COMMUNICATIONS WITH LEO BERANEK

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1 FIRST CONTACT AND CHRG

My first significant contact with Leo Beranek was in 1991, and it led to a series of concert hall measurements in the northeastern USA, as well as to the founding of the Concert Hall Research Group (CHRG) in the USA. At the time, there were no email messages but there were many faxes and letters by conventional post. In the 80's and early 90's architectural acoustics sessions at ASA meetings were often mostly verbal descriptions of halls along with photographs of attractive new auditoria, but with little technical information other than a few reverberation time results. To help rectify the lack of more technical information, I organised 3 sessions on "newer" architectural acoustics measurements at the ASA meeting in Baltimore in the spring of 1991. There were interesting papers by authors from 6 different countries, including 13 invited papers and 6 contributed papers. They

Fig. 1. Participants at the initial meeting in Leo Beranek's dining room. standing from left to right: Tim Foulkes, John Bradley, Jerry Marshall, Bill Cavanaugh, and Bob Essert, seated from left to right: Chris Jaffe, David Griesinger, M. Burkhardt, Leo Beranek, and Dave Breslau, and in front on the floor, Thomas Horrall.

included papers on new measurement parameters, new measurement systems and on applying new quantities. In total many new ideas were exchanged.

After the sessions were over, I was talking to Chris Jaffe about the need for new measurements in some North American halls. Jaffe had been impressed by the presentation by Anders Gade and suggested we should get Anders involved. I told him how I had been able to make measurements in several European halls in 1987 by collaboraty with Anders Gade and that the comparisons of results had been very helpful. I suggested we should organise a set of comparison measurements in US halls with: Anders Gade, myself, and Gary Siebein who was quite active with his students at the University of Florida. Parallel measurements by the three measurement teams could provide a wealth of new data and make possible invaluable comparisons among the 3 groups. Previous measurement comparisons between myself and Anders Gade had been a great help to resolving measurement differences and the details of the calibration of G values in 1987. If new measurements in US halls could be made and reported at an ASA meeting, many others would benefit and it would help move concert hall acoustics practice to a more quantitative level. When I asked Jaffe how he thought we might be able to fund the travel costs for such a measurement study, he immediately suggested I should contact Leo Beranek. He seemed confident that Beranek could make it possible. I later contacted Leo Beranek by letter (22/06/1991) with suggested details for a measurement series to get data of various new types of quantities in US halls. Within a few months we were all meeting over lunch in Beranek's dining room in Cambridge, Massachusetts. A letter from Beranek, dated 5 September 1991, to consultants: W. Cavanaugh, R. Johnson, L. Kirkegaard and C. Jaffe, requesting a total of $25,000 to support the proposed measurements, suggests the initial meeting occurred in late August or early September 1991.

There was an amazing respect for Leo Beranek among the various consultants and Leo was easily able to convince them to make significant contributions to the costs of the proposed series of measurements. People who didn't answer my telephone calls would readily send cheques for several thousand dollars to Leo Beranek to support the proposal.

The initial measurements were made in 9 halls in the NE USA in May 1992. Comparisons among the results of the three measurement teams led to helpful improvements in measurement techniques and

Fig.2 Tanglewood showing revised over-stage and rear wall reflectors

many results were reported a year later at the Fall 1992 ASA meeting in Ottawa. The three measurement teams each benefited in various ways from the comparisons of results in often quite different halls. One result was that I was asked to write a first draft of the Appendix for the ISO 3382 standard that described the various quantities that should be measured in addition to conventional reverberation times. Of course, for Leo there was also the expected benefit of more data for the next version of his book [1]. From this initial meeting in Beranek's home, the Concert Hall Research Group, CHRG, developed and is still organising events to promote concert hall acoustics research. For me it was an impressive demonstration of how Beranek was able to help push the science and practice of auditorium acoustics forward.

The CHRG also made possible measurements of acoustical conditions in the Tanglewood Music Shed in 1993. I didn't realise it at the time, but BBN had earlier been involved in work that very successfully improved the acoustics of the facility, by adding a new orchestra enclosure, acoustic canopy and diffusing stage rear wall (see Fig. 2), completed in 1959 [1]. Beranek participated in our measurements and brought a measurement system he had borrowed from Hidaka at Takenaka Labs. We moved his microphone and sound source and he obtained measurements at the same source and receiver positions as ours. It was a beautifully sunny August afternoon and the experience was an enjoyable pleasure and a more complete introduction to Leo Beranek.

Fig 3. Boettcher Hall Denver.

