Erwin Meyer – A great German acoustician
Biographical Notes*

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1. Introduction

Erwin Walter Meyer (1899–1972) was the leading German acoustician of his time. His interests covered an exceptionally wide range. He and his co-workers have contributed essential progress to many aspects of acoustics, in the early years mainly to electro-acoustics and acoustic measurement techniques. Erwin Meyer (he rarely mentioned his second Christian name Walter) was born on July 21, 1899 in Königshütte (Upper Silesia, then in Germany, now in Poland). His parents were the postmaster Paul Meyer and his spouse Margarethe, née Schleiffer. Erwin Meyer died on 6 March 1972 in Pontresina (Switzerland). The photo in Figure 1 shows him at an age of 65 years. His professional career was determined by three places: Breslau, Berlin, and Göttingen, all in Germany.

Figure 1: Erwin Meyer in the year 1964.

*Modified translation of the German text "Erwin Meyer – ein bedeutender deutscher Akustiker / Biographische Notizen": http://www.guicking.de/dieter/Erwin-Meyer.pdf – in short form also published as a book, Universitätsverlag Göttingen 2012, ISBN 978-3-86395-059-0. Also onliner: http://webdoc.sub.gwdg.de/univerlag/2012/Guicking_meyer.pdf

Figure 2: Erwin Meyer as soldier im Jahre 1917.

2. Breslau

Erwin Meyer grew up in Breslau (then German, now Polish). He attended a grammar school (with bias on Latin and Greek) which he finished on December 12, 1917 with an early graduation since the final school classes were recruited for military service in World War I (1914–1918). Presumably to please his parents, he posed for a photo in uniform (Figure 2), incidentally the only photo of the young Erwin Meyer. Being a soldier was an unloved duty for him – he later said that he was proud to leave the army as "Gefreiter" only, a very low rank. But the terrible war-time experiences determined his further life as he gave up the former plan to study Greek and Latin languages in favor of something nearer to modern life. His desire to study medicine had to be abandoned because his parents could not finance a doctor's practice for him [1]. Instead, he enrolled for Mathematics and Natural Sciences at the University of Breslau in December 1918.

At that time, acoustics was considered an almost finalized field, after the work of Hermann von Helmholtz. In Breslau, however, Erich Waetzmann worked on acoustics and gave Erwin Meyer a PhD theme about forces that sound waves exert on resonating membranes (Bjerknes forces). Meyer finished this work in December 1922 and gained the German title of Dr. phil. [4]. Meyer's parents could not imagine that a physicist could earn his living, and urged him to apply for a high-school teachers qualification, the "Staatsexamen" for which he wrote a paper on a mathematical problem [5, 8]. He passed the oral examination on February 22/23, 1924 with excellence,[1] and when the chairman asked him afterwards if they could now expect him to serve as a teacher, he answered honestly "I don't think so" [1]. From January 1, 1923 through November 15, 1924 Meyer served as lecture assistant for Otto Lummer, also professor of physics in Breslau. This sensitized him for the conception of impressive lecture experiments.

[1] All documents referred to in this publication are still in our possession.

Meyer's father brought him post-internal publications about new technical developments so that he could familiarize himself, among others, with the brand new broadcasting technology. A lecture given in Breslau by Hans Salinger, a member of the central post authority in Berlin, was essential for Meyer's further career. Salinger wanted to demonstrate his radio set, but it had suffered from a transport damage and could not be repaired in time. Lummer knew that Meyer had built his own receiver which Salinger borrowed for his demonstration. Salinger realized not only that Meyer's set was better than his own, but he was deeply impressed by talking to Meyer and suggested that Karl Willy Wagner, the director of the Berlin post authority, should offer Meyer a position at his institution [1]. Meyer accepted the offer and started as "Wissenschaftlicher Hilfsarbeiter" (which means something like scientific laborer) on November 16, 1924 at the "Telegraphentechnisches Reichsamt," later renamed "Reichspostzentralamt." His research field was telephone and radio technique, in particular music reproduction as naturally as possible.

