Y"
- 30–XLR female to XLR female turnaround
- 30–XLR male to XLR male turnaround
- 10–1/8" to stereo male XLR
- 35–Ethercon barrels
- 10–XLR ground lifts
- 10–XLR phase reverser
- 10–IL-19 ground isolator
- 10–BNC female to male right angle adaptors
- 30–BNC FF Couplers
- 10–2' NL4 to banana plug

Rigging Hardware

- 2–8' section 1' x 1' spigoted TomKat truss
- 3–Light Source 12" Mega Truss Pick
- TBD–threaded rod
- 12–rated truss bolts
- 2–L'acoustics M-Bump
- 2–L'acoustics M-Bars
- 5–L'acoustics dv Bump 2
- 12–L'Acoustics dV shackles
- 35–safeties
- 12–rigid chesboro
- 8–swivel chesboro
- 4–8' x 1.5" pipe
- 2–10' x 1.5" pipe
- 8–pipe flanges
- 12–safer sidearms
- 4–2' pipes for safer sidearms
- 4–3' pipes for safer sidearms
- 4–4’ pipes for safer sidearms
- 8–2 1/2’ x 3/4" steel stingers with shackles
- 8–eye bolts with nylocks
- 4–3/4" or 7/8" pear rings
- 10–Crosby 5/8" shackles
- 40–Mega-Clamp aluminum
- 29– Steel Mega-Claws
- 10–3' Steelflex span sets
- 10–6' Steelflex span sets
- 10–10' Steelflex span sets
- 10–5' steel sling (eye-to-eye)
- 10–10' steel sling (eye-to-eye)

Miscellaneous

- 30–Motorola walkie-talkies with both low and high power channels
- 1–Motorola walkie-talkie that runs on direct power
- 30–Motorola walkie-talkie batteries
- 22–Motorola fist microphones
- 8–Motorola single chargers
- 6–Motorola six slot chargers
- 2–Motorola to page interface cable
- 20–Sony MDR 7506 headphones
- 15–10' Headphones Extensions (1/4")

- 2–Furman HR2 heaphone remote box
- 6–Shure FP22 headphone amp
- 28–Rack mount Little Lites
- 6–Rack mount dual Little Lites
- 3–Ergotron VESA mount computer arm
- 5–3-space rack drawers
- 8–2-space rack drawers
- 2–32-space racks with surrounds
- 3–Dual Mac Mini tray
- 5–1 space rack shelf
- 4–Middle Atlantic single space sliding shelves
- 2–Digital Laser/Inclinometer for KARA (top/bottom)
- 2–Digital Laser/Inclinometer Reader for KARA
- 6–Digital Laser/Inclinometer for dV Dosc (top/bottom)
- 6–Digital Laser/Inclinometer reader for dV Dosc
- 4–Kensington locks for laptops
- 1–ICOM RC-20

Perishables

- 6–1/2" P-Touch cartridges black on white
- 2–1/4" P-Touch cartridges black on white
- 6–Rolls 2” Black Gaffers tape
- 4–Rolls 2” White Gaffers tape
- 6–Rolls 1” White Gaffers tape
- 6–Rolls friction tape
- 1–500 yards black trick line
- 4–cans KrylonUltra flat black paint
- 4–sesame locks
- 3–1000 count bag 8" black ZipTies
- 1–1000 count bag 14" heavy duty black ZipTies
- 10–rolls black 3M electric tape
- 2–rolls brown 3M electric tape
- 5–rolls red 3M electric tape
- 5–rolls orange 3M electric tape
- 5–rolls yellow 3M electric tape
- 6–rolls green 3M electric tape
- 5–rolls blue 3M electric tape
- 2–rolls purple 3M electric tape
- 12–cans Dust-Off
- 6–Little Late bulbs
- 10–Little Lites w/ bases

- 3–cases ‘AA’ batteries
- 100–‘AAA’ batteries
- 12–‘C’ Batteries
- 48–9V Batteries
- 24–PL123 lithium batteries
- 1–Big Green Box battery recycling Box
- 3–2 gig memory Kingston sticks (for use with SD7/SD10)
- 1–case 1" Transpore
- 1–case 1/4" Transpore
- 1–case 1" Blendderm
- 1–case 1" beige Elastikon (Elastoplast)
- 1–4x11 roll of Tegaderm
- 4–case skin prep
- 2–case adhesive remover
- 12–large black toupee clips
- 36–medium black toupee clips
- 36–small black toupee clips
- 12–large brown toupee clips
- 36–small brown toupee clips
- 12–large brown toupee clips
- 36–medium brown toupee clips
- 36–small brown toupee clips
- 12–large beige toupee clips
- 36–medium beige toupee clips
- 36–small beige toupee clips
- 24–Motorola plastic ear pieces
- 24–Motorola metal ear pieces
- 1–Hellerman tool
- 100–black Hellerman sleeves (H15)
- 100–pink Hellerman sleeves (H20)
- 100–pink Hellerman sleeves (H15)
- 1–roll male Velcro
- 1–roll 3M dual-lock fastener
- 2–Clearsonics A5-5 plexi panel
- 2–Clearsonics A5-3 plexi panel
- 2–Clearsonics A2-4 plexi panel
- 24–Clearsonics S2 24" high x 22" wide Sorber panel
- 2–ClearSonic IsoPac A “Complete Drum Iso Booth” package with lid
- 4–cases Auralex Sonolite 2'x2' black foam pieces
- 4–cases Auralex 2" Studiofoam pyramids 2’ x 2' charcoal foam pieces