Another project supported by CHRG made possible measurements in Boettcher Hall in Denver. Chris Jaffe had designed it to be a hall with the audience completely surrounding the stage and with several variable acoustical features. Gary Madaras, who was working with Jaffe at the time, joined me in Denver to make measurements which were to assess the hall and its variable features in both

occupied and unoccupied conditions. Many measurements were made and later reported at the ASA meeting in the spring of 1997 [2 - 4]. However the occupied measurements were somewhat limited, because after a few measurements two armed Denver police offices escorted us off the stage and out of the hall. Apparently, there had been some miss-communication concerning what we were allowed to do!

One of the recurring problems that various comparisons of measurements revealed was the problem of precisely calibrating measurements of G values. These were mostly resolved but Beranek was trying to combine data from a number of labs for his 1996 book [1]. He had meticulously compared the results of a number of measurement teams in the same halls. However, he was not able to explain the small differences in G values between the results from Japanese researchers and those from what he called “Western” measurements. He found that the Japanese G values were about 1.2 dB higher than the others. There are many possible reasons such as small differences of source positions on-stage and the possible presence of music stands and chairs on stage during some measurements and not others. There were a number of exchanges of information between various research groups but no technical problems were identified. Beranek suggested that the differences might be due to calibration differences, but to my knowledge this was not confirmed. Anders Gade and I had both spent considerable effort resolving differences in our measured G values and I think we were reasonably confident we were getting the correct answers. Because the differences that Beranek found were quite small, he eventually corrected the G value results such as in Figure 4 by subtracting 0.6 dB from the Japanese G values and adding 0.6 dB to the other data. A practical way to get his book [1] finished and to move forward.

2 PUTTING THINGS IN CONTEXT

After reading through many old letters and emails, I realised that to better understand his comments one must put things into the right context. For example, he had published articles in JASA before I was born and he continued to do this until after I had retired. His last JASA article was in 2016 a few months before he passed away at the age of 102. It is hard for me to imagine how anyone could have the drive and determination to continue to be a productive researcher over such a long period. Table 1 gives a simplified summary of some parts of his acoustical life. In the middle of this chart, we see he essentially retired when he left his very successful position as president of BBI TV, a Boston television station, when he was 68 years old. Of course, after this he did not retire; he returned to acoustical research and collaborated with Hidaka and colleagues at Takenaka Labs in Japan. This commenced a second research life! There followed many more journal papers and books at a period in his life when most people would have been retired. More details of his life are described in his autobiography [5].

A number of details in his messages suggest his age. For example, one message asked how accurately my draftsman plotted the points on my graph published in JASA. Of course, I had long been producing my own graphs on a computer, with hopefully no plotting errors. I received many requests to comment on drafts of new papers. These often included very short deadlines; such as one which was essentially, “please respond today or tomorrow morning”! Returning to concert hall acoustics after a 10 year gap (while running BBI TV) meant he had to do a lot of reading to catch up with new publications in JASA and other journals. His review turned into a 39 page paper in JASA [6] which started from a brief summary of the history of western music, the early history of concert halls, and later included a large photograph of Wallace Clement Sabine who greatly inspired Beranek. In this historical review, Beranek mostly focussed on developments in the USA, but missed the important earlier discovery of the importance of early reflections in auditoria by Joseph Henry in the 1850s, as described by Shankland [7]. This important addition to our understanding of room acoustics was of course described more quantitatively by Haas [8] a hundred years later which was also not included in Beranek’s historical review paper.

Year	Age	Event
1914		Leo Leroy Beranek, born September 15, 1914
1931	17	Finished high school
1936	22	Graduated from Cornell College, Iowa
1940	26	Harvard, completed DSc
"	"	Submitted 2 papers to JASA
1947	33	Started as Associate Prof. at MIT
1948	34	Bolt Beranek and Newman (BBN) founded
1962	48	Philharmonic Hall NY, opened
1971	57	Resigned from BBN
1972	58	BBI TV on air, Beranek President
1982	68	BBI TV sold to Metromedia
"	"	Beranek begins return to acoustics
1996	82	Concert Halls & Opera houses: How They Sound
1997	83	Tokyo City Music Hall opens
2004	90	Concert Halls & Opera Houses: Music, Acoustics & Architecture
2016	101	JASA vol. 139 April 1548-1558
2016	102	October 10, Leo Leroy Beranek passed away

Table 1: Brief outline of some events related to Leo Beranek's acoustical life

Many of his messages were requests for comments on a new draft of a paper that he had produced, which he sometimes said he had sent to his "friends". It was often difficult to know how to critique the work of a much senior and eminent researcher. I usually tried to limit my comments to issues on which I had some more significant knowledge, along with suggestions for additional references or related work he might consider. I think that over the years his responses to my comments became gradually more accepting of my suggestions.