3. Berlin

Meyer realized soon that satisfactory radio reception was only possible with a better understanding of room acoustics, properties of microphones, loudspeakers, musical instruments, sound fields and gramophone pick-ups. It became evident that new measurement procedures had to be developed which did not yet exist and which became possible only with the recently developed vacuum tubes (mainly for amplifiers and rectifiers). In addition to two papers on the hearing process from the collaboration with Waetzmann (1925) [6, 7] and a comprehensive handbook article about hearing [15] (1927), a rapid sequence of articles were published on testing loudspeakers [9] and sound fields [10] (both 1926), on measuring frequency response curves of telephones and loudspeakers [13], and on nonlinear distortion of loudspeakers [14] (all 1927). In 1928, Meyer described a method for automatically recording reverberation curves with frequency mixtures [17] and a further method for automatic sound spectra recording with the search tone method [18, 19]. Together with M. Grützmacher, Meyer developed a calibration procedure for capacitor microphones [20]. "Modern methods of sound analysis" was the subject of his "Habilitationsvortrag" at the Technical University of Berlin, a talk to be given in the German procedure to qualify for teaching at a university (December 1928). From that time on, Meyer gave lecture courses on Technical Acoustics. He also made some experiments on auditory testing and wrote a critical paper on the methods used at that time [16]. In the same year Meyer won a RM 1000.– prize for a paper on the application of modern acoustic measurements to electroacoustic problems, in particular loudspeakers [223].

In 1929, Meyer published investigations on the cathodophone, a diaphragmless microphone with a plasma section which then was used for sound film and radio records [22]. Meyer showed that it was a particle velocity receiver (rather than a pressure sensor as common microphones are). He further described methods for the measurement of frequency response curves of gramophones and pick-ups [25]. Also in 1929, Meyer was the first to introduce reverberation room measurements for the total power radiation of sound sources [26], and he improved sound absorption measurements [23] which until then were performed by ear and stop watch as introduced by W. C. Sabine [559] – both of Meyer's innovations are now standard procedures.

For "Müller-Pouillets Lehrbuch der Physik", a multi-volume physics handbook, Meyer contributed sections on microphones [27, 28], on methods of sound recording [29], on automatic sound analysis [30], and a comprehensive textbook article on the measurement of sound intensity [31]. The editors of a dictionary on electrical telecommunication asked Meyer to contribute definitions of acoustic terms [21]. Manfred von Ardenne wrote in a book that he had vivid discussions on telecommunication with Erwin Meyer when Meyer visited him in August 1929 [300]. Also the editors of a book on pioneers of telecommunication asked for a chapter about Erwin Meyer [298].

Karl Willy Wagner, the director of the Reichspostzentralamt, had realized the importance of analogies between mechanical, acoustical, and electrical oscillations and promoted the foundation of the (still today existing) "Heinrich-Hertz-Institut für Schwingungsforschung" [Heinrich-Hertz-Institute for Vibration/Oscillation Research] in Berlin where investigations in these disciplines could be performed in four closely cooperating departments: Electrical Oscillations and High-Frequency Technology, Telegraph and Telephone Technology, Acoustics, and Mechanics. Erwin Meyer was appointed head of the Acoustics Department on April 1, 1929.

In 1930, Meyer published (with his coworker G. Buchmann) a method to measure the particle velocity amplitude of gramophone records by the width of the reflected light beam [34], in German popularly known as "Meyer-Breite," which even 30 years later was used and improved [578]. He further developed an automated device to measure the reverberation time [36]. Sound insulation and absorption measurements with his new electronic equipment were published in [24, 32]. For applications in audiology, Meyer had constructed a new electronic device to measure the hearing loss more precisely than with previous equipment [35]. Papers on sound insulation in buildings were published in 1931 [37, 38], and he applied the search tone analysis to measure the spectra of musical instruments [40].