- 6–Westone UMPro 20 clear In-Ear Monitors
- 4–Westone Epic replacement cable
- 6–small ratchet straps (3 w/hooks, 3 w/out)
- 1–NTI Minilyzer ML1
- 1–NTI Minirator MR1
- 1–Masque MTB-51B microphone test box
- 1–RF Explorer RF spectrum analyzer
- 1–100' 2-wire plenum wire
- 1–1000' roll 1/8" black anodized steel aircraft cable
- 200–1/8" Nico press sleeves
- 100–1/8" thimbles
- 50–1/8" Varilocks
- 1–250' roll 1/16" black anodized steel aircraft cable
- 100–1/16" Nico press sleeves
- 50–1/16" thimbles
- 40–1/4" x 1" shouldered eye-bolts
- 1–C7 cutters
- 1–Nico press tool for 1/8" Nico press
- 1–swagging tool for 1/16" Nico press

APPENDIX C: BRIAN RONAN PERMISSION LETTER

Tim Tracey

1111 Arden Street
Longwood, FL 32759
407-488-8827 (cell/text)
timjtracey@gmail.com

March 23, 2015

Brian Ronan
75 Church Hill Road
Carmel, NY 10512

Dear Brian,

I am completing my thesis as part of obtaining a Master of Arts in Music Degree from University of Central Florida. My thesis title is "The Forging Of Modern Broadway Sound Design Techniques In The Fires Of The Rock Musicals Of The Late 1960s And 1970s." I am grateful for your many contributions to this work in both our face-to-face meeting and follow-up emails. I am writing to obtain your permission to quote you and/or source you with the following statements and quotes (all originating from our face-to-face interview in NYC on April 3, 2014):

- While the sound design and production budget was dwarfed by *Spider-Man*'s special effects and other dazzling production elements, sound design, according to multiple-Tony-award-winning sound designer Brian Ronan, is typically among the more moderate line items in today's Broadway musical production budget.
- In fact, sound design is one of the tools that many of Broadway's present-day composers presume upon when creating new works.
- Sound design shares its level of contribution with the other design disciplines for the artistic success of a Broadway show. In larger Broadway theaters and touring theaters across America, who's size can often double Broadway houses, sound design bears additional responsibility for the show's financial success. Brian Ronan notes: "In larger venues some of the visual components of a show, its wigs, costumes, scenery, props, etc., become, literally, distant in remote seating areas. However, if the audience can hear the show in the far reaches of the theatre well they can still appreciate the show's story line and music. This allows seats to be sold in distant and visually impaired areas opening up a wider ticket base."
- As Brian Ronan indicated, trust with the theatergoer is compromised when there is a single failure in sound (a microphone or speaker goes dead, an actor's line is missed, an unplanned sound system startle such as feedback or other noise, etc.). As listening beings, "...we (hearing people) take [sound] for granted and become impatient when

it's less than nominal." More importantly, perhaps, Ronan notes that a sound failure has a negative affect on the actor as they often are not aware as to why it happened, when it will happen again, or how often it will happen. Ronan notes "[i]t's their resilience and spontaneity that helps them wok through technical failures and deliver the story to the audience."

- No doubt many of these acoustic based theaters produced masterworks of the American Musical theater genre, especially during Broadway's Golden Age, where electric sound reinforcement was virtually non-existent. Brian Ronan, winner of two Tony awards for his sound designs of both The Book of Morman and Beautiful: The Carol King Musical recounted the anecdotal remarks he heard from former theater ushers who remembered when theatergoers would purchase mezzanine or balcony seats over the far more expensive orchestra seats. If they liked the show, legend has it, they would stop by the box office and pick up a ticket for a future performance in the orchestra to hear all they missed while sitting in the balcony or mezzanine. Ronan notes this was standard practice for local theatergoers so that they might hear all they missed while sitting in the mezzanine or balcony in their first viewing.

- According to Brian Ronan, "...with special acknowledgment to Jack Mann [mentioned earlier as the first person to receive an official sound design credit for Carol Channing's 1961 Showgirl] and his pioneering efforts to bring electric sound reinforcement to some important musicals , e.g., *Company*, *Follies*, *A Little Night Music*, etc.,...today's designers are all direct descendants of Abe."

- Today's Broadway sound designers are direct beneficiaries of the groundbreaking work on Broadway in the late 1960s and early 70s, especially as pioneered by Abe Jacob. In addition to Jacob, Brian Ronan also credits the following: "In the 1980s, Otts Munderloh got producers to invest more in the sound departments' budgets, and then the British invasion of Martin Levan (*Cats*, *Phantom*) and Andrew Bruce (*Les Miz*, *Miss Saigon*) really ramped up what we expected in terms of quality."

