Leo Beranek's Contributions to the Field of Transportation Noise

Carl E. Hanson

Email:
carlh01730@alum.mit.edu

Postal:
Co-Founder (Retired)
Harris Miller Miller & Hanson Inc.
77 South Bedford Street
Burlington, MA 01803

The field of aviation noise has evolved, but the seminal work conducted by Leo Beranek and his colleagues provided the foundation for the current state-of-the-art.

Transportation Noise

Noise from transportation vehicles and facilities has long been the dominant source of community annoyance. In recent years, as air traffic has increased the aviation industry has been the focus of noise control activity. Airport operators saw the need to pay attention to noise starting in the early 1950's when legal action against airplane noise was threatened by neighbors of Newark Airport. The increasing traffic of propeller aircraft resulted in very high annoyance in the community. A few years later, the impending introduction of jet-propelled airliners at Idlewild Airport in New York (now JFK) was expected to cause even more noise complaints. The Port of New York Authority turned to Leo Beranek and his staff at Bolt Beranek and Newman (BBN) for help. The resulting project was seminal to the future of aviation noise control, as we shall see later. But the New York airport project was not the start of Leo Beranek's role in reducing noise associated with airplanes. It started during the early days of World War II.

Quieting Military Aircraft (1941 – 1947)

In 1940, Crufts Laboratory at Harvard and Radiation Laboratory at Massachusetts Institute of Technology were tasked with developing ways to reduce noise in bombers for the U.S. Army Air Corps. Leo Beranek at Harvard University's Crufts Laboratory was placed in charge of the experimental work as director of "Research in Sound Control." He organized laboratory space, assembled a staff, and acquired instrumentation. His staff was impressive – a veritable "Who's Who" in physics and acoustics, including Francis Wiener, Robert Wallace, Rudolph Nichols, Harold Ericson, Wayne Rudmose, Robert Newman, and Sparky Ennis. An immediate task was to develop a light-weight material to absorb the intense sound inside airplanes from their propeller-engine systems. The excessive noise in the cockpit caused interference with crew communications as well as pilot fatigue and, in some cases, failure of combat missions.

Leo's Ph.D. research topic on the acoustic impedance of materials proved to be ideal preparation for this task. Up until that time, typical materials for absorbing sound were fairly heavy, including wood shavings, cornstalks, and kapok, all of

- American Academy of Arts and Sciences (2000): Scholar-Patriot, Distinguished Service Award
- Honorary Member, American Institute of Architects (2000)
- Completion of Dai-ichi Seimei Concert Hall (2001)
- The National Medal of Science, conferred by the President in a White House ceremony (Nov 2003): *"for his leadership dedication and contributions to the art and science of acoustics, for co-founding one of the world's foremost acoustical research and consulting firms, and for sustained contributions to scientific societies and civic organizations"*
- Second edition: *Concert Halls and Opera Houses: Music Acoustics and Architecture* (2004)

2000 2001 2002 2003 2004

which had the additional disadvantage of being flammable. A major manufacturer, Owens-Corning Fiberglass, produced a heat insulation material of thick glass fibers, somewhat effective but also dense and heavy. Leo developed a description of an ideal material. Because sound absorption depends on friction of air particles on surfaces, the more surface area exposed to air in a given volume, the more absorption will occur. As the diameter of the fibers decreases, the volume (and therefore the weight) decreases more rapidly than the surface area. Therefore the ideal material should be made up of very fine fibers packed into a small volume. Leo asked Owens Corning if they could fabricate fiberglass with very small diameter in a blanket form. They said they would try and, indeed, produced a sample in a few weeks. The resulting light-weight acoustical blanket was called "Fiberglass AA." It is still used today in quieting the interior of aircraft.

The staff under Leo's direction at Crufts measured sound levels and spectra in 18 types of military aircraft under various operating conditions typically encountered during a mission. Data were collected from representative aircraft of the period, including B-17, B-24, B-25, C-47, A-20, PBY-1, DC-3 among others. In general, propeller and engine noise dominated the low frequencies, while air leaks around bomb bays, turrets, and escape hatches dominated the higher frequencies. Analysis of the data resulted in recommendations for reduction in interior sound levels with treatments for existing aircraft and for future designs. Guidelines for implementing these recommendations were documented in a restricted publication, "Principles of Sound Control in Airplanes" (Beranek et al., 1944). Leo and his staff can be credited with developing many of the same principles that are applied to modern aircraft (**Figure 1**).