Soon after the foundation of the Acoustical Society of America (ASA) in 1929, Meyer applied for membership, and he was elected a Fellow in 1931 [230], indicating his already great international reputation.

In 1932 Erwin Meyer married Editha Bergan, 11 years younger than himself. Their daughter Angelika was born 1942. Mrs. Meyer survived her husband by more than 26 years. Since 1968 Angelika is married with the author of this article who thereby had close personal contact to Erwin Meyer in his last years and learnt to estimate him not only as his academic teacher but also as a man with warmth and humor. Erwin Meyer saved all documents relevant for his professional career, and we have access to all of them.

Meyer and his staff published measurements of the acoustic properties of wooden plates [43] and glass panes in 1932 [44], on the noise emission of vehicles [47], on the angular frequency dependence of sound absorption by porous materials [48, 49], on magnetic sound recording [45, 46, 50], on the strike tone of bells [53], and on the acoustics of rooms lined with wooden panels [54]. Here, Meyer pointed out that the better acoustic performance was caused by absorption of low-frequency sound (which improves the frequency dependence of reverberation) and not by sound radiation of the panels acting as sounding boards as was previously believed.

In 1934, Meyer wrote overviews on acoustic measurement techniques [55], on the sound recording methods available at that time [56], on the worldwide progress in acoustics during the last four years [57], and on the measurement of structure-borne sound [59]. Meyer had developed a method for sound spectroscopy equivalent to the optical grating spectroscopy [61, 67] which, however, did not find much application. At a meeting for teacher's training, Meyer gave a talk on acoustic measurement techniques and musical acoustics [58].

In 1935, Meyer developed a level recorder with logarithmic characteristic for reverberation time measurements; it contained an exponentially shaped fluid resistor through which a scanning needle was moved [60, 62]. The device displayed an impressive dynamic range of 80 dB. This equipment was used, e. g., to measure reverberation in concert halls, including the influence of the audience [63]. Meyer and Thiede contributed new insight into the electronic noise of thin-layer carbon resistors [65, 66]. The sound transmission through multi-panel walls was modeled as acousto-mechanical low-pass filter [68, 69], and a newly developed pick-up to measure the particle velocity of structures was applied to vibrations in buildings [70, 71]. A detailed analysis of low-frequency sound absorption by non-porous plates with damped air cushions in front of walls is published in [73]. Meyer also developed methods to improve the sound insulation of double and triple walls or windows by placing absorptive material at the gap edges and by subdivisions, and he was the first to publish an equation for the cut-off frequency of such structures [81].

The publication list, starting with [4], shows a wide spread of acoustical papers over a variety of journals. The increasing research activities in Germany and here mainly by Meyer's team at the HHI raised the desire "to establish a special journal in which all scientific and technical progress in the various acoustical disciplines can be collected" [72]. With support by the "Deutsche Forschungsgemeinschaft" Meyer and his co-worker M. Grützmacher succeeded in 1936 to found the "Akustische Zeitschrift," after "Revue d'Acoustique" (since 1932) [570, p. 19, bottom right] the second journal in Europe specialized in this field (the Journal of the Acoustical Society of America, JASA, existed since 1929). Meyer and Grützmacher were the editors until the publication of the "AZ" had to be terminated in 1944 due to restrictions imposed by the war.

Meyer and Waetzmann pointed out interesting relations of acoustics to general physics in a paper given at the 1936 Meeting of the German Physical Society [75, 76] where they emphasized impedance aspects in acoustics and electricity, physiological similarities of ear and eye, power measurements in the Ulbricht sphere (optics) and the reverberation room (acoustics), as well as the role of ultrasonic spectroscopy for molecular acoustics. Further publications on room and building acoustics in 1937 and 1938 aimed at acoustic measurements [84, 90, 99], propagation of air- and structure-borne sound in buildings [83, 85], reverberation room measurements [86], sound absorption by springs and damping materials [87], and sound recording for cinema films [89]. Meyer wrote a further survey of international progress in acoustics from 1934 through 1937 [94], and on testing materials with ultrasound in 1938 [88] and 1939 [98]. Ernst Lübcke organized a lecture course on noise protection in the spring of 1938 where E. Meyer gave a paper on measurement techniques; the papers were published as a book in 1940 [99].