- Today, according to Brian Ronan, Broadway sound designers use line-array speaker technology to achieve: "...wider areas of coverage from a single source, cutting down on what can often be the problematic use of multiple conventional speakers to cover a given section of the theatre...[which] has greatly improved intelligibility. Cutting down on multiple source amplification [and the negative effects of multiple sources arriving at different times to the theatergoer] has greatly improved intelligibility."

- From a sound design vs. architectural acoustics perspective, Brian Ronan notes of today's Broadway musical sound designs: "Most Broadway [sound] designers know how to use and have access to state of the art equipment. I believe that a production can decide what kind of sound it's going for and apply it. It's true that, in most cases, the tools to overcome the challenges that classic theatrical architecture presents to sound designers on contemporary musicals are available. There may be reasons that architecture wins–budget, speaker placement due to scenic requirements, sightline

considerations, etc. All factor in to what a designer can and can't do in trying to overcome architectural challenges. But given a decent scenario and adequate time, a good designer has the option to choose what quality or volume they're going for."

- See attached Appendix A: Your sound equipment list of 2014's Broadway production of *Last Ship.* I am including it in *full* by way of comparing and contrasting it with Abe Jacob's equipment list for the 1972 Broadway production of *Pippin.*

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own the copyright to and are the source of the above-described material.

If these arrangements meet with your approval, Brian, please sign this letter where indicated below and return it to me. Thank you.

Sincerely yours,

Timothy J. Tracey

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

BY: Brian Ronan

Brian Ronan

DATE: 3/30/15

Appendix A Brian Ronan's Permission Letter, March 23, 2015

Following is Brian Ronan's equipment list specified to support his sound design of the 2014 production of Sting's *Last Ship.*

Mixers

- 1–DigiCo SD7T Control Surface w/ Dual engines
- 1–DigiCo SD10-24 Control Surface
- 3–DigiCo SD Racks w/ opticore
- 3–100 Meter Opticore Cable
- 5–5 meter Opticore Cable
- 16–DigiCo A to D mic/line input cards
- 14–DigiCo D to A line output cards
- 4–DigiCo AES Output Card
- 1–DigiCo SD7 Script Dolly
- 4–Aviom A-16D Pro Net Distributor
- 20–Aviom A360 personal mixers
- 20–A360 Aviom Stand mounts
- 1–ATI 8MX2 8 Channel Rack Mount Mixer
- 4–Fostex RM-2 Stereo Rack Monitor
- 3–Sonifex RB-DA6 Headphone Distribution

Computers

- 2–Mac Mini w/OSX 10.9, i7 2.6ghz, 16gb Ram, 500gb Solid State Hard Drive
- 2–Mac Mini w/ Windows
- 1–Windows Machine for Sennheiser Software
- 1–Apple iPad 2 16gb
- 2–DigiCo MADI USB 2.0 Interface
- 2–RME MADI Bridge
- 3–Rack Mount 24 Port Gigabit Switch
- 2–Rack Mount 16 Port Gigabit Switch
- 6–8 Port Gigabit Switch
- 1–Asus RT-N664 Wireless Router
- 2–Gefen CAT5 USB Extender
- 3–Apple Displayport to VGA Adaptors
- 4–Apple USB to Ethernet Adaptors
- 6–USB Panel Mounts
- 4–MIDI Panel Mounts
- 3–DVI Panel Mounts
- 5–6-port USB Hubs
- 3–Dell 24" Monitors
- 6–19" Pelco
- 2–EVGA UVPlus+ USB to DVI Adaptor
- 2–Gefen EXT-DVI-24IDL

- 4–VGA A/B Switch
- 2–Geffen DVI Detectives
- 4–Logitech Marble Mouse for Qlab/LA-8 (compatible w/KVM Switcher)
- 4–Standard Keyboards for Qlab/LA-8 (compatible w/KVM Switcher)
- 2–Kensington Pro Trackballs
- 2–Apple Thin Keyboards
- 2–Long view KVM Extenders/Receivers
- 1–Startech 4-Port Cat5 VGA Video Splitter/Distribution (for RF View)
- 4–Startech STUTPRCL Long Range Receiver (for RF View)
- 1–L'Acoustics Soundvision prediction software license
- 1–Microsoft Office
- 1–Smaart software v.7
- 2–QLab ProMidi Sound Effect Software v.3
- 1–Roland Quad Capture for use with SMAART 7
- 4–Edirol USB-ONE MIDI to USB Interface
- 4–MIDI Solutions Quadra Merge MIDI Mergers
- 4–MIDI Solutions Quadra Thru
- 2–MIDI Power Supplies
- 2–MIDI Soultions Dual Footswitch Controller
- 2–2-Button Go/Stop Box (For use with Dual Footswitch Controller)
- 4–6' DVI Cable
- 4–12' DVI Cable
- 4–6' VGA Cable
- 4–12' VGA Cable
- 8–APC 1500 Rack Mount UPS