An inescapable conclusion from the research, however, was that the cockpit area was not amenable to being treated with sound-absorbing material. Windshield, side and overhead windows, instruments, and controls were packed into the space, leaving no room for "fuzz surfaces. But radiophone communication among crew members was nearly impossible due to the high noise levels. Speech interference testing showed that less than 60 percent

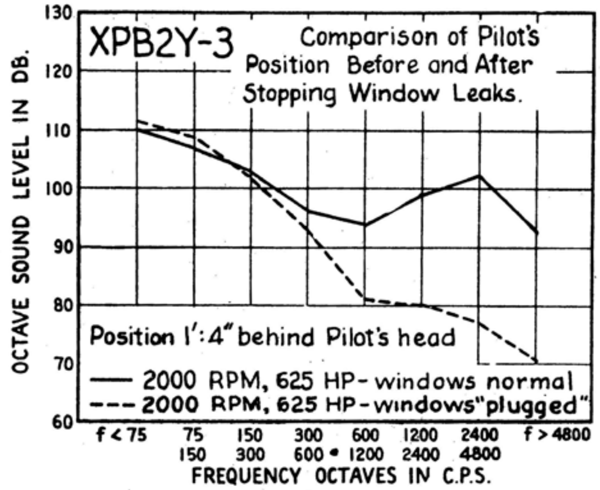

FIG. 7. Effect of eliminating wind leaks around windows on the noise inside the cabin of a XPB2Y-3.

Figure 1. *Example of noise control test on military aircraft.*

of words could be understood using the existing earphones under simulated military flight conditions. Consequently, another direction needed to be taken to reduce the deleterious effect of noise on communication. Once again, Leo's background came into play. This time it was his long-time interest in radio technology. Microphones and headsets needed to be improved. Studies in speech information needed to be conducted. The research was split up between Leo's laboratory and Harvard's Psycho-Acoustics Laboratory under the direction of S. S. Stevens. The result of the combined effort was an improved headset that met communication requirements and was designed to fit all helmets. It was adopted as the standard for all the aviation services in 1942 and used throughout WW II.

Jet Engine Test Cells/NACA Wind Tunnel (1950)

With jet propulsion considered to be a key component of the future of aviation, facilities for testing engines were needed in the early 1950s. The noise from testing outdoors in the open was not acceptable to neighboring communities. Early unmuffled test cells were little better. Leo and his staff at BBN developed a successful business with quieting treatments for these noisy facilities (Watters et al., 1955).

A larger challenge came in 1950, when Leo was called on by the National Advisory Committee for Aeronautics (NACA)

• Second edition: *Noise and Vibration Control Engineering* (co-authored with István L. Vér, 2006)

• Autobiography: *Riding the Waves - A Life in Sound, Science, and Industry* (2008)

• Acoustical Society of Argentina, Certificate of Appreciation (2009): *"certificate personally signed by over 100 members of the Society"*

2005 2006 2007 2008 2009

to control the excessive noise emitted by the supersonic wind tunnel used for testing jet engines at Lewis Flight Propulsion Laboratory in Cleveland. Leo and his BBN colleagues measured the noise levels and determined the necessary noise reduction criteria. Scale model testing was used to design the resulting muffler which, in addition to providing the noise reduction, was required to maintain free flow through the wind tunnel. Leo based part of the muffler design for mid-range frequencies on principles he discovered in a research project at MIT for reducing noise in ventilation ducts. The treatment for controlling low frequencies was a series of Helmholtz resonators. Higher frequencies were controlled by the standard treatments used in test cells. Scale model tests were successful and the resulting full scale muffler (220 feet long, 33 feet wide, 46 feet high) was built. When the supersonic wind tunnel came back on line within a year, it was so quiet that people were unaware of its operation.

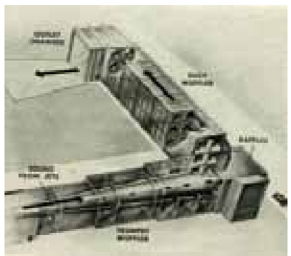

Figure 2. *World's largest muffler, NASA, Cleveland, 1951. (from Riding the Waves)*

The project's success was heralded in a feature article about the "world's largest muffler" in the June 11, 1951 issue of Life magazine. Many of the principles developed by Leo in this landmark NACA project in 1950 have been used in quieting testing facilities throughout the world. (Beranek et al., 1955) (**Figure 2**).

