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Roelof Vermeulen at Philips: A Search for Space in Music

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Abstract

Roelof Vermeulen's career at Philips started in 1923 and ended with his retirement in 1959. He developed a stand-alone loudspeaker for Philips' first radio receiver in 1925 and was the driving force behind many developments in the field of electroacoustics.

Despite the high sound quality for their time achieved by Philips radios of the 1920s and 1930s, according to Vermeulen, the reproduction of music through a single loudspeaker remained a serious limitation: monaural sound offered the listener not more than a virtual hole in the wall of the space in which the music was performed.

While the introduction of stereophony was an improvement, in the sense that the location of the instruments in the performance space now became perceptible and their diverse sound-colours better distinguishable, something essential was still missing from the musical experience, namely the experience of the performance space itself.

Experiments with artificial head microphones for binaural recordings and with stereophonic recording were therefore soon expanded with so-called ambiophony; a technique developed by Vermeulen whereby loudspeakers reproducing stereo sound were supplemented with indirectly oriented speakers for "diffuse" sound.

Out of the desire accurately to record and reproduce the acoustical properties of a musical performance space evolved a new ambition: to use electroacoustic means to vary those properties in the concert hall in real-time. Stereo reverberation devices for this purpose, already developed by Philips in the 1950s, were in use in numerous theatres and concert halls, for example in the Teatro alla Scala in Milan, and found further application in the production and performance of electronic music.

Keywords

Philips Research Laboratories, Roelof Vermeulen, electroacoustics, loudspeaker design, stereophony, artificial head microphones, Leopold Stokowski, ambiophony, electronic reverberation, acoustic enhancement, Hermann Scherchen

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Philips Research Laboratories

In January 1914, the physicist Gilles Holst began his work for the Philips Company. It was the starting point for systematic scientific research at Philips Research Laboratories. Holst would stay in charge of the laboratories until 1946. During the Holst period, the laboratories were an integrated part of the company and played an important role in the diversification of the product range.[1] Holst had managed to obtain a position for the research laboratories that was highly independent from Philips' main industrial groups. These groups could express their wishes of course, but it was Holst and his staff who decided what the research programme was. By the time of Holst's retirement in 1946, the diversity of research topics was so large that he proposed to the Philips Board of Governors to hand over the command of the laboratories to three new directors, each of whom would become responsible for a wide field of research. Hendrik Casimir would lead the research in the field of physics, Evert Verwey would lead the chemical research, and Herre Rinia would lead the groups that were occupied with machines and systems.[2] By now, the laboratories functioned as an autonomous entity among the autonomous Product Divisions of Philips, each of which had its own development lab. By the end of the 1950s, so around the time of the electronic music studio at the research laboratories and the Philips Pavilion project for the World's Fair in Brussels, Philips had 58 thousand employees in the Netherlands and 153 thousand employees worldwide.

Radios and Loudspeaker Development

During a stay in Paris in the summer of 1923, Anton Frederik Philips, the director of the Philips Company, had seen the appealing neon advertisement lighting made by the French company Paz & Silva. After Philips had obtained a license contract from the patent holder George Claude, Roelof Vermeulen (1897–1970), who had taken degrees in both mechanical and electrical engineering at the Technische Hogeschool Delft (today Delft University of Technology), was recruited at Philips Research Laboratories in that same year for the construction of the so-called Claude-tubes. The development of these tubes would start in March 1924.[3]

But already on 21 October 1925, Vermeulen applied for a patent that would form the basis of his further career: that of a loudspeaker. The patent described a "Toestel voor het omzetten van electrische in mechanische trillingen" (device for the conversion of electrical into mechanical vibrations) and was granted on 24 April 1928.

1 VRIES, Marc J. de. *80 Years of Research at the Philips Natuurkundig Laboratorium 1914–1994.* Amsterdam: Pallas Publications, 2005, p. 16.

2 BLANKEN, I. J. *Geschiedenis van Philips Electronics N.V. – een industriële wereldfederatie* [History of Philips Electronics N.V. – an industrial world federation]. Zaltbommel: Europese Bibliotheek, 2002, p. 123–25.

3 BLANKEN, I. J. *Geschiedenis van Philips Electronics N.V. – de ontwikkeling van de N.V. Philips' Gloeilampenfabrieken tot elektrotechnisch concern* [History of Philips Electronics N.V. – the development of the N.V. Philips' lightbulb factory to electro-technical concern]. Leiden: Martinus Nijhoff, 1992, p. 216–17.