Production

- 1–HP Color Laserjet printer w/ Network Hardware
- 1–24' DVI Monitor
- 1–27" Apple Cinema Display (Displayport or Thunderbolt)
- 2–Apple full size keyboard THIN
- 1–Kensington K64325 Expert Mouse Pro
- 1–Logitech Trackball
- 1–8 Port Gigabit Switch
- 2–Sennheiser SKP500-G2 Transmitter/Receivers
- 1–Pop Phase Checker
- 6–Motorola Walkies w/6 bay charger
- 6–Motorola Walkies
- 6–Single Bay Chargers
- 6–Motorola Fist Mic
- 10–Clear Com RM 440
- 6–CC-26 Light Weight Headsets
- 10–Sennheiser HMD-46 Headset
- 2–Sennheiser SK5212 Transmitters for wardrobe/hair

- 1–Asus RT-N664 Wireless Router
- 1–Tripplite 3' plugging strip Sound Tech table
- 30–Sennheiser MKE-2 to SK50 Beige Microphones
- 12 Sennheiser MKE-2 to SK50 black microphones (rental stock)

Wireless

- 20–Sennheiser 3532 Receivers
- 2–SKM 5000 (combo)
- 40–Sennheiser SK5212 Transmitters
- 4–Masque PWS Ground Plane Antennas
- 2–Spudnik Antennas for use with Wireless Telex
- 1–Monitoring System for 50 channels of RF
- 3–Masque RS96-MM Remote Stations
- 1–Startek 4-Port Cat5 VGA Video Splitter/Distribution
- 4–Startech STUTPRCL Long Range Receivers
- 1–Keyboard and mouse for RF extension
- 4–Shure PSM 1000 Rx/TX IEM
- 6–Sennheiser MKE-2 to SK50 beige microphones
- 6–Sennheiser MKE-2 to SK50 black microphones
- 30–Sennheiser MKE-1 to SK50 beige microphones (Paintable)
- 12–Sennheiser MKE-1 to SK50 black microphones
- 4–DPA 4061 to SK50 brown microphones
- 2–DPA 4061 to SK50 beige microphones
- 6–Countryman B-3 to SK50 beige microphones
- 8–3' Female XLR to LEMO
- 12–Spare transmit antennas
- 6–Sennheiser MKE-2 black inlet caps
- 12–Rubber antenna tips
- 25–Beige Ratpack X-Mit Belts
- 2–100' RG-213
- 2–75' RG-213
- 6–50' RG-213
- 8–25' RG-213
- 96–Powerex AA rechargeable batteries
- 8–Powerex chargers

Playback

- 2–Tascam SS-CDR2000 Solid State Recordera

Processing

- 1–Klark Teknik DN6051 Precision Mic
- 2–TC Electroncs S-6000 w/ remote
- 2–TC Electonic Remore CPU for S-6000
- 2–Grace m802 preamps

- 2–Grace m802 remote

Microphones

- 3–AKG 414 w/ windscreens
- 10–Neumann KM 184
- 3–Neumann KM 185
- 4–Neumann U87
- 4–Windscreens for Neumann U87
- 4–Pop Filters for Neumann U87
- 3–Neumann U89
- 8–Sennheiser MKH40
- 7–Sennheiser MKH800
- 3–Royer R-121
- 4–Shure SM58
- 8–Shure SM57
- 4–Shure Beta 56a
- 3–Shure Beta 52a
- 4–Shure 565SD
- 3–Shure SM91 w/inline preamp
- 2–Shure SM98 w/inline preamp
- 6–Shure 404 PTT mics w/ hanging clip
- 3–Crown PCC 160
- 2–Crown GLM 100
- 8–Avalon DI's
- 6–Radial JDI MK3
- 2–Radial JD6 6Ch DI Boxes
- 1–Opus DI-1000
- 6–Mic Mute On/Off foot switches w/ 48v and LED
- 2–Roland RT-10K Trigger
- 2–Alesis DM-10 Trigger Interface
- 2–DPA 4021
- 8–DPA 4061
- 8–DPA MHS6001 Microphone Holder
- 8–DPA DAD6001 Adapter

Microphone Accessories

- 35–Atlas MS12C w/ bases
- 20-–Atlas TS-8 Banquet Stands w/large bases
- 20-AKG KM238 side clamps
- 8–Atlas MS25E base with long straight and transducer
- 4–13" goosenecks
- 6–6" goosenecks
- 35–telescoping booms
- 6–Atlas AD5 coupling

- 6–Atlas 6" nipple
- 24–Atlas AD-11 female flange
- 24–Atlas AD-12 male flange
- 10–Atlas AD-14 90 degree nipple
- 4–BC-1 clamp
- 15–LP claws
- 20–K&M KM 240-5
- 12–Ultimate clamps
- 8–Mega clamps
- 6–Tall tripod mic stands (1247)
- 6–Medium tripod mic stands (1283)
- 4–Atlas TM1 stereo bar
- 50–Atlas L0-2B lock-on accessory
- 1–Kelly Concepts-SHU Flatz isolation system
- 6–KM216 female to male thread adaptor
- 6–KM216 5/8" to 3/8" thread adaptor