Meyer was elected personal tenured professor on April 1, 1938. He refused calls to the universities of Breslau (1938) and Jena (1939).

Meyer's reputation as an expert in acoustics, in particular electroacoustics, resulted in many invitations to give lectures abroad. In June 1931, he reported in London on his measurements of the spectra of musical instruments and the analysis of noise [41], also in 1931 he gave papers at an acoustical conference in Leningrad and at an international congress on otology in Basel (Switzerland), in 1932 at an international congress on electrical engineering in Paris [51], 1935 again at a meeting on audition in London. Meyer's participation at an acoustical congress in Moscow in November 1935 was, "from basic considerations," not permitted by the (Nazi) science ministry. At the Physical Society of Zürich (Switzerland), Meyer reported on "room acoustic problems" with emphasis on reverberation and absorption measurements [77]. The Acoustical Society of America gave a Luncheon [232] in honor of Erwin Meyer at their 16th Meeting in October 1936 where he presented two papers on room and building acoustics [78, 79, 80]; he also gave lectures at the Bell Telephone Laboratories and at the Harvard University during his trip to USA. In 1937, he participated in an International Conference on Standardization in Paris, and in October 1937 he gave five lectures with experimental demonstrations on electroacoustics in London (see Figure 3) which were published as a book by the Uni-

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By Prof. Dr. ERWIN MEYER

(of the Institut für Schwingungsforschung, Berlin)

at 5.30 p.m. on

October 12th, 13th, 15th, 18th, and 20th, 1937

SYLLABUS

LECTURE I—October 12th

Chairman: PROF. L. BAIRSTOW, C.B.E., D.Sc., F.R.S.

PHYSICAL AND PHYSIOLOGICAL FOUNDATIONS.—The different types of sound waves and their physical properties. Sound intensity. Loudness Units, db and phon. Frequency and intensity ranges of sound sources. Supersonic sound.

LECTURE II—October 13th

Chairman: Mr. A. P. M. FLEMING, C.B.E., M.Sc., M.I.E.E., F.Inst.P.

ELECTRO-ACOUSTICAL MEASUREMENTS.—Sound intensity measuring devices. Apparatus with a logarithmic scale. Phonmeter. Sound analysis, searching tone, spectrometer with filters, grating spectroscopy, filter oscillograms.

LECTURE III—October 15th

Chairman: SIR NOEL ASHBRIDGE, B.Sc., M.I.E.E.

MICROPHONES AND LOUDSPEAKERS.—Distortion (frequency response, nonlinear distortion, transients) and its measurements. Pressure and pressure gradient microphones, especially those of the electrostatical type. Pick-up of speech in noisy rooms. Loudspeakers and their application at large meetings.

LECTURE IV—October 18th

Chairman: SIR GEORGE LEE, O.B.E., M.C.

RECORDING OF SOUND.—Gramophone recording, Magnetophone (steeltape and iron powder filmband).

LECTURE V—October 20th

Chairman: Mr. A. T. DOVER, M.I.E.E.

ARCHITECTURAL ACOUSTICS.—Geometrical and statistical room acoustics. Eigenperiods of rooms. Electro-acoustical reverberation meters. Porous and vibrating sound absorbers. Electrically coupled rooms.

The Lectures, which will be illustrated with lantern slides and accompanied by demonstrations of some modern acoustical apparatus, are addressed to students of the University and to others interested in the subject.

ADMISSION FREE, WITHOUT TICKET

S. J. WORSLEY,
Academic Registrar.

Figure 3: Announcement of Erwin Meyer's lecture course in London, October 1937.

versity of London [95]. At the Technical University of Zürich (Switzerland) he gave a lecture course on room and building acoustics in 1938.

