



INTERNATIONAL NETWORKS OF FINNISH ACOUSTICIAN PAAVO ARNI

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ABSTRACT

Mr Paavo Arni (1905–1969) was a central influencer in the field of acoustics in Finland since the 1940's until his death. Paavo Arni ran an engineering office specialized in acoustics, but he was also active in education, founding of the Acoustical Society of Finland, preparing regulation concerning sound insulation of apartment buildings as well as occupational noise. He also supported research on acoustics in Finland and internationally, too. In addition, he was the author of the first Finnish handbook on acoustics published in 1949. The base of the wide range of activities of Paavo Arni was possible because of his main work at the Finnish Broadcasting Company YLE. He began as a studio manager in 1931 and ended his career as a technical director of YLE. Construction of studios provoked a need for knowledge on acoustics. Paavo Arni started to form international connections with other broadcasting companies and with acousticians in the 1930s by making visits, attending conferences and hosting international experts' visits in Finland.

Keywords: *acoustics, history of technology, technology transfer, Finland*

1. INTRODUCTION

Paavo Arni (1905–1969) graduated in 1930 as a Master of Science in Technology from the Department of Mechanical Engineering of the Helsinki University of Technology, but he only worked for a short time in the mechanical engineering industry. During the Great Depression, Arni

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could not find work in his own field, and he ended up working for the Finnish Broadcasting Company as a studio technician in 1931. [1–2]

The engineers of the Finnish Broadcasting Company had to familiarise themselves with acoustics when designing the studios [3]. Arni described this phase in 1963 [4]: “In Finland, as elsewhere, broadcasting was on the rise in the 1930s. Broadcasting technology, like the closely-related sound film and record technology, urgently needed information on sound production, room acoustics, sound insulation and problems encountered while listening to the programme. For this reason, broadcasters in different countries, including Finland, began to delve deeper into sound engineering issues and their solutions.” Knowledge of acoustics was thus focused in the Finnish Broadcasting Company, where an acoustics laboratory was built in the basement of the Radio House (1934) to measure the acoustic properties of structures and materials. [1, 3, 5, 6] Paavo Arni has been featured in research literature from the point of view of the Finnish Broadcasting Company, in which he held several significant positions [1, 3 7–9]. For example, in 1952, he was responsible for the radio broadcasting of the Helsinki Olympic Games around the world (Fig. 1) and, at the end of the decade, for the launch of the Finnish Broadcasting Company's television operations [9–10]. During his career at the company, he progressed to become Chief Engineer in 1952 and then Technical Director in 1964 [9].

Arni's work as an acoustics expert, on the other hand, is only briefly mentioned in research literature [1, 9]. His activities have been described a little more extensively in one area of acoustics: in research on the technology transfer that led to the creation of sound insulation regulations for residential buildings. Paavo Arni played a key role in the technology transfer that took place in the absence of domestic research [11].

Paavo Arni's work as an acoustics expert took place in an era when the advancement of industrialisation and

urbanisation in Finland made noise caused by machines, traffic and housing a social problem that had to be solved in some way. In order to achieve this, it was necessary to define what amount of noise was acceptable in different situations and from different sound sources, meaning that regulations on noise had to be created [11–12]. At the same time, there was also a need for acoustic expertise because theatres and orchestras that had previously performed at town halls, clubhouses, community centres, workers' halls or community halls began to be municipalised, and performance facilities were built for them [13–14]. In the 1940s, people also started paying attention to the acoustics of schools [15].

The purpose of this article is to present Paavo Arni's work as an acoustics expert through his international connections. This article examines how Arni networked with international acoustics experts and how he acquired information about acoustics and conveyed it to Finland. The article focuses on Arni's activities especially in the fields of building and room acoustics and noise abatement. Electroacoustics is excluded from this article. Similarly, Arni's activities at the Finnish Broadcasting Company are not discussed except in relation to building and room acoustics.



Figure 1. Paavo Arni interviewed by the reporter Saara Palmgren during the Helsinki Olympic Games in 1952. Source: Finnish Broadcasting Company Yle Archives.