Loudspeakers

- 2–Meyer UPQ-1P w/hardware
- 8–Meyer UPM1-P w/ hanging hardware
- 6–Meyer UPA1-P w/ hanging hardware
- 2–Meyer UPJ-1P w/ hanging hardware
- 18–Meyer UPjr w/ hanging hardware
- 8–Meyer M1D's
- 10–Meyer MM-4 w/ hanging hardware
- 4–MeyerUM-1 horn w/ hanging hardware
- 20–L'Acoustics Kara
- 38–L'Acoustics dvDosc
- 6–L'Acoustics SB18 Subs
- 50–d&b E3 w/ hanging hardware
- 10–d&b E5 w/ hanging hardware
- 2–d&b B-2 subwoofers
- 40–EAW JF80 w/ hanging hardware
- 6–Anchor AN1000 w/ hanging hardware
- 8–Genelec 8030 w/ mic stand adapter
- 4–Anchor AN-Mini portable sound system w/batteries and charger
- 24–Galaxy HotSpots

Amplifiers/Processors

- 2–d&b D12
- 17–d&b D6
- 16–L'Acoustics LA-8
- 12–Lab Gruppen FP2400 4 Channel amp
- 4–Meyer M1a processor

- 2–Meyer MM4-CEU processor
- 3–Meyer Galileo processors

Communication

- 4–ClearCom MS440 4-Channel Main Station
- 8–ClearCom RM440 4-Channel Remote Station
- 10–ClearCom RS 502 Stereo BeltPack w/6pin Y
- 4–RS 502 Stereo Beltpack w/6 Pin Y with program
- 10–RS 501 BP
- 2–Masque Spot Com box
- 4–Headset Mic Mute boxes with lighted switch
- 6–Clearcom RM-702 dual channel rack mount unit
- 6–Clearcom KB-702 dual channel speaker station w/enclosure
- 4–Beyer DT108 headsets
- 30–Sennheiser HMD 460 double-muff headsets
- 16–CC-26 lightweight headsets
- 12–HS-6 w/ hanging clips
- 3–Telex BTR 825 dual channel wireless system w/four remotes (12 total)
- 1–Antenna distribution system for Telex BTR 825 system w/dual RX/TX distribution
- 4–Antennas for Telex BTR825 distribution
- 2–Clearcom IF4W4 4-wire interface
- 8–4-wire terminal block to Telex RG 4-wire
- 6–15' headset extension cables
- 8–Clearcom terminators

Video Distribution

- 1–Vadio WallView HD-20 Cat5 w/camera control system
- 1–Panasonic AG-DVX100B
- 1–.7x wide angle convertor for AG-DVX100B
- 10–Panasonic WV-CP504
- 10–Vitek VTC-IRE30/2810
- 2–Sony EVID90 PTZ cameras
- 10–Panasonic 2.9-6mm lens for CP-504
- 4–Panasonic 8x zoom lens for CP-504
- 10–IR lens covers for Panasonic lenses
- 16–Bogen 3028 camera mounts
- 5–Infrared remote repeaters over Cat5
- 3–USB to RS-232 adaptors
- 3–RS-232 over Cat5 extenders
- 3–RS-232 to male VISCA mini-DIN 8-pin
- 10–Advanced LED technology Clarius short range LED illuminator
- 3–Vitek VT-IR2/110 infrared illuminator 200' 65 degree (7646)
- 1–BlackMagic mini convertor SDI to analog

- 3–BlackMagic mini convertor analog to SDI
- 1–Kramer VM-20HD 1X10 dual-link HD-SDI distribution system
- 2–Kramer VM-22HD 1X2 dual-link HD-SDI distribution system
- 10–Kramer VM1010
- 6–Kramer PIP-4 4 composite video picture-in-picture inserter
- 4–Kramer VM-42 composite video switcher
- 6–Kramer 4x1 VB video switcher
- 2–Kramer VS-801xlm composite video switcher
- 2–Kramer/Ocean Matrix OMX-9032 16x1 switcher
- 4–Video hum bucker
- 10–ETS SDS887 video distribution hub
- 30–Foresight TTP414V 4-channel video transceiver RJ45 Balun
- 14–Foresight TPP016-RJ45 16 Port Transceiver Hub
- 8–9" b/w monitors with hanging hardware
- 8–19" Pelco monitors
- 4–19" Pelco rack-mountable monitors
- 6–Marshall Triple 5" LCD Monitors
- 6–Dual mount 8" flat panel monitors
- 20–Delvcam Pro56 monitors
- 20–Delvcam Delv-SM swivel mount adapter
- 10–Panasonic PLCD8C 8" LCD monitors
- 5–Marshall V-LCD17H-2HD 17" Rackmount LCD Monitor with Dual HD-SDI
- 2–Marshall V-MD241 MD-HDSDIx2 dual link HD-SDI 24" monitors
- 10–K&M Vesa 75/ Vessa 100 microphone stand mount for small LCD
- 2–Ergotron LX desk LCD arm w/short poll
- 2–Ergotron LX desk LCD arm w/tall poll
- 2–Ergotron LX dual side-by-side arm
- 4–Chief universal monitor wall mount
- 2–Chief height-adjustable static dual arm monitor desk mount
- 2–Low-latency flat panel monitor for balcony rail
- 2–20" CRT b/w monitors w/hanging hardware
- 1–DMX blackout circuit
- 1–Delvcam 7" LCD field pack with battery and charger
- TBD–dual link SDI cables