Of eminent importance is Meyer's invention of the lining of "anechoic rooms" with absorber wedges of porous material [91]. Such a room was built at the Heinrich-Hertz-Institute [100, 101], and a detailed description was published in 1940 [102].

In order to gain experience with the sound absorption measurements in reverberation rooms and possibly develop a standard, Meyer initiated comparative measurements with equal material samples at eight laboratories [96]. But a standard was published only much later [584].

Together with Konrad Tamm, Meyer investigated natural vibrations of gas bubbles in liquids and their damping [97], and dynamic moduli of elastic materials [103].

During the second world war (WW II, 1939–1945) interest in underwater acoustics was promoted, especially by the development of sonar ranging. All scientists in Germany (as in other countries) were committed to do research on "war-essential subjects." Meyer's working group at the HHI investigated sound propagation in shallow sea water and sound absorption in sea water, in particular the influence of gas bubbles. The initially successfully operating German submarines were, since 1943, detected by the improved sonar technology and most of them were destroyed. Meyer's group was instructed to produce an acoustic countermeasure. They developed absorbers of underwater sound: rib-type absorbers for the lining of test basins (acting in a similar way as wedge-type absorbers for air-borne sound), consisting of three rubber layers glued together with air inclusions in the central layer, and, to protect underwater objects (e. g. submarines) against sonar ranging, a thin-layer absorber of a few millimeters thickness, consisting of a cleverly structured rubber layer with air inclusions – a two-circuit resonance absorber effective in the typical frequency range of sonar systems. The research results were classified and could not be published. The project "rib-type absorber" carried the cover name "Fafnir," the thin-layer absorber was named "Alberich," after old nordic legend figures who could hide themselves by magic hats. Meyer was convinced that the war and the Nazi regime would not last very long and retained – with much personal risk – carbon copies of all reports which he hid under the attic floor in the home of his parents-in-law in Thuringia [1].

Meyer and his co-workers believed that the submarine lining was not applied in combat during WWII [106, p. V]. But it became evident as late as in 1998 that the German Navy had coated at least one submarine (U-480) with the sound absorbing rubber layer. This boat succeeded in August 1944 in the British Channel by torpedoing four ships of the allied forces without being localized by sonar. Prior to a new action early in 1945, the British Secret Service had recorded and deciphered the radio communication encoded by the German machine "Enigma," and the code name "Alberich" revealed to them the nature of the undetectable submarine. The British Navy had secretly moved the navigational route and mined the previous route so that U-480 in vane looked for targets before it was destroyed by a mine on February 24, 1945. The wreck was found by chance in 1988, when a fishing net got entangled by the boat. Divers realized that they had found the first "Stealth U-Boat" ever built. The TV transmitter *arte* has produced an emotional film (in German) about U-480 and its history which was broadcast on February 18, 2008 [587].

At the end of the war, Meyer and his staff were in Pelzerhaken at the Baltic Sea in the German State Schleswig-Holstein where they had been evacuated two months before the war ended, after the Berlin HHI was destroyed by bomb raid. Meyer was on leave from his duties at the Technical University of Berlin, his position was held by E. Lübcke for some time.

Schleswig-Holstein was in the British occupation zone, Thuringia in the American. When it became obvious that Thuringia should go to the Russian zone in exchange for parts of Berlin, Meyer contacted the British Military administration and asked for someone with technical background. He was received by an officer who told him that he had studied in Berlin and heard Meyer's lectures, and he asked how he could help him. Meyer informed him that there were important documents in Thuringia which he would like to save before the Russians occupied the village of his parents-in-law, and since railroad connections were not yet working again, Meyer asked the officer for a vehicle with driver, if possible a lorry to bring into "the West" some personal belongings and his wife and daughter. So Meyer traveled mid 1945 through the destroyed Germany on the platform of the lorry (the driver did not allow the former "enemy" to sit in the cabin), and finally could bring the documents, his family and some personal belongings to Pelzerhaken [1].