2. FORMATION OF ARNI'S INTERNATIONAL CONTACTS

The construction of the Finnish Broadcasting Company's studios required knowledge of acoustics, but there was no research and teaching in acoustics in Finland in the 1930s [16]. Therefore, knowledge had to be acquired from elsewhere through technology transfer. One form of this is study trips abroad, which Paavo Arni frequently had in various positions at the Finnish Broadcasting Company from the 1930s onwards [3]. For example, in 1938, he acquainted himself with "modern studio constructions" in Sweden and, in the following year, he studied the sound insulation solutions of the recently completed Vienna radio building [17–18]. Some of Arni's trips were to acoustics conferences [19–20], but most had to do with broadcasting technology. In connection with his travels, he seems to have tried to arrange visits to research institutes specialised in acoustics or to building sites of acoustic interest. Arni's travels abroad were reported in newspapers in great detail. His interest in acoustics is shown by the fact that the newspapers quoted his often enthusiastic reports of the sound insulation, room acoustics and noise abatement solutions he had seen on the way.

An example of how technology developed abroad was transferred to Finland is adjustable room acoustics. In 1946, on the initiative of Hella Wuolijoki, Director General of the Finnish Broadcasting Company, a new music hall was planned for the company in an old military building, the Riding Hall of the Guard in Helsinki [7]. In *Helsingin Sanomat*, the leading Finnish newspaper, in autumn 1946, Arni said that he had recently made a "quick expedition to similar buildings abroad" and continued: "I travelled to Copenhagen and Brussels." In the recently completed radio buildings of these cities, his attention was first drawn to the fact that the concerts broadcast were not played in studios but in concert halls located in the radio buildings. In Brussels, he was also interested in the fact that the studio could "automatically change the acoustics", i.e. use electric motors to rotate hexagonal columns covered with different sound-absorbing materials to the positions required to achieve the ideal reverberation time for the performance [21]. However, the Finnish Broadcasting Company's project to convert the old Riding Hall into a 600-seat concert hall was soon dropped [22].

Despite the discontinuation of the concert hall project, plans for a music studio continued and, in 1949, the Finnish Broadcasting Company's "hall with changing acoustics" was introduced to the press, mentioning that it was unique in the Nordic countries. The hall featured structures that could be turned by hand to adjust the reverberation time to

suit different purposes. Arni (Fig. 2), who presented the hall in *Helsingin Sanomat*, predicted that “construction plans for larger halls in the next few years will use the ‘invention’ now being tested by the Finnish Broadcasting Company.” [23] This did happen: in the early 1950s, the new buildings of the School of Business and Hanko City Hall were completed, and Arni had designed adjustable acoustics for both of them. A little later, the new building of the Swedish School of Economics was completed, featuring a 350-seat festival hall with mechanically adjustable acoustics [24–25].



Figure 2. Paavo Arni presents the adjustable acoustics of the music studio of the Radio House of the Finnish Broadcasting Company in 1950. Source: Finnish Broadcasting Company Yle Archives.

After developing the Finnish application of adjustable acoustics, Arni did not keep it to himself; in 1950, he published its principle in a Finnish architectural journal in his article on the acoustics of the new building of the School of Business [24]. In the same year, he published an article on the subject in *The Journal of the Acoustical Society of America* [26]. In spring 1950, Arni gave a presentation on “changing acoustics” at an international acousticians’ meeting in Marseille. As a result, a group of English acousticians visited Finland in the summer of that year to learn more about this technique [27].

The above shows how Arni networked with foreign acousticians. Thanks to the networking, in the 1940s and

1950s, the meetings of the Acoustical Society of Finland featured presentations by three Danes – Dr. Per Brüel, founder of an acoustic measuring equipment company and assistant professor at Chalmers University of Technology, Dr. V. L. Jordan, leading room acoustics expert in the Nordic countries, and Professor Fritz Ingerslev – as well as Swiss Professor Willi Furrer [28]. During a trip to the United States to study acoustic laboratories in spring 1948, Arni met Leo Beranek, the American regarded as the most important acoustician of the 20th century. During the trip, he visited the acoustic laboratory at MIT, where Beranek was working at the time [29]. At the International Congress of Acousticians in London in summer 1948, Arni met Beranek again [19]. Late that same summer, Beranek made a visit to Finland, hosted by Arni, and mentioned it in his memoirs published 60 years later [30].

By the beginning of the 1950s, Paavo Arni had achieved international fame to the extent that, in autumn 1951, he was invited to London to listen to the problematic acoustics of the newly completed Royal Festival Hall at a test concert [31]. The building was one of the first large concert halls built after the Second World War, and its design had aimed to follow up-to-date guidelines on acoustics as closely as possible [32]. Of the 18 members of the international group of experts that evaluated the acoustics of the originally 3,404-seat concert hall, Arni was among the most critical [31]. The international appreciation for Arni is also shown by the fact that Professor Willi Furrer, after visiting Finland in 1953, published a spectacularly illustrated article on Arni’s design work in the *Schweizerische Bauzeitung* [25].