Commercial Aircraft Treatments (1954-1957)

From experience gained by treatment of military aircraft during the war, Leo applied similar noise reduction principles on a commercial airplane in 1954. The Convair-Liner 340, a two-engine propeller-driven, 44-seat passenger airplane suffered from unacceptable noise levels in the passenger compartment. Airlines were not interested in buying it unless the noise could be reduced. Excessive low-frequency noise resulted in passenger discomfort and high-frequency noise interfered with speech communication. Leo led a BBN effort to diagnose the sources of noise and to apply treatments to bring noise down to acceptable levels. Treatments included design of innovative engine mufflers, application of damping and acoustical blankets (Dow Corning's Fiberglass Type AA) to the inside of the fuselage, and installation of double windows. The treatments resulted in successful noise reduction even better than expected. The airplane was a sales success after that, making Convair a happy client. Once again, Leo was at the forefront of noise control in the aviation industry, establishing methodology to be used in future designs of aircraft.

Figure 3. *Leo Beranek and Laymon Miller with helicopter crew, 1960. (from Riding the Waves)*

But another type of aircraft was in need of noise control – the helicopter. Little effort had been expended in quieting military helicopters during the war. Converting those helicopters to commercial use required reduction of noise in the passenger compartment. Leo and Laymon Miller from the BBN staff conducted an extensive noise measurement program on a military helicopter to diagnose the sources and transmission paths of noise. Applying many of the same principles used in the Convair project, Leo recommended a design treatment to make the helicopter acceptable for commercial use. The treatments were applied to two test helicopters. Subsequent measurements confirmed the success (Sternfield et al.,1957). The results of this project led to other helicopter noise control assignments for Leo and the BBN staff (**Figure 3**).

Airport Noise Control (1956 – 1958)

In what was perhaps his most important contribution to the field of transportation noise, Leo Beranek managed the first airport noise control project of the jet age. His work for the Port of New York Authority project at Idlewild Airport, now JFK, had far reaching consequences both in the quieting of

• Visiting Professor in Architectural Science, University of Sydney, Australia (2010)
• Certificate of Gratitude for service as Trustee of the Acoustical Society Foundation (2010)
• Lifetime Achievement in Acoustics Award, International Congress on Acoustics (2010)
• Institute of Acoustics (British): Peter Barnet Memorial Award (2010): *"for technical excellence in the fields of electroacoustics and speech intelligibility*
• 75th Membership Anniversary Citation (June 2013), presented at the 165th ASA - Montreal, Canada
• Happy 100th Birthday Leo! (September 15, 2014)

2010 2011 2012 2013 2014

future aircraft and in establishing noise standards for communities around airports.

The story began in November 1956 with a Pan American Airways request for permission to start jet aircraft passenger operations in two years at Idlewild Airport. Pan Am planned to use the new commercial version of the Boeing 707. Anticipating public concerns, the Port Authority had previously established a policy that jet aircraft could be no noisier than the existing large propeller airplanes on takeoffs and landings. Boeing had assured the airlines that the 707 and the largest propeller airplanes had the same noise levels. However, when Port Authority officials listened to demonstration overflights of the 707, they were shocked about how loud the jet sounded compared to the propeller airplanes. The officials threatened that the 707 would not be approved for use at Idlewild unless it was quieter.

Both parties had strong cases: Boeing's measurements with a sound level meter showed that the overall sound level for the 707 was the same as for the largest propeller airplanes; the Port Authority's perception was that the 707 was much louder. Leo believed the difference to be related to the response of human hearing over the audible frequency range. Knowing that he had world-class experts among the staff at BBN – Karl Kryter, in experimental psychology, and Laymon Miller, in noise measurements -- Leo proposed a project to the Port Authority that would resolve the problem. Under Leo's direction, calibrated measurements of noise from a 707 (jet powered) and a Super Constellation (propeller driven) were to be made under identical conditions followed by psychoacoustic testing to determine equal perceived noisiness.