Meyer succeeded to make a contract with the British occupying authority which allowed him and his team to write a comprehensive report from the war-time documents.

Figure 4: The “Red House,” Bunsenstr. 7 (from [558, p. 73]).

This report “Sound Absorption and Sound Absorbers in Water” was published by the American Navy [106] and is still today highly esteemed by hydroacousticians all over the world because of the wealth of material and the carefulness of the investigations.

4. Göttingen

After the war, Meyer got two appointments to university chairs in the USA, and one to the University of Göttingen which he accepted – hoping that science in Germany would recover after the war. On April 1, 1947 Meyer became director of the newly founded Third Physical Institute (“Drittes Physikalisches Institut,” later abbreviated DPI). This Institute was created by merging a former Institute for Applied Mechanics with an Institute for Applied Electricity (both chairs were vacant at that time). This tradition fitted well with Meyer’s intention to lead an Institute with research groups on vibration and oscillation research, both in mechanics/acoustics and electricity/microwave technology as he had experienced it at the Heinrich-Hertz-Institute in Berlin. The former Institutes were housed in different buildings, the “Applied Electricity” in a red clinker building, in the Institute’s jargon the “Red House” (Figure 4), to discriminate it from the former Institute for Applied Mechanics, the “White House,” a former villa (Figure 5). Both buildings were separated by a footpath of about 200 m – not optimal, but acceptable for the beginning. In the “Red House” was a small lecture hall and rooms for practical courses (“Praktika”) where students could perform a series of experiments on several aspects of the research fields of the former Institute (applied electricity), under Meyers’s guidance extended to include acoustics and mechanical vibrations. In 1952, an additional practical course on electronics was established. Both “Praktika” were updated continually to provide the students with modern equipment and subjects. In the Red House was also located an electronics workshop with the exceptionally competent leader Heinrich Henze who also served as Meyer’s lecture assistent (see Figure 15).

The practical courses and the lecture experiments were typically complementary conceived: an acoustic experiment was followed by an analog electrical experiment (or vice versa). Some of these experiments are described in [112]. The co-author Hans Severin had guided the “Red House” during the vacancy and continued his research work

Figure 5: Right: the “White House,” Bürgerstr. 42.

on microwaves until he left the Institute 1957. Meyer and Tamm presented 1949 a new impedance locus recorder which presents the loci of electro-acoustic devices or of purely electric circuits very fast and is therefore well suited for lecture demonstrations [110].

Meyer’s new Institute received soon worldwide recognition. He was very successful in fund raising. In order to continue his former work on underwater sound, Meyer completed a research contract with the British “Department of Scientific and Industrial Research” (DSIR), later on the “Department of Naval Physical Research” (DNPR). This contract started mid 1948 and was extended year after year until 1978 – long after Meyer’s death when Manfred Schroeder (also a former student of Erwin Meyer) was his successor as director of the DPI.

Meyer’s first PhD student in Göttingen (starting July 1, 1947) was Helmut Haas, and the subject of his thesis were experiments on the influence of a single echo on the audibility of speech. Meyer suggested Haas to study the influence of many parameters: echo delay, intensity, coloration, direction of incidence, speed of speaking, and room reverberation. It was known since about 1927 that early reflections of a sound signal are not recognized by our ears as echoes, but subjectively blended with the primary sound if the delay is no longer than about 50 ms (e. g., [562, p. 8]). The most important and new result of Haas’s experiments was that the early echo can be up to 10 dB louder than the primary sound without disturbing the acoustic impression. Meyer realized immediately the relevance of this finding for public address systems and initiated a rapid English translation of Haas’s thesis which was published in December 1949 [306] and found rapidly worldwide interest. R. H. Bolt proposed to call the effect “Haas effect” [2]. The (German) journal publication followed in 1951 [308]. Parallel to the Haas thesis a similar investigation was performed at the Harvard University (USA) and the term “precedence effect” was introduced [574]. An early practice test is described in [309] and [310]: at the “Ruhrfestspiele” in Recklinghausen (Germany) in 1951 a “sound-delayed low-speaker group” (instead of “loud-speakers,” because they are not heard) was installed with great success. Even the musicians who usually refused any electroacoustics had no objections. The “Haas effect” or “precedence effect” is meanwhile widely applied in many large halls, typically with sound delay systems. How perfectly such “low-speakers” with delayed feeding operate can be experienced particularly in the large concert and opera hall of the Kremlin in Moscow. Even in the backmost rows of the nearly 6000 seats one has the illusion to hear the optically rather tiny actors on the stage sing or speak directly, although the sound is radiated from loudspeakers integrated in the seat backs in front of the listener. A detailed overview of further work on the precedence effect was published in [585].