3. ORGANISATIONAL DUTIES AND PUBLICATIONS

A visit to Helsinki in 1942 by the German Dr. Hans Joachim von Braunmühl proved to be very important for the development of acoustics in Finland. The visit was related to the Finnish Broadcasting Company’s project to construct a new radio building to replace the quickly overcrowded premises on Fabianinkatu [9]. An expert in acoustics and broadcasting technology, von Braunmühl gave a presentation for the company on the acoustic design of buildings, sound insulation, room acoustics and the acoustic properties of building materials. The presentation was published as an extensive two-part article in a Finnish professional journal, translated by Arni [33–34].

The radio building project was dropped during the war, but von Braunmühl’s presentation generated so much interest and enthusiasm for acoustics that, on 25 August 1942, a

meeting was held at the Finnish Broadcasting Company, attended by 11 experts from various fields of acoustics, from both business life and research institutions. Paavo Arni had prepared a proposal for the meeting that “a society should be established in Finland whose task would be to carry out research and measurements in the field of acoustics and to carry out educational work among certain circles.” All participants supported the establishment of the society and, at the end of the meeting, an ad hoc committee was set up to draw up rules for the society. Paavo Arni was elected secretary and convener of the committee. [28]

After the committee had completed its duties, the founding meeting of the Acoustical Society of Finland was held on 29 March 1943, during which the rules of the society were approved. According to them, the society was to organise meetings, presentations and lectures, promote research in the field and the distribution of professional literature, engage in publishing and advisory activities and develop Finnish vocabulary in the field. Paavo Arni was elected a member of the Board of the society. He served as a member of the society’s Board for three periods totalling 26 years, 15 of them as Chairman. [28]

The Acoustical Society of Finland became one of the channels for technology transfer. Although technology transfer relies to a large extent on the actions of individual people, the connections between them and their mobility, contact between individuals is not enough to make it happen. In order to adopt the technology, a more general interest is needed, and the activities must be well-organised [35]. The Acoustical Society of Finland provided the necessary framework for the promotion of acoustics. During its first ten years of operation, eight foreign experts lectured at its meetings. Arni himself gave nine presentations during the same period, at least four of which were based on his trips abroad. [28]

Arni’s most important literary work is a textbook published in 1949, *Käytännöllisen akustiikan perusteet (The Basics of Practical Acoustics)* [36], which remained the only Finnish textbook in the field for over a decade. It was also the result of Arni’s trips and contacts abroad and visits by international experts to Finland: of the 61 titles in the book’s bibliography and recommended literature, 20 were from Germany, 13 from the Nordic countries, 10 from the United States, and the rest from the United Kingdom, the Netherlands and Switzerland. There were only six Finnish references [11]. Based on his book, Arni also lectured on an acoustics course at the Helsinki University of Technology in the 1950s [16]. The development of teaching was on the agenda of the Acoustical Society of Finland during the time that Arni was on its Board [28].

In the 1950s, Paavo Arni’s organisational duties expanded outside Finland. He attended the first International Congress on Acoustics (ICA) in Delft in 1953 [37]. Towards the end of the congress, the representatives of the four Nordic countries gathered together and decided to establish a Nordic acoustical society under the name *Nordiska Akustiska Sällskapet (NAS)* [38]. The Acoustical Society of Finland appointed Paavo Arni as Finland’s representative to the Board of the Nordic society [39]. After the success of the NAS test conference held in Copenhagen in 1954, the first actual Nordic conference was held in Helsinki in 1956, as the Acoustical Society of Finland was the oldest national society in the field in the Nordic countries [38]. The conference was opened by the Chairman of the hosting society, Paavo Arni. When the ICA congress was held in Copenhagen in 1962, the NAS was responsible for organising it. The advisory committee of the congress was composed of members of the Boards of the national member societies. Finland was represented by Paavo Arni and two other Finns [40].

4. COMMITTEE AND RESEARCH WORK

At the initiative of the Acoustical Society of Finland, the Government appointed a committee at the beginning of 1945 to prepare legislation to reduce the harmful effects of noise at workplaces. Paavo Arni was invited to be a member of the committee but, after the death of the Chairman of the committee, he was appointed as the new Chairman in 1947 [19]. At this time, Arni’s study trips abroad were to sites that were important in terms of hearing protection. For example, during a trip to Sweden for a presentation at a radio association meeting in Stockholm in 1945, he studied the “magnificent work done at the ASEA factory in Västerås to suppress the high levels of noise in the factory and offices” [41]. Between 1948 and 1949, he made three trips abroad in connection with the work of the noise abatement committee: in April 1948 to the United States to study acoustic laboratories and “the protection of workers against noise” [28], in July 1948 to the International Congress of Acousticians in London, and again to London in September–October 1949. The experts that Arni met during his travels provided the Committee with research literature in the field [19].