The fabrication of electron tubes at Philips had expanded strongly and had been integrated with the fabrication of light bulbs. By the end of the 1920s, the activities of the company included all areas of the radio industries, with the exception of broadcasting of radio programmes itself. The mass fabrication of radio devices, which had started in 1927, marked the beginning of a period of almost uncontrolled expansion, which not only changed the size, but in many aspects also the nature of the company in a fundamental way. Whereas Philips had started only as a factory of light bulbs, the development of loudspeakers would bring the company into an area that went far beyond radio, which was that of acoustics. The development of the first radios at Philips Research Laboratories started in September 1926. One year later, a first commercial radio set to include Vermeulen's loudspeaker design was presented at the Annual Fair of Utrecht.[4] The industrial design for the receiver and the loudspeaker was made by Louis Kalff.[5] By May 1928, Philips produced fifteen hundred radio receivers a week, and in 1928–1929 that figure would be raised to twenty-five hundred. The success of the introduction of radios had greatly exceeded the expectations of the company's board of directors.[6]

Through radio, Philips also became involved in sound recording techniques. Being a scientist and a musician himself, for Vermeulen, the acoustics department of Philips Research Laboratories was the perfect environment. It allowed him to develop many of his ideas that involved both electroacoustics and music. In 1945, Vermeulen would state that it was embedded in the company's vision on the future of music that Philips considered radio receivers, gramophone players and sound film projectors as being musical instruments.[7]

Stereophonic Sound

Although the development of stereophony would turn out to have enormous advantages for the faithful recording and reproduction of music, the first article in *Philips Technical Review* in which stereophonic "artificial head" microphones were presented did not have a musical context. The article from 1939 contained a description of an installation particularly developed to study the necessity of directional hearing with hearing aids for people that suffered from partial deafness.[8] The authors stated that without binaural information, the possibility to focus on a particular sound source was lost in a situation where many sources are simultaneously present. This was also described as a reason for

4 Ibid., p. 263–82. The "Jaarbeurs Utrecht" was held from 6 until 15 September 1927.

5 Kalff would later become general art director at Philips, and played an important role as animator of the Philips Pavilion project for the Brussels World's Fair 1958.

6 BLANKEN, *Geschiedenis van Philips Electronics N.V. – de ontwikkeling van de N.V. Philips*, p. 285.

7 VERMEULEN, R. *Muziek Centrum*, report for Philips Research Laboratories of 20 June 1945, Philips Company Archives NL 315 Acoustiek (rapporten).

8 BOER, K. de and VERMEULEN, R. Een installatie voor een slechthoorende [an installation for hearing impaired]. *Philips Technisch Tijdschrift* 11, 1939. Kornelis de Boer took his doctoral degree in December 1940 with a dissertation on stereophonic sound reproduction.

the fact that in broadcasting studios, the amount of reverberation had to be smaller than under normal circumstances.[9] It was argued that during the reproduction, the sounds that were originally reaching the microphone from all directions within the studio where now received by the listener from only one direction, which was that of the opening of the loudspeaker. By using two microphones and two loudspeakers, it should be possible to maintain the directional information. To be sure that differences in intensity and timing were identical to those of the human ears, the microphones had to be mounted on an artificial head. It was considered sufficient just to use an approximation of the human head, which had more or less the same dimensions.

In an article from April 1940, the necessity for stereophonic sound reproduction in radio and cinema was again argued on the basis of an extensive explanation of the phenomenon of directional hearing. In addition, the role of reverberation in the perception of the distance of a sound was mentioned. The artificial head technique was now introduced as a means to reproduce a stereophonic sound image through loudspeakers in an auditorium. Despite the fact that according to the theory, every listener in the auditorium should be wearing headphones, a sufficient stereophonic effect was obtained with loudspeakers during tests. For stereophonic sound reproduction in cinemas, the article proposed the use of one loudspeaker for frequencies below 300 Hz at an arbitrary place, for instance behind the projection screen, and two loudspeakers for the higher frequencies at both sides of the screen, since the lower frequencies do not contain any directional information. The concept of separated low and high frequency reproduction would later be used for loudspeaker systems in the 1950s' living room and, more importantly in this context, in the Philips Pavilion of 1958.