BBN personnel and Boeing engineers measured and recorded the noise from the two airplanes at Boeing's airport. The recordings were used by Kryter in four sets of listener tests where the subjects were instructed to adjust the volume so that the two aircraft had equal "noisiness." The result was clear in all four cases. The noise from the 707 needed to be reduced by 15 dB in order to match the effect of the Super Constellation. This finding led to a major effort by Boeing to muffle the jet engine exhaust noise on the 707.

Carrying the information from these tests one step further, Kryter had the data necessary to develop a new metric, Perceived Noise Level (PNL) with units of PNdB. He based this new metric on the known characteristics of human hearing wherein low-frequency sounds are perceived to be less noisy than high-frequency sounds. Further tests confirmed that the new metric was superior to other ratings in use at the time for judging noisiness of various aircraft (Beranek et al., 1959). Consequently, Perceived Noise Level measured in PNdB became the rating adopted internationally for measuring aircraft noise. It continues to be used today in certification of airplanes.

Measurements in a residential area two and a half miles from Idlewild Airport showed that twenty five percent of takeoffs of propeller aircraft exceeded the value of 112 PNdB. Although not immediately disclosed, the level of 112 PNdB measured on the ground became the standard used by the Port Authority for judging acceptability of noise from aircraft at an altitude of 1,200 feet. Measurements on two European passenger jets, the French Caravelle and the British Comet 4, showed that these aircraft could comply with the standard by employing special takeoff climb and turn procedures. If it followed the same procedures, Boeing's 707 fitted with mufflers was able to meet the standard also.

This ground-breaking project sponsored by the Port of New York Authority led to regulations on aircraft noise and was instrumental in the development of noise control for existing aircraft and quieter jet engines in the future. Although he was unpopular with the airlines and airplane manufacturers at the time, Leo Beranek proved to be the leader in establishing procedures resulting in quieter technology for the aviation industry.

Airport Noise Contours (1952)

In what may have been the first use of noise contours to illustrate zones of annoyance around airports, Leo gave several presentations in 1952 in which he showed bounded areas on the ground divided into four categories of "disturbing effects of noise" associated with jet operations near airports (**Table 1**). In a paper delivered to the Acoustical Society of America

The Ride on the Waves Continues……………………..

2015 2016 2017 2018 2019

Category	Shading in Figure 4	Nuisance (complaints)	Interference with Speech
A	White	Negligible	Easy to talk outdoors
B	Slant-Shaded	Moderate (occasional complaints)	Necessary to talk loudly Outdoors. Almost no interference with speech inside frame house.
C	Cross Hatched	Sizeable (about one-quarter of the population may complain)	Necessary to shout outdoors. Must raise voice inside frame house.
D	Black	Major(majority will probably complain)	Impossible to converse outdoors. Must talk loudly or stop talking inside buildings.

Table 1. *Estimated disturbing effect of noise for four takeoffs per hour over one residential area*

in May 1952 and published in the Journal of the Acoustical Society of America, he introduced the concept of categories of "disturbing effects" and showed corresponding shaded regions on the ground beneath the line of flight on takeoff where each category would prevail. Although the categories were related to noise levels, the values were not listed in the table (Beranek, L.L., 1952).

Later that same month at a U.S. Senate Committee Hearing in New Hampshire, Leo presented contours of disturbance resulting from operations of jet-propelled B-47 aircraft at the proposed Portsmouth Air Force Jet Air Base (which became Pease Air Force Base, and is now known as Portsmouth International Airport)

Although we are now familiar with the use of noise contour plots around airports and other transportation facilities, Leo's presentations were innovative at the time. Relating areas on the ground to noise disturbance from the air was a major step forward in communicating with the public in neighborhoods around these facilities (**Figure 4**).

Other Modes of Transportation

Although Leo focused his work on aviation noise, his influence on other modes of transportation has been significant. Besides his classic textbooks on acoustics from teaching at Harvard University and Massachusetts Institute of Technology, Leo was responsible for gathering distinguished experts for a series of noise and vibration control handbooks containing valuable information used in the design of vehicles and transportation facilities (Beranek, L.L, 1960; Beranek, L.L., 1971; Beranek, L.L. and Ver, I., 1992; and Ver, I. and Beranek, L.L., 2006). These books are considered "bibles of noise control information" and are used throughout the world for noise and vibration control purposes.