Later, Arni was involved in an international committee relating to noise. Since the early 1950s, he had been involved in motor vehicle noise measurements and, when the NAS started developing a measurement standard in 1956, Arni was appointed as the leader of the standard

workgroup. The workgroup's proposal later served as the basis for the international ISO standard [38].

In 1947, the Board of the Acoustical Society of Finland decided to approach the Ministry of the Interior with a letter on "the drafting of sound engineering standards for house builders". This had been influenced by the fact that, at the society's meeting in the spring of the same year, Dr. V. L. Jordan from Denmark had given a presentation on the regulations concerning sound insulation and noise abatement in various countries. The secretary of the society, Paavo Arni, submitted Jordan's presentation to the press, translated into Finnish, with the title *Current legal rules and standards concerning noise and sound insulation in different countries*. A proposal for a committee for the drafting of domestic standards was submitted to the Ministry of the Interior in spring 1948. [11]

Achieving sound insulation standards proved to be a long-lasting project, whose important milestones were the sound insulation research committee in 1952–1955 and a committee established in 1957, which drafted a proposal for sound insulation regulations published in 1960. Paavo Arni was invited to be a member of both committees. The achievement of sound insulation regulations is probably societally the most significant project initiated by the Acoustical Society of Finland, resulting in the improvement of sound insulation in homes and thereby affecting the daily lives of millions of Finns. The project was not completed until 1975, when the National Building Code of Finland was published for the first time. Its part C1 dealt with sound insulation in buildings. [11]

Arni did not only use his networks to transfer information from abroad to Finland, but he was also able to support research elsewhere [31]. For example, he was involved in organising Leo Beranek's second visit to Finland in 1960, when Beranek was writing the first version of his famous book on concert halls [30]. During his trip, Beranek visited the University of Helsinki's festival hall, which had been rebuilt and expanded in 1945, as well as the Helsinki House of Culture and the Turku Concert Hall. Arni was responsible for acoustics in all these projects. At the time, the Turku Concert Hall (Fig. 3) appears to have had a good international reputation, and thus it and the House of Culture were introduced in Beranek's book [42].

In the early 1950s, the diffusion of the sound field in a space was a subject of interest to researchers, since it had been observed that the smooth surfaces favored by the architecture of the era did not provide listeners with the same experience of acoustics as old concert halls did, even if the reverberation time was the same. Arni defined the matter as follows: "In old halls, the sound is reflected from broken surfaces, columns, recesses, balconies, etc. as

irregularly as possible, diffusively, which again means as even a reflected sound field as possible throughout the hall, i.e. balanced and good audibility. In a modern hall, special diffusers are used in an attempt to achieve this diffusion [...]". Convex spherical surfaces had been arranged on the surfaces of the festival hall of the Swedish School of Economics designed by Arni and finished in 1953, and vertical wavy and prismatic surfaces had been placed on the side and back walls [43]. Arni's article in the architectural journal in 1955 is apparently the first Finnish text describing diffusion.

Among the researchers Arni met in London in 1951 [31], Professor Willi Furrer and Professor Erwin Meyer from the University of Göttingen studied diffusion in the early 1950s. Furrer also gave a presentation on the subject at a conference in Delft in 1953 [44], attended by Arni. In an article in 1955, Arni said that a research group at the University of Göttingen was studying diffusion in acoustically interesting halls [43]. The festival hall of the Swedish School of Economics was also measured in this context, and so was the Turku Concert Hall. Paavo Arni was involved in arranging access to both spaces for the group of researchers, for which Meyer and Thiele thanked him in a scientific article they published in 1956 [45].



Figure 3. Paavo Arni was responsible for the acoustics of the Turku Concert Hall finished in 1952. Source: Sibelius Museum archive.