Paging

- 1–TOA M912MK2 mixer/amp
- 3–L-01 line inputs
- 5–M-01 mic input
- 10–TOA CS-64 70v dressing room speakers w/volume control

Microphone Cable

- 15–100' XLR

- 25–50'XLR
- 40–25' XLR
- 40–15' XLR
- 40–10' XLR
- 40–5' XLR
- 20–3' XLR
- 20–2' XLR
- 20–1'XLR

AES/EBU Digital Cable

- 10–>5' AES XLR
- 10–5' AES XLR
- 10–10' AES XLR
- 10–15' AES XLR

Siamese Cable

- 10–200'
- 10–150'
- 10–100'
- 15–50'
- 15–25'
- 15–15'
- 15–10'

CAT-5 Cable

- 15–Dual ethercon to ethernet panel mount
- 15–250'
- 8–200'
- 28–150'
- 25–100'
- 45–50'
- 20–25'

BNC Video Cable

- 20–1' RG-59
- 12–2' RG-59
- 12–5' RG-59
- 20–10' RG-59
- 12–25' RG-59
- 20–50' RG-59
- 20–100' RG-59
- 15–150' RG-59
- 4–250' RG-59
- 10–BNC terminators

AC-Edison Electric Cable

- 4–250'
- 15–150'
- 15–100'
- 15–50'
- 15–25'
- 10–10'
- 6–Triplights (8 edisons/1 rack space)
- 15–Waber strips
- 6–25' edison-quad
- 5–Furman PLUGLOCK

Edison to Quad Electric Cable

- 4–50'
- 4–25'

AC Twist 5-wire, 30 amp

- 4–100'
- 4–150'
- 4–10'
- 8–25'
- 6–5'
- 5–5-wire to powercon
- 4–5-wire to powercon hanging distribution
- 5–5-wire to edison panels
- 3–5-wire to PD3 panels
- 6–5-wire to L5-30 panels (LA-8s)

Power Distribution

- 1–Complete Motion Labs PD system
- 1–PD 60 Powercon 18 L21-30 (6222)
- 1–100' feeder
- 1–50' feeder
- 1–25' feeder
- 1–10' feeder
- 1–set Cam-Lok tails
- 2–Cam-Lok F-F turnarounds
- 2–Cam-Lok M-M turnarounds

Power Conditioning

- 4–250'
- 4–200'
- 16–150'
- 20–100'
- 30–50'
- 25–25'

- 20–15'
- 20–10'
- 10–<5'
- 50–powercon barrels
- 4–powercon "Y"
- 4–Female edison to powercon grey
- 40– Powercon to 4 edison distros
- 6–1U rack-mount powercon distros, 1 blue front/8 white front
- 4–1U rack-mount powercon distros 1 blue front/8 grey rear
- 30–1U rack-mount powercon distros 1 blue front/edison rear

Custom

- 8–5 channel, 6-way XLR rack mount panels

Adaptors

- 12–1/4" to 1/4" Whirlwind instrument cable
- 10–6' 1/4" to 1/8 " headphone cables
- 10–1/4" male to 1/8 " female headphone adapters
- 10–6' 1/4" headphone extension cables
- 10–female XLR to MIDI
- 10–male XLR to MIDI
- 25–RCA male to female BNC
- 25–RCA female to female BNC
- 25–BNC "T"
- 10–Nuetrik NL4 to bare wire
- 15–XLR female to 2 XLR male "Y"
- 15–XLR-M to 2 XLR-F "Y"
- 20–Male TRS 1/4" to male XLR pin 2+
- 10–male-TRS 1/4" to female Pin 2+
- 6–speaker twist parallel "Y"
- 3–complete set patch cables
- 10–1/4" male TS to XLR male pin 2+
- 10–1/4" male TS to XLR female pin 2+
- 5–RCA male to female XLR pin 2+
- 5–RCA male to male XLR pin 2+
- 13–NL4 A/B to 2 NL4 "Y"
- 30–XLR female to XLR female turnaround
- 30–XLR male to XLR male turnaround
- 10–1/8" to stereo male XLR
- 35–Ethercon barrels
- 10–XLR ground lifts
- 10–XLR phase reverser
- 10–IL-19 ground isolator
- 10–BNC female to male right angle adaptors

- 30–BNC FF Couplers
- 10–2' NL4 to banana plug

Rigging Hardware

- 2–8' section 1' x 1' spigoted TomKat truss
- 3–Light Source 12" Mega Truss Pick
- TBD–threaded rod
- 12–rated truss bolts
- 2–L'acoustics M-Bump
- 2–L'acoustics M-Bars
- 5–L'acoustics dv Bump 2
- 12–L'Acoustics dV shackles
- 35–safeties
- 12–rigid chesboro
- 8–swivel chesboro
- 4–8' x 1.5" pipe
- 2–10' x 1.5" pipe
- 8–pipe flanges
- 12–safer sidearms
- 4–2' pipes for safer sidearms
- 4–3' pipes for safer sidearms
- 4–4' pipes for safer sidearms
- 8–2 1/2' x 3/4" steel stingers with shackles
- 8–eye bolts with nylocks
- 4–3/4" or 7/8" pear rings
- 10–Crosby 5/8" shackles
- 40–Mega-Clamp aluminum
- 29– Steel Mega-Claws
- 10–3' Steelflex span sets
- 10–6' Steelflex span sets
- 10–10' Steelflex span sets
- 10–5' steel sling (eye-to-eye)
- 10–10' steel sling (eye-to-eye)