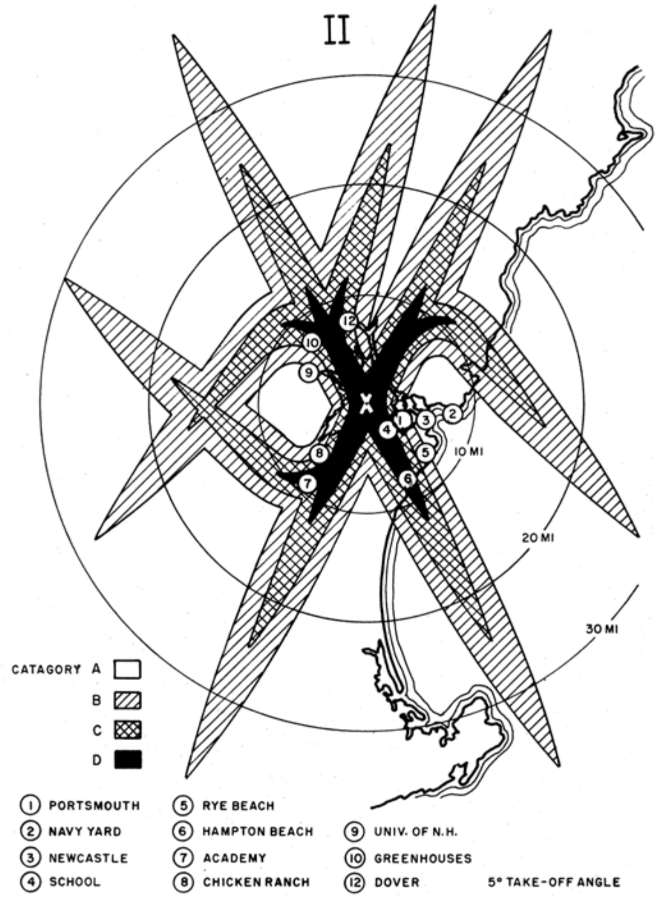

Figure 4. *Noise contours around the proposed B-47 air base, Portsmouth, NH, 1952.*

Final Comments

Pioneers in new and developing fields of science and technology have a difficult task. They push the boundaries and sail in uncharted waters. They have a responsibility to get the science right and to not be overly influenced by politics or remuneration. During his many years of work related to noise of aircraft, Leo Beranek was one of those pioneers. Individually, and with the support of his staff at Harvard, MIT and BBN, he made outstanding contributions to the field of transportation noise control. One can get a full appreciation of his pioneering efforts in aviation noise as well as his many other fields of interest by reading his autobiography, Riding the Waves (Beranek, 2008). The field of aviation noise has evolved and assessment procedures have been refined, but it is undeniable that the seminal work conducted by Leo and his colleagues during the early years provided the foundation for the current state-of-the-art.

My Good Fortune

I met Leo Beranek the first day I worked at BBN in 1962. It was not long after the opening of New York City's Philharmonic Hall. Leo was friendly and welcoming, as were the others I met during those first days and weeks. (Bob Newman had introduced me to acoustics in his "Introduction to Architectural Acoustics" course at MIT. After taking Bob's second, "Advanced Problems in Architectural Acoustics," I was asked whether I wanted to work part-time at BBN.)

Shortly after the opening of Philharmonic Hall, a group of concert hall acousticians from BBN and elsewhere were meeting periodically in order to consider ways to improve the room acoustics of the hall. My task was to help with some drawings.

Although I knew that the hall had opened to mixed reviews, I knew little about the history of the hall's design – and not very much about acoustics consulting. I had heard that the hall was built differently from the final design that BBN had prepared. This was a wonderful opportunity to be involved in an intense brainstorming session, if only as a draftsman preparing a series of drawings for possible adjustments to the reflective, acoustical "clouds" and other room details, and as an onlooker.

BBN New York Office staff

Andy Harris
Ex BBN, New York Office Manager, 1962-1980)
Andrew Harris Associates
andyvestry@gmail.com

Biosketch

Although **Carl Hanson** never had the opportunity to work directly with Leo Beranek, he has always considered Leo one of his mentors. Leo's textbooks and guidelines provided a foundation for Carl's education in acoustics and eventual consulting practice. Carl was the Group Leader of Surface Transportation Noise Control Consulting at BBN during the 1970s. In 1982, Carl joined three former BBNers as a co-founder of Harris Miller Miller & Hanson Inc. (HMMH). He was a member of the Acoustical Society of America for over 30 years and is a Fellow of the Institute of Noise Control Engineering.