During the first year of the German occupation of the Netherlands, research at Philips' laboratories had continued more or less in a normal manner. But although in the years that followed, activities did not come to a complete hold, the amount of scientific publications and colloquia by scientists seriously declined.[10] *Philips Technical Review* did not appear from October 1942 until the end of 1945.[11] But already in the second post-war edition, it was again De Boer who stressed the importance of stereophony.[12] This time he particularly addressed the benefits of stereophonic sound reinforcement in concert halls, theatres and cinemas. De Boer explained that with stereophonic reproduction in cinema, the sound would be heard as coming from the same direction as where the sound source was seen. But especially in those situations where sound reproduction was

9 Both effects were later experimentally confirmed and termed "Binaural masking level difference (BMLD)" and "Binaural suppression of reverberance," see: DURLACH, Nathaniel I. "Binaural signal detection: equalization and cancellation theory". In *Foundations of Modern Auditory Theory, Volume 2,* ed. J. V. Tobias. New York: Academic Press, 1972.

10 BOERSMA, Kees. *Inventing Structures for Industrial Research – A history of the Philips Nat.Lab. 1914–1946.* Amsterdam: Aksant Academic Publishers, 2002, p. 69–70.

11 Although in the foreword of *Philips Technical Review* of January 1946, it is mentioned that the magazine did not appear from July 1942 until December 1945, the July, August and September editions of 1942 did definitely appear.

12 BOER, K. de. *Stereofonische afbeelding* [stereophonic imaging]. *Philips Technisch Tijdschrift* 2, 1946.

being applied without the possibility for the listeners to see the original sources, a considerable improvement in quality could be achieved by the application of stereophony. The artificial head microphone technique therefore had been further developed, and two additional electronic controls were introduced by De Boer to transform the stereophonic image: a "wide–small" controller and a "left–right" controller.

Collaboration with Leopold Stokowski

Leopold Stokowski had published his book *Music for All of Us* in 1943.[13] Although Vermeulen did mention Stokowski in a proposal written in 1945 for a music laboratory, it is not clear whether he had read the book of Stokowski already at that time. There are however clear similarities.[14] Immediately in the first chapter, "Music the Universal," Stokowski described a way in which technology was able to solve a problem that occurred as the result of a sociological development:

> Formerly music was chiefly confined to privileged classes in cultural centers, but today, through radio and records, music has come directly into our homes no matter how far we live from cultural centers. This is as it should be, because music speaks to every man, woman, and child – high or low, rich or poor, happy or despairing – who is sensitive to its deep and powerful message. [...] Today there are millions interested in music where there were formerly a few thousands.[15]

But also technically, Stokowski addressed topics that were certainly of interest to Vermeulen and his department. In chapter fifteen, "Reflection and Absorption – Echo and Reverberation," Stokowski mentioned that:

> In the future, it will be possible to build concert halls and studios for radio and recording that have variable acoustics. [...] In the future it will be possible to pick up and amplify any zone of frequency, and prolong it by reverberation. [...] This will not be done by reflection, but by an electrical process.[16]

In 1946 Vermeulen started to develop what would soon be called the "Stokowski-installation" around a stereo version of the Philips-Miller recording system. Eventually, the sounding result would be described as "Stokophonie"[17] (Stokophonics). Vermeulen's journal of 4 September 1946 contains many details about the progress made with the Stokowski-installation, divided into topics such as the construction and measurements

13 STOKOWSKI, Leopold. *Music for All of Us.* New York: Simon and Schuster, 1943.

14 The first reference in Vermeulen's journal to the book of Stokowski is of 14 May 1947.

15 STOKOWSKI, *Music for All of Us,* p. 1–2.

16 STOKOWSKI, *Music for All of Us,* p. 98.

17 VERMEULEN, R. Dagboek [journal] 17, 10 June 1947, Philips Company Archives NLwb 2850.

of new amplifiers, microphones, loudspeakers, the artificial head microphone, mixing and control decks and modifications for the Philips-Miller recorder.

On 14 December 1946, Vermeulen presented a new research programme proposal for the acoustics department of Philips Research Laboratories. The first chapter, "Conclusion of the Current Programme," dealt with the Stokowski-installation, which was planned to be completed in April 1947. It would then be necessary to make test recordings, after which the Concertgebouw Orchestra and Stokowski should be contacted again. On 16 May, the small hall of the Amsterdam Concertgebouw was equipped as well as possible with a stereophonic loudspeaker monitor system. That same night, a concert with Yehudi Menuhin was recorded and played back to him. He was not very happy with the sound of the violin, but enthusiastic about the recording of the orchestra under Paul Hindemith. On 17 May, Stokowski arrived. Some recordings were played to him in the monitor room. Then, during the rehearsal, some excerpts were recorded and played back to him on the speakers in the small hall. His verdict was: Not enough high tones, low tones all right, and something was missing between 1,000 and 2,000 Hz. Then finally, on 21 and 22 May, the concerts of Stokowski were recorded. On 15 June 1947, Vermeulen wrote a report for people who had been involved in the project with the title "Philips Stereophonic Recording Experiments with Mr. Leopold Stokowski in the Concertgebouw in Amsterdam." Vermeulen stated that:

> [...] the most interesting of all was Stokowski's idea that the music as heard in the concert hall is only a compromise and does not by any means represent the ideal sound picture. [...] Reproduction from loudspeakers, however, offers entirely new possibilities, because it leaves much more freedom in the placing of the sources of the sound. Music should not reach the ear from one direction, as it does in a concert hall. The listener should be surrounded by it, receiving no impression of direction at all but being bathed, as it were, in the music. [...] For many it will indeed be a strange experience to hear an orchestra in this way, accustomed as we are since so many generations to hearing the sound from one place in the hall, but it is none the less certain that with such a sound picture, very remarkable results are to be attained, which will probably represent better the music as heard by the composer when he created it.[18]

Just as in *Music for All of Us*, the ideas of Edgard Varèse seem to have entered the mind of Stokowski here, for Varèse had dreamed earlier about a machine that would create "*a sense of sound-projection in space by means of the emission of sound in any part or in many parts of the hall.*"[19]

18 VERMEULEN, R. Philips Stereophonic Recording Experiments with Mr. Leopold Stokowski in the Concertgebouw in Amsterdam. 15 June 1947, attachment to dagboek [journal] 17, Philips Company Archives NLwb 2850. The term "Stokophonie" that Philips introduced unofficially seems to have referred primarily to this idea.

19 VARÈSE, Edgard. *Music as an Art-Science*, lecture given at the University of Southern California in 1939, quoted in WEN-CHUNG, Chou (ed.). The Liberation of Sound (Excerpts from lectures by Varèse). *Perspectives of New Music,* 1966, vol. 5, no. 1, p. 13.

Based on the experiments with Stokowski, Vermeulen would come to the understanding that the musical value of stereophony lies in the better differentiation between the instruments by means other than their timbre alone. However, stereophony could give a satisfactory imitation of the sound of the orchestra, but not of the experience of a live concert. An additional technique was necessary to create a satisfying spatial illusion, which Vermeulen would call "ambiophony."[20] The research into ambiophony and variable acoustics by using electronic reverberation systems would dominate his scientific work for the years to come.

Ambiophonics and Reverberation

During the tests with the Stokowski installation in Amsterdam, several positions of the monitoring loudspeakers had been tried out. Stokowski had asked to position the front loudspeakers in the monitoring room off-axis, while the loudspeakers in the rear of the monitoring room had to be positioned with their speakers pointing upwards. After all, Stokowski had said that the reproduction of sound from loudspeakers offered entirely new possibilities, because it leaves much more freedom in the placing of the sources of the sound. Vermeulen later mentioned in his journal that in this way, something that he had imagined in the past had now been achieved. The composers Sam Dresden and Willem Pijper had once said to Vermeulen that stereophony lacked the possibility to really "surround" the listener with the music. For him it turned out that in order to achieve this, it wasn't necessary to introduce an additional time delay. Instead, pointing up the rear speakers was enough not to disturb the stereophonic effect of the front speakers.[21] Some ten years later, in the article "Space in Music," Vermeulen explained the concept of ambiophony as follows:

> There are two different space effects essential to the complete enjoyment of music: first the differentiation between the directions of the direct sounds from the musical instruments, which can be simulated by means of stereophony; second the diffuseness of the reverberant sound, which can be simulated by ambiophony. At the moment it is not yet quite feasible to introduce both stereophony and ambiophony in the home by means of the two channels that can be recorded in the single groove of the phonograph record. It is therefore an important problem to establish which of these two produces the musically most essential effect. [...] There are, however, indications that ambiophony may be the more essential.[22]

Vermeulen would write in 1955 that while too long a reverberation time made speech unclear, a reverberation time which was too short made music sound "dry" and brittle. Many varieties of acoustic materials were available for shortening the reverberation time

20 VERMEULEN, R. *Space in Music*, typescript of 23 February 1959, place of publication unknown, Archive of the Institute of Sonology.