3 BERANEK'S SECOND RESEARCH LIFE

After the sale of BBI TV, and resigning as its president, Beranek began to return to acoustics and soon began to work with Hidaka and colleagues at Takenaka Labs in Japan. He was involved in their work on a number of new halls and was an author on a number of their papers. In several cases his publications touched on topics that I had considered. One such area was the issue of predicting occupied and unoccupied chair absorption in halls. Much earlier, Beranek had developed a practical scheme for predicting the absorption due to seating in halls that involved adding absorbing strips in the calculations of the area of blocks of chairs to account for edge effects [9]. I published papers in 1992 [10] and 1996 [11] that predicted chair absorption in auditoria from measurements of the same chairs in a reverberation chamber using the P/A (perimeter/area) method. This was an extension of a procedure that had previously been shown to work for simple flat absorbing panels, that I showed was also valid for predictions of the absorption of chairs in auditoria. Beranek's response to this work was, "...it is hard for me to accept that one can extrapolate reverberation chamber data to measured data in halls", and that it might not apply to larger halls [letter received 5 Jul 1995]. Fortunately, a few years later Barron and Coleman [12], published a study that included a comparison of Beranek's

method and the P/A method and showed that they were mathematically equivalent. This makes it possible to better understand why Beranek's method works and how one might fine tune it.

Another area where our work overlapped concerned the relative merits of lateral energy fractions (LF) and inter-aural cross correlation values. In 1994, I published an analysis of measurements in 14 different concert halls comparing octave band lateral energy fractions and inter-aural cross correlation measurements [13]. Values at individual seat locations were compared as well as hall-average values. My results showed that both types of measures for individual seat measurements were significantly correlated for octave band results from 125 to 1000 Hz and for hall average results were significantly related for results from 125 to 4000 Hz octave band results. Mostly these quantities provide similar information about sound fields in halls. Beranek argued that because variations in measured low frequency LF values were quite small, LF values were not useful. However, I would say that because the two quantities are significantly correlated, LF and IACC values provide similar information about sound fields. One could scale LF values to have larger low frequency variations and they would then seem more important.

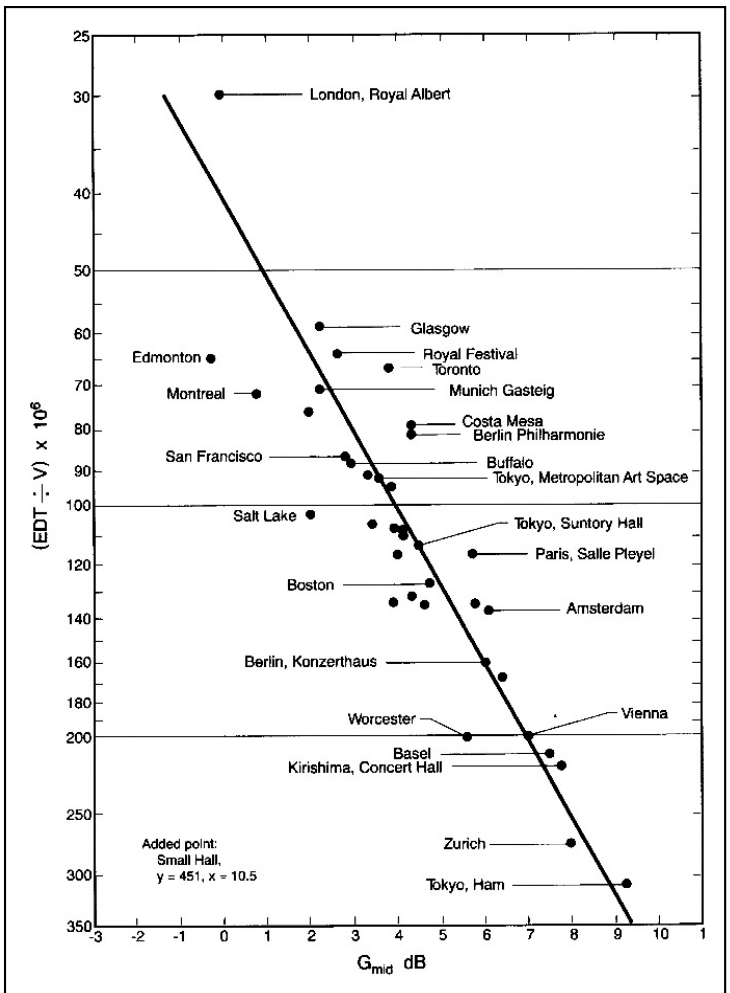

Fig. 4 Beranek's plot of hall average EDT/V values versus G_{mid} values, from Fig 9.4 reference [1].