References

Beranek, L.L. (1952). "Unsolved Military Noise Problems," *Journal of the Acoustical Society of America*, 24, No.6, 769-772.

Beranek, L.L. (1960). Editor. *Noise Reduction*. (McGraw Hill Book Company, New York)

Beranek, L.L. (1971). Editor, *Noise and Vibration Control*. (McGraw Hill Book Company, New York)

Beranek, L.L. (2008). *Riding the Waves*. (The MIT Press, Cambridge, Massachusetts).

Beranek, L.L., Kryter, K.D., Miller, L.N. (1959). "*Reaction of People to Exterior Aircraft Noise," Noise Control,* September 1959, pp. 23 – 31, 60.

Beranek, L.L., Labate, S., Ingard, U. (1955). *"Noise Control for NACA Supersonic Wind Tunnel." Journal of the Acoustical Society of America,* 27, No.1, 85-98.

Beranek, L. L., Nichols, R.H., Rudmose, H.W.,Sleeper, H.P., Wallace, R.L., Ericson, H.L. (1944). *Principles of Sound Control in Airplanes* (National Defense Research Committee, Office of Scientific Research and Development, Washington, D.C.) Report OSRD No. 1543.

Beranek, L.L., Ver, I.(1992). Editors, *Noise and Vibration Control Engineering: Principles and Applications.* (McGraw Hill Book Company, New York)

Sternfield, H., Miller, L.N., Beranek, L.L. (1957). "*Acoustic Design for Transport Helicopters," Journal of the American Helicopter Society,* 2, No.4, October 1957.

Watters, B.G., Labate, S., Beranek, L.L. (1955).*"Acoustical Behavior of Some Engine Test Cell Structures." Journal of the Acoustical Society of America*, 27, No.3, 449-456.

INCE Beranek Student Medal

Beranek Student Medal for Excellence in Noise Control Studies

In recognition of Leo Beranek's profound impact on noise control engineering, INCE/USA and the INCE Foundation in 2010 established the Beranek Student Medal. The medal recognizes excellence in the study of noise-control by undergraduate and graduate students at academic institutions in North America with courses in, or related to, noise-control engineering including practical applications.

Additional information about this award is available at www.inceusa.org.

Eric W. Wood
President, INCE Foundation
ewood@acentech.com

Not Easy to Keep Up with Leo

When I first opened Dr. Leo Beranek's 1954 book "Acoustics" around 1985, I was delighted to find so much technical information presented in a way that I, as a young engineer, could readily follow. What I didn't imagine at that time was that I would come to know Leo or that I would share so many wonderful conversations about his research and ongoing work in acoustics. I really have Russell Johnson to thank for making that introduction and opening the dialogue between Leo and myself. Although Russ left BBN to form Artec in 1970, Leo remained in contact with Russ and me through the years I worked at Artec, and he has been a great source of advice since Russ passed away in 2007.

One of my favorite experiences with Leo occurred at Nashville's Ryman Auditorium in 2003. Dick Stern was improvising at the piano for a gathering of Society members. We climbed to the top row of balcony seats to hear how the room sounded for the piano without amplification. Upon announcement that the scheduled event would begin in just a few moments, Leo leapt to his feet and proclaimed that we must quickly get to the main level to compare the sound of the piano there with what we were hearing at the top of the room. Despite being more than 50 years my senior, he reached the main level by steep stairs well ahead of me. More than just Leo's mind remained sharp at age 88. I'm happy to report that in his most recent note to me, written with his usual wit, he expressed his intention to join us at the Boston ASA/EAA conference in spring of 2017.

Damian Doria
Principal, Stages Consultant
damiandoria@gmail.com

Taking the Train to Israel

In September 1949 I enrolled at MIT in electrical engineering with the clear intention of becoming a railway electrification engineer. But I also took all acoustics courses that were available, including Basic Acoustics and Electroacoustics taught by Leo Beranek.

Leo Beranek set my Army career by his well-placed suggestion to Colonal Kibling of the Army's Psychological Warfare branch that I was the candidate they were looking for to serve as a test engineer for various acoustical devices at their Fort Bragg test center. This led me directly to a Master's Thesis on A Binaural Recording System for Concert Hall Evaluation and employment at BBN staring in May 1957. Thanks to some excellent mentoring by Francis Weiner and others, I became one of BBN's sound system designers.