21 Ibid.

22 Ibid.

and thereby improving the clarity of speech. The opposite, which was the lengthening of the reverberation time and – perhaps more important – making the sound diffuse, could be achieved by electroacoustic means. Tests would later show that in this way, a good theatre hall could be made suitable for concerts.[23] Having played the violin in the theatre hall of the Philips Ontspanningsgebouw with the Philips Symphony Orchestra many times, the desire to find a solution for the problem pointed out by Vermeulen was presumably also based on his own practice as a musician. That hall had obtained very good acoustic qualities for theatre productions after the renovation of 1935, but as a concert hall it had left a lot to be desired for.[24]

Vermeulen's research in the field of artificial reverberation was also related to ideas of Stokowski. In chapter fifteen of *Music for All of Us*, called "Reflection and Absorption – Echo and Reverberation," Stokowski had written that:

> In the future, it will be possible to build concert halls and studios for radio and recording that have variable acoustics. [...] In the future it will be possible to pick up and amplify any zone of frequency, and prolong it by reverberation. [...] This will not be done by reflection, but by an electrical process.[25]

In the article "Stereo-Reverberation," Vermeulen explained that stereophony could only reproduce the diffuse character of the reverberant sound in a limited way. It could however be reconstructed even from a single channel by feeding several loudspeakers distributed over the hall with different, random delays, repeated many times at decreasing levels.[26] Although the electronic reverberation system used magnetic recording techniques, it did not use magnetic tape. Instead of tape, it used a delay wheel. A magnetic recording surface was applied to the outline of the wheel. The sound of the music performance on stage was picked up by microphones and recorded onto the wheel from the recording head. The playback heads around the wheel then played the recorded signal back with different delay times. The delay times could be determined by moving the individual positions of each of the playback heads. The output of the last head could be fed back to the recording head to prolong the series of repetitions. The outputs from the heads were routed to loudspeakers at various positions in the hall such as the ceiling, alongside the balustrade of the balconies and in the "dead" corners underneath the balconies. Every output was routed to several loudspeakers that were spread throughout the hall in an arbitrary way, so that each delayed signal received the ear of the listener from multiple directions and distances, thereby increasing the diffuseness of the overall sound impression. The audience should never have the impression that the sounds came from the speakers.[27]

23 VERMEULEN, R. Stereonagalm [stereo reverberation], *Philips Technisch Tijdschrift* 7–8 (1955): p. 223.

24 Ibid., p. 224.

25 STOKOWSKI, *Music for All of Us,* p. 98.

26 VERMEULEN, R. Stereo-Reverberation. *Journal of the Audio Engineering Society,* 1958, vol. 6, issue 2, p. 124.

27 VERMEULEN, Stereonagalm, p. 224–28.

A first experimental setup of the system was made in the demonstration hall of the acoustics department of Philips Research Laboratories, where it was presented to the public for the first time during the first International Congress on Acoustics in Delft (ICA) in June 1953. Instead of installing the complex system in Delft, the participants of the congress were brought to Eindhoven by bus to attend the demonstration.[28] The system had been demonstrated so successfully that in 1954, the step was made to try and change the acoustics of the previously mentioned theatre hall of the Philips Ontspanningsgebouw into the acoustics of a concert hall. A similar prototype version of the system was installed in the hall of the Gebouw voor Kunsten en Wetenschappen (building for arts and sciences) in The Hague that same year. The first public performance was given on 30 November 1954 with the The Hague Philharmonic. A more pronounced demonstration of the system's capabilities was given after the concert. The response of the audience was positive, and the members of the orchestra and the soloists had clearly and consciously experienced an improvement in the "playability" of the hall.[29]

After the development of the system at Philips Research Laboratories had left its experimental phase, it became commercially available through Philips' ELA-division under the serial number EL6910. It now had four playback heads instead of six. The system was sold for instance to the Teatro alla Scala in Milan, where the conductor Herbert von Karajan collaborated with ELA engineer D. Kleis during its calibration. The reverberation system was inaugurated with a performance of Mozart's opera Die *Zauberflöte* under direction of Von Karajan on 7 December 1955.[30] Later, in 1958, when Von Karajan was asked to conduct a performance in the Grand Auditorium of the World's Fair in Brussels, he would only accept the invitation on the condition that a similar system would be installed there. His request was granted.[31]

The Congress for Music and Electroacoustics in Gravesano

In August 1954, the conductor Hermann Scherchen hosted the international congress *Musik und Elektroakustik* (music and electroacoustics) at his studio complex in Gravesano, Switzerland.[32] The lecturers included Vermeulen, the German physicist Werner Meyer-Eppler,[33] the inventor of the *ondes Martenot* Maurice Martenot, the composer and

28 ZUURVEEN, Frans. Van radiolamp naar Compact Disc – en verder [from radio bulb to Compact Disc – and beyond]. In *Eindhoven Muziekstad,* ed. Jan van OORSCHOT and Frans KRÄMER. Hapert/Eindhoven: Kempen Pers bv, 1992, p. 141.