Concerning my comments on which factors affect the perceived strength of bass sound in halls, Beranek said in an email dated March 27, 2010 that he, "was bothered by so much attention to the seat dip effect" in a book chapter I had written [14]. However, in his paper at the International Symposium on Room Acoustics in Melbourne, a few months later (August 2010) [15], he quoted my work on the seat dip effect [16] and acknowledged that the seat dip effect could be important to the perceived strength of bass sounds in halls. In a presentation at the ICA in Sydney in 2010 [17] and a little later in JASA [18] he referenced work by Bradley and Soulodre [19] as indicative of the importance of low frequency G_{125} values as a better indicator of the strength of bass sounds than low frequency reverberation times. He calculated values of Barron's Bass Index [20] from octave band G values and discussed the values of this Index in a number of concert halls. Although he pointed out the work by Bradley and Soulodre [19] as showing the importance of low frequency G values as an indicator of the perceived loudness of bass sounds, he didn't mention that we were referring to low frequency early-arriving G values, i.e. $G_{80}(125)$ values. However, he did include a copy of our graph which was correctly labelled in terms of $G_{80}(125)$ values.

As Beranek became more aware of the evidence for the importance of G values (for example, see Fig 4), he returned to the problem of the differences in G values measured by different measurement

teams. Initially he explained the differences as due to the differences of source calibrations between those in a reverberant room and those in an anechoic room. In reference [1] he simply subtracted 0.6 dB from Hidaka's G_{mid} values and added 0.6 dB to the results of others to get comparable values as in the results of Fig. 4. The reason was initially explained as due to calibration differences between those calibrated in an anechoic room and those in a reverberant test chamber. However, this didn't always explain the differences correctly. He later attributed the differences as due to calibration procedure for the Takanaka tests [21]. I think it is also very important to better understand how the day-to-day changes in halls affect measured G values. This would include changes to curtains, loud-speakers and items located on-stage closer to the test sound source. It would also be very easy to make small errors in repeating source positions between one set of measurements and another.

4 BERANEK'S APPROACH

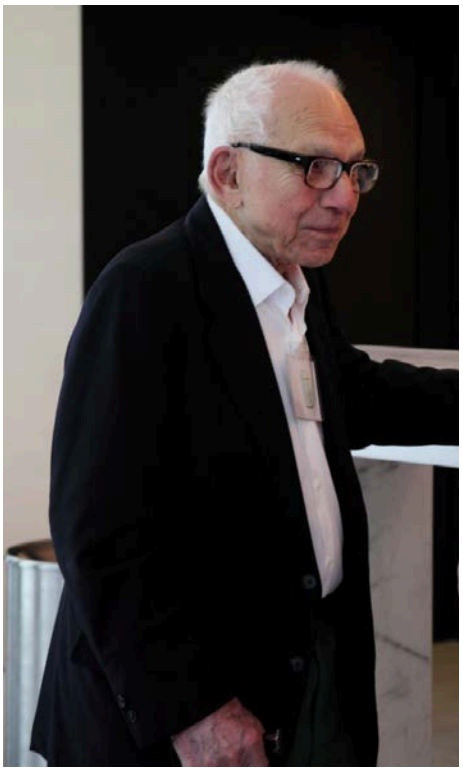

Fig. 5 Beranek at ISRA 2013 in Toronto

Beranek's approach to evaluating various new parameters was often to determine how well they predicted the overall perceived acoustical quality of concert halls. However, this was often not the original intent of most parameters which were usually intended to relate to some particular aspect of concert hall quality. As a result, he would conclude that particular parameters were inferior because they were not found to be good predictors of overall acoustical quality. The other problem was that to test measures as predictors of overall quality, you have to have subjective ratings of overall acoustical quality for a significant number of halls. Beranek had developed subjective ratings including many halls and the most recent were described in [22]. He said of these most recent subjective data that his technique, "…did not constitute a scientific canvas of expert opinions". In the same paper he says he included results of a group of conductors who he felt, "spoke most clearly about their choices of preferred hall acoustics". Further in the same paper, he says that, he, "makes no claim that the results are the same as those that would be obtained by a scientifically rigid procedure". He does make it clear that there are limitations to his data and hence to his results, but it is never completely clear exactly how he obtained his subjective ratings. However, there may be no better data set of subjective ratings of many international concert halls and we can perhaps use his ratings to get an initial impression of what is most likely important for assessing and predicting concert hall acoustics quality. Hopefully such initial studies will lead to more rigorous follow-up studies.

Beranek's acoustical achievements are very numerous and very impressive. The various versions of his concert hall books, for example references [1 and 21] are an incredible resource providing information on concert halls for us all. It is hard to imagine how anyone could improve them. After trying to comprehend the many messages I have received from Leo Beranek over a period of at least 25 years and his many publications, I can only be amazed by his never ending energy and accomplishments. And this was in the last quarter of his life when he was probably slowing down!

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