Miscellaneous

- 30–Motorola walkie-talkies with both low and high power channels
- 1–Motorola walkie-talkie that runs on direct power
- 30–Motorola walkie-talkie batteries
- 22–Motorola fist microphones
- 8–Motorola single chargers
- 6–Motorola six slot chargers
- 2–Motorola to page interface cable
- 20–Sony MDR 7506 headphones
- 15–10' Headphones Extensions (1/4")
- 2–Furman HR2 heaphone remote box
- 6–Shure FP22 headphone amp
- 28–Rack mount Little Lites

- 6–Rack mount dual Little Lites
- 3–Ergotron VESA mount computer arm
- 5–3-space rack drawers
- 8–2-space rack drawers
- 2–32-space racks with surrounds
- 3–Dual Mac Mini tray
- 5–1 space rack shelf
- 4–Middle Atlantic single space sliding shelves
- 2–Digital Laser/Inclinometer for KARA (top/bottom)
- 2–Digital Laser/Inclinometer Reader for KARA
- 6–Digital Laser/Inclinometer for dV Dosc (top/bottom)
- 6–Digital Laser/Inclinometer reader for dV Dosc
- 4–Kensington locks for laptops
- 1–ICOM RC-20

Perishables

- 6–1/2" P-Touch cartridges black on white
- 2–1/4" P-Touch cartridges black on white
- 6–Rolls 2" Black Gaffers tape
- 4–Rolls 2" White Gaffers tape
- 6–Rolls 1" White Gaffers tape
- 6–Rolls friction tape
- 1–500 yards Balck trick line
- 4–cans KrylonUltra flat black paint
- 4–sesame locks
- 3–1000 count bag 8" black ZipTies
- 1–1000 count bag 14" heavy duty black ZipTies
- 10–rolls black 3M electric tape
- 2–rolls brown 3M electric tape
- 5–rolls red 3M electric tape
- 5–rolls orange 3M electric tape
- 5–rolls yellow 3M electric tape
- 6–rolls green 3M electric tape
- 5–rolls blue 3M electric tape
- 2–rolls purple 3M electric tape
- 12–cans Dust-Off
- 6–Little Late bulbs
- 10–Little Lites w/ bases
- 3–cases 'AA' batteries
- 100–'AAA' batteries
- 12–'C' Batteries
- 48–9V Batteries
- 24–PL123 lithium batteries
- 1–Big Green Box battery recycling Box

- 3–2 gig memory Kingston sticks (for use with SD7/SD10)
- 1–case 1" Transpore
- 1–case 1/4" Transpore
- 1–case 1" Blendderm
- 1–case 1" beige Elastikon (Elastoplast)
- 1–4x11 roll of Tegaderm
- 4–case skin prep
- 2–case adhesive remover
- 12–large black toupee clips
- 36–medium black toupee clips
- 36–small black toupee clips
- 12–large brown toupee clips
- 36–small brown toupee clips
- 12–large brown toupee clips
- 36–medium brown toupee clips
- 36–small brown toupee clips
- 12–large beige toupee clips
- 36–medium beige toupee clips
- 36–small beige toupee clips
- 24–Motorola plastic ear pieces
- 24–Motorola metal ear pieces
- 1–Hellerman tool
- 100–black Hellerman sleeves (H15)
- 100–pink Hellerman sleeves (H20)
- 100–pink Hellerman sleeves (H15)
- 1–roll male Velcro
- 1–roll 3M dual-lock fastener
- 2–Clearsonics A5-5 plexi panel
- 2–Clearsonics A5-3 plexi panel
- 2–Clearsonics A2-4 plexi panel
- 24–Clearsonics S2 24" high x 22" wide Sorber panel
- 2–ClearSonic IsoPac A "Complete Drum Iso Booth" package with lid
- 4–cases Auralex Sonolite 2'x2' black foam pieces
- 4–cases Auralex 2" Studiofoam pyramids 2' x 2' charcoal foam pieces
- 6–Westone UMPro 20 clear In-Ear Monitors
- 4–Westone Epic replacement cable
- 6–6 small ratchet straps (3 w/hooks, 3 w/out)
- 1–NTI Minilyzer ML1
- 1–NTI Minirator MR1
- 1–Masque MTB-51B microphone test box
- 1–RF Explorer RF spectrum analyzer
- 1–100' 2-wire plenum wire
- 1–1000' roll 1/8" black anodized steel aircraft cable
- 200–1/8" Nico press sleeves

- 100–1/8" thimbles
- 50–1/8" Varilocks
- 1–250' roll 1/16" black anodized steel aircraft cable
- 100–1/16" Nico press sleeves
- 50–1/16" thimbles
- 40–1/4" x 1" shouldered eye-bolts
- 1–C7 cutters
- 1–Nico press tool for 1/8" Nico press
- 1–swagging tool for 1/16" Nico press