Leo sent me to Israel in 1960 to supervise completion of the Jerusalem Congress Hall. My Aunt Leah Klepper, my first Hebrew teacher, had moved to Tel Aviv, and that one visit was not enough to quench my interests, and so I kept returning to Israel. Even after I left BBN (in 1971, Gerry Marshall, Larry King, and I started our own consulting firm), Leo helped support a vacation trip for me in the Spring of 1992 in order to obtain data for his second concert hall book including halls in both Tel Aviv and Jerusalem. I finished the work in Jerusalem and then went straight to the Interior Ministry, arranged for my necessary forms in Hebrew to prove my residency requirements, and became an Israeli citizen four years before permanently moving to Israel. I am indebted to Leo for a life-time of support and friendship.

David Klepper
Jerusalem, Israel
daveklepper@yahoo.com

Leo Changed My Life Significantly, Even Before We Met

George Kamperman as head of the Chicago BBN office, 1960s

The Navy drafted me in 1944 on D-Day (the Normandy Invasion). My first year as a sailor I learned electronic circuit theory so that I could help maintain shipboard radar and communication systems. During college after the war, I landed a summer job at the General Motors Proving Ground (GMPG) near Detroit. For three summers I was an electronics technician at the Noise and Vibration Laboratory (Sound Lab), where I modified commercial sound and vibration instruments to enhance vehicle testing on the Proving Ground roads. This was my first experience with acoustic measurements and I became hooked.

In the spring of 1949 I purchased a pre-publication copy of Leo's Acoustic Measurements. I devoured this book (all 900 pages) and it changed the direction of my life. To study under Dr. Beranek become my goal. After receiving my BS degree in 1950 I applied to MIT as a Special Student to study acoustics for one year. To my delight, my supervisor and mentor was none other than Leo. His office was in the MIT Acoustics Laboratory and my lab was a seldom-used broadcast booth nearby.

The psycho-acousticians in the Lab were asking Beranek (Lab Director) for headphones with improved transient response. Leo assigned me the task of developing an improved headphone concept. I learned of a researcher at Harvard who was trying to develop an electrostatic loudspeaker, and who proved to be a goldmine of information on diaphragm materials that did not work; this was long before aluminized Mylar was available. I ended up fabricating about half-inch diameter "ear-buds" using a very thin membrane from the gut of a pig. All my earphone testing was with square waves applied to the earphone sealed to a 6cc coupler between the earphone and a 640AA condenser microphone with the results viewed on an oscilloscope. I could show proof of concept. The final construction sounded very good listening to music but the earphones were not practical because of the short life of the pig gut diaphragm and the high voltage hazard.

Chicago office Staff, left to right: Larry Kirkegaard, George Kamperman, David Klepper

Near the end of the MIT spring term in 1951, Leo offered me a job working at Bolt Beranek and Newman. When I joined BBN there were fewer than a dozen employees including the five partners. Leo was a great mentor. He explained all his projects we worked on in sufficient detail so I could efficiently follow through in his absence and have a draft report ready for his review upon his return. My earlier years with BBN at 16 Eliot St are the most memorable. The organization was small and fostered a continuous exchange of great ideas among the staff. Leo remained my best friend and mentor for many years.

George Kamperman
Kamperman Associates
George@kamperman.com

The Editing Process

Starting in 1990 I had the privilege to work with Leo on the editing and writing of a substantial portion of chapters in the 1992 and 2006 editions of the widely used reference book *"Noise and Vibration Control Engineering."*

Among other things, I learned from Leo a single important, but frequently overlooked, aspect of the editing process. Leo emphasized how essential it is for a reader to quickly find the location of any specific subject of his or her current interest. If he or she cannot do this, the book is of limited use and likely will end up on the shelf mostly unused. Very few, if any, of the users will read a 900 page book like ours cover-to-cover. Consequently, there must be a thorough index. The index of the 2006 Edition is 24 pages long. Compiling the index, as the last step of the tedious editing process, took more than a man-week of effort. If you find it easy to locate a subject in the book, please remember the dedication and effort that Leo and I made to compile the index.

Istvan L. Ver
Co-editor Noise and Vibration Control Engineering
Concord, MA
iver@onemail.com