5. ARNI AS ACOUSTICAL DESIGNER

Paavo Arni's design work includes concert halls and theatres, sacral buildings, educational institutions, office buildings and hotels. They were designed by leading Finnish architects of their time, and Arni seems to have had long-term cooperation especially Kaija and Heikki Siren. Of Alvar Aalto's projects, Arni was involved in designing

the acoustics of the House of Culture, and he also started design work for the Finlandia Hall before his death. Abroad, Arni participated in the design of the Brucknerhaus Concert Hall in Linz and the studios built by Austrian Radio in Salzburg, Innsbruck, Dornbirn and Linz [46]. Paavo Arni described his design work methods in his book *Käytännöllisen akustiikan perusteet (The Basics of Practical Acoustics)* [36]. According to Architect Alpo Halme, who worked in Arni's office, the book "contained almost all the relevant information that existed at the time." [46] In terms of measurement methods, Arni refers in his book to the German DIN 4110 standard from 1938, and he presents a mass law formula for the calculation of airborne sound insulation. For room acoustics design, the book presents formulas by Sabine, Eyring and Millington for calculating reverberation time. In addition, there are tables and diagrams on both topics with recommendations for different spaces and material properties. Arni also introduces the use of geometric room acoustics in design and the light and water models used by the Finnish Broadcasting Company. Geometric room acoustics were used by him in the design of the rebuilding of the University of Helsinki's festival hall.

The water model was used in the discontinued project of converting the Riding Hall of the Guard into a concert hall for the Finnish Broadcasting Company. Arni explained the water model to the press in 1946: "A metal basin has been made that closely follows the shape of a concert hall, and its bottom is made of glass. There is also a metal ball hanging at the end of a kind of lever. The metal ball corresponds to a sound source in tests made with this water model. When it touches the surface of the water, waves are formed on the surface that correspond to sound waves. By observing these, we can see how sound waves are reflected from the surfaces of the room." It was also reported that the Finnish Broadcasting Company's personnel had named the water model "Arni's aquarium" (Fig. 4). [47]

When Arni started his work, there were yet no international standards for acoustic measurements, but he lived to see measurement standards published for most conventional measurements. The magnitude of the change is illustrated in an article published by Arni in 1944, in which he describes reverberation time measurements in concert halls. At the time when Arni wrote his article, an orchestra was used as the sound source, and works suitable for measurements included "for example, the end of Sibelius's 5th symphony, the first bars of Beethoven's Coriolan Overture, the beginning of Bach's Toccata and Fugue in D Minor." In all of these works, forte sections are followed by rest, during which the reverberation time could be measured from the decrease in sound pressure. [48]



Figure 4. Paavo Arni demonstrates his aquarium, a water model built to study the acoustics of the upcoming concert hall in 1946. The hall was never realized. Source: Finnish Broadcasting Company Yle Archives.

6. CONCLUSIONS

The above is an account of Paavo Arni's work as an acoustician and his international networks, created on the basis of written sources. In recent decades, the history of technology has been dominated by ideas about the social construction of technology [49], with little attention being paid to the influence of individuals on the development of technology. According to the sources available, Paavo Arni seems to have been an exceptionally influential person in his field. Arni's design work does not necessarily differ in significance, scope or difficulty from the work of other Finnish acousticians who worked at the same time. What sets him apart from his contemporaries is his broad scope and apparent desire to acquire and share information as well as to promote the development of the field of acoustics and the creation of better sound conditions in Finland. This also made him the first internationally known Finnish acoustician who, through his extensive contacts, was able to convey the latest research information to Finland, where the chair of acoustics was established only after his death [16]. Paavo Arni's main occupation in the fast-developing broadcasting industry provided opportunities to establish

contacts with international acoustics experts at conferences and on study trips and by hosting visits by foreign experts in Finland. Young Arni's aim seems to have been to learn about different fields of acoustics and convey information about them to Finland. Subsequently, he seems to have sought to alleviate the social problems associated with sound conditions that were developing, as exemplified by his work in the noise abatement and sound insulation committees. His work thus ranged from practical design work to societal influence. Some of the things he advocated became reality only after his death, such as the issuing of sound insulation regulations [11].

A key part of Paavo Arni's career and achievements was the international network of experts that he had formed since the 1930s, which enabled the transfer of technology to Finland, where there was not much teaching and research of acoustics in the absence of a chair. Juhani Borenus, who worked under Arni at both the Finnish Broadcasting Company and Arni's engineering office, assumed that Arni's mobility in international circles was made easy by his diverse language skills and his childhood environment in the multicultural Vyborg. Although Arni managed to achieve a lot and was efficient in all his duties, his work was left unfinished: Paavo Arni died in spring 1969 at the age of 64, and his plan to focus on acoustic design during retirement did not materialize [1].

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