APPENDIX D: DAVID CHASE PERMISSION LETTER

Tim Tracey

1111 Arden Street
Longwood, FL 32759
407-488-8827 (cell/text)
timjtracey@gmail.com

March 23, 2015

David Chase.
536 W. 111th Street
Apartment #67
New York, NY 10025

Dear David,

I am completing my thesis as part of obtaining a Master of Arts in Music degree from University of Central Florida. My thesis title is "The Forging Of Modern Broadway Sound Design Techniques In The Fires Of The Rock Musicals Of The Late 1960s And 1970s." I am grateful for not only the time spent in our personal interview, but your enormous contribution to the Musical Theater genre for the past twenty years. I am writing to obtain your permission to source you (footnote) with the following statements, all originating from our face-to-face conversation we had in NYC April 3, 2014:

- According to the Broadway League, forty theaters operate on Broadway today. All but three–the Gershwin Theatre (opened in 1972), the Minskoff Theatre (1973), and the Marquis Theatre (1986)–were designed and built to utilize architectural acoustics for the reinforcement of voice and music in theatrical productions.
- Sound designers also help compensate for the ever shrinking Broadway choruses and orchestras or perhaps, it could be argued, today's sound design techniques allow for smaller choruses and orchestras. Though carefully staged and directed to appear as a single ensemble, Broadway choruses were historically a combination of separate, but equal talent–singers and dancers. Today's casting requires a single performer to do both. Thus, singing and vocal projection suffer. Consequently, stage directors and musical directors rely more heavily on sound reinforcement technology to make up the gap.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own the copyright to and are the source of the above-described material.

If these arrangements meet with your approval, David, please sign this letter where indicated below and return it to me. Thank you.

Sincerely yours,

Timothy J. Tracey

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

BY: _____
David Chase

DATE: 3/27/15

APPENDIX E: JOHN MEYER PERMISSION LETTER

Tim Tracey

1111 Arden Street
Longwood, FL 32759
407-488-8827 (cell/text)
timjtracey@gmail.com

March 23, 2015

John Meyer, Chief Executive Officer
Meyer Sound Laboratories, Inc.
2832 San Pablo Avenue
Berkeley, CA 94702

Dear John,

I am completing my thesis as part of obtaining a Master of Arts in Music Degree from University of Central Florida. My thesis title is "The Forging Of Modern Broadway Sound Design Techniques In The Fires Of The Rock Musicals Of The Late 1960s And 1970s." I am grateful for yours and Meyer Sound's many contributions to the advancement of this design discipline within the theatrical community. I am writing to obtain your permission to quote you and/or source you with the following statements and quotes (all originating from a face-to-face conversation we had in Berkeley May, 2010):

- John Meyer is the founder and president of Meyer Sound Laboratories, Inc., a preeminent loudspeaker manufacturer whose products are found in virtually every professional theatrical installation throughout the world. Meyer, who holds twenty-three loudspeaker design patents, once remarked that: "Sound and music are the most powerful forces exerted on the human mind." A student and scientist of sound, Meyer made the empirical observation: "Everyone thinks that visual stimuli are powerful. How often, over the course of a lifetime, do you watch your favorite video source (movie, television show, etc.)? By comparison, how often do you listen to your favorite song or musical recording?"

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own the copyright to and are the source of the above-described material.

If these arrangements meet with your approval, John, please sign this letter where indicated below and return it to me. Thank you.

Sincerely yours,

Timothy J. Tracey

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

BY: _____
John Meyer

DATE: 3-27-15

APPENDIX F: MIKE TRACEY PERMISSION LETTER

Tim Tracey

1111 Arden Street
Longwood, FL 32759
407-488-8827 (cell/text)
timjtracey@gmail.com

March 28, 2015

Mr. Michael Tracey
522 W. 50th Street, Apt. #A2
New York, NY 10019

Dear Mike,

I am completing my thesis as part of obtaining a Master of Arts in Music Degree from University of Central Florida. My thesis title is "The Forging Of Modern Broadway Sound Design Techniques Amid The Fires Of The Rock Musicals In The Late 1960s And 1970s." Thank you for all your help and contribution to my research efforts. I am writing to obtain your permission to quote you and/or source you with the following statements and quotes , all originating from our phone conversation February 15, 2015:

- According to *If/Then*'s assistant sound designer, Mike Tracey, the distance from the farthest downstage point to the farthest seat in the Richard Rodgers is eighty feet.
- To bring this into a "real-world" scenario, Tracey stated that today's Broadway sound designers build sound systems to provide nearly even sound pressure, tolerating variances no greater than +/- 3 dB across a theater's entire seating area. "Anything beyond those limits," Tracey said, "will result in sound that is too loud in some seats and unintelligible in others."
- Tracey estimated the cubic volume of the Richard Rodgers Theatre to be ~165,000 cubic feet.

The requested permission extends to any future revisions and editions of my thesis, including non-exclusive world rights in all languages. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own the copyright to and are the source of the above-described material.

If these arrangements meet with your approval, Mike, please sign this letter where indicated below and return it to me. Thank you.

Sincerely yours,

Timothy J. Tracey

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

BY: _____
Michael Tracey

DATE: 03/30/15

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