29 VERMEULEN, Stereonagalm, p. 231.

30 KLEIS, D. Moderne geluidstechniek II – elektro-akoestische voorzieningen in grote theaters [modern sound engineering II – electroacoustic facilities in large theatres]. *Philips Technisch Tijdschrift* 1959, 2–3, p. 64.

31 ZUURVEEN, *Van radiolamp naar Compact Disc,* p. 141.

32 Ibid.

33 Werner Meyer-Eppler had previously founded a studio for electronic music at the Nord West Deutsche Rundfunk (NWDR) together with Robert Beyer in 1951.

trautonium player Oskar Sala, the inventor of the *trautonium*[34] Friedrich Trautwein, the composer Pierre Schaeffer and his technician Jacques Poullin. The Philips electronic reverberation system – though still in its experimental phase – was set up in Gravesano for the occasion. To demonstrate Vermeulen's achievements, a recording of the final chorus of Johann Sebastian Bach's *Matthäus Passion* was played and fed to the loudspeakers of the system with different time delays.[35]

The proceedings of the congress were published as a book in July 1955 under the title *Musik –Raumgestaltung – Elektroakustik* (music – space design – electroacoustics)[36] and were edited by Meyer-Eppler. In his contribution to the proceedings, Vermeulen described the fact that despite all technical progress, it was still possible to distinguish sound reproduction by loudspeakers from the original sources. Vermeulen considered this to be the key problem of electroacoustics. He agreed that increasing the frequency range to 12 kHz, 20 kHz or even into the ultrasonic might be necessary,[37] but he doubted whether that alone would solve the problem.[38] Stereo reproduction was also considered to be a part of the solution, but then still the listener was in a much smaller space than that where the music performance had been recorded. The next step therefore had to be to imitate the proportions of the concert hall in the listening room.[39] Although there was no final proof yet, Vermeulen believed that diffuseness played an even more important role here than reverberation.[40]

Vermeulen's Retirement

When Vermeulen gave a lecture in Gravesano during the celebration of the fifth anniversary of Scherchen's Elektroakustisches Experimentalstudio on 8 August 1959, the day of his retirement was less than two months ahead. Vermeulen used that opportunity to look back at his career:

> When, thirty-five years ago, I built my first loudspeakers, I quite naturally supposed that I could best check my results by asking the opinion of professional musicians. It was a great disappointment to say the least, and still worse, that their opinion was more influenced by the quality of the musicians, both composer and interpreter, than by the defects of my loudspeaker. They would prefer the reproduction of good music by a bad loudspeaker to that of bad music by

34 The Trautonium is an electronic keyboard instrument invented by Friedrich Trautwein around 1929.

35 VERMEULEN, R. *Music and Electroacoustics, Lecture with Demonstrations*. Gravesano, 8 August 1959, manuscript at the archive of the Institute of Sonology.

36 MEYER-EPPLER, Werner (ed.). *Gravesano – Musik – Raumgestaltung – Elektroakustik* [music – space design – electroacoustics]. Mainz: Arsviva Verlag, 1955.

37 In the 1948 article about the multiplication of concerts, Vermeulen had described an upper limit of 8,000 Hz as being sufficient.

38 MEYER-EPPLER (ed.), *Gravesano,* p. 132.

39 Ibid., p. 136.

40 Ibid., p. 138.

> a good loudspeaker. [...] So I came to the conclusion that the reproduction of music was not a musical but a technical problem and that we should not draw musicians into it.[41]

And even in the development of ambiophony and electronic reverberation systems, there had been little or no collaboration with musicians. "*Music was still considered as a given object, to be studied as such by scientists, to be handled by the technician according to objective standards. Their subjective taste or musical preferences should not be allowed to enter into their work.*"[42]

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41 VERMEULEN, R. *Music and Electroacoustics, Lecture with Demonstrations*. Gravesano, 8 August 1959, manuscript at the archive of the Institute of Sonology.

42 Ibid.