Meyer and Tamm presented in 1941 an impedance locus recorder for the audible frequency range which operated very fast and was therefore well-suited for demonstrations [110]. With industrial support, Meyer has also developed a siren in which the sound production and the (often disturbing) air stream could be adjusted independently [111]. Measures to improve the acoustic quality of large halls were outlined in [114].

After the war, Meyer and Grützmacher as the former editors (together with the publisher, Hirzel Verlag) planned to re-establish the "Akustische Zeitschrift." After initial problems, a new start appeared possible in 1950, and the editorial work for the first issue was completed when attempts to produce an international – mainly European – acoustical journal, the "ACUSTICA" changed the situation. After weighing up the pros and cons, Meyer and Grützmacher refrained from pursuing the German solo effort and supported intensively the new journal [117]. The European acousticians made the decision when they met at the first International Ultrasound Congress in Rome (June 14–17, 1950). ACUSTICA started in 1951, papers could be published in English, German, or French, and abstracts were given in all three languages. Meyer served as German (besides an English and a French, at the beginning also a Dutch and an Italian) co-editor until his death. Grützmacher was Editor-in-Chief from 1956 through 1979 [138].

Since unpublished research results had accumulated after the war, the editors enabled the publication of additional issues of Acustica, the "Akustische Beihefte" with AB... page numbering [117] where these manuscripts could be published, among others also important results of the hydroacoustics work at the HHI [121, 124, 132, 311, 312, 313].

Figure 6 from a series of "Professors' Photos" offered in a book store in Göttingen shows Erwin Meyer at this time.

4.1. Institute Expansions

As soon as possible, Meyer expanded his Institute by acoustic special rooms as he used them at the HHI, primarily a large Anechoic Room, lined with absorber wedges. He solicited financial support from several German authorities and organizations [250]. The room in a separate extension of the "White House" was completed in January 1953. With a volume of 1600 m^3, this room was at that time the worldwide largest of this kind. Two innovations were realized here after Meyer's ideas for the first time: the absorber wedges were backed by resonance absorbers (Helmholtz resonators) which were tuned to the lower limiting frequency of the wedge absorbers whereby the frequency range of the lining was extended to lower frequencies without needing much space [314, 92], and on the other hand graphite powder was sucked into the mineral wool wedges so that the wall lining also absorbed electromagnetic waves [127, 128]. A detailed description was published in [131]. The considerable international interest in this development was also documented by the US magazine LIFE International [244] where a photo of the new anechoic room was published in a special issue about the rebuilding Germany (Figure 7). In spite of the fancy illumination, a net of steel wire ropes well above the bottom wedges is hardly recognized which made it possible to walk through the room. The net acts as a short-circuit for electromagnetic waves so that the room is "semi-anechoic" for microwaves, but fully anechoic for sound waves which are diffracted around the thin wire ropes. Further improvements could be realized in another anechoic room which was installed somewhat later in Bern (Switzerland): instead of graphite powder, short steel wool fibers were embedded in the absorber material, and instead of the metallic net a net of polymer ropes was applied so that also the bottom is electrically absorbing [315].

Figure 6: Erwin Meyer in the year 1950.

For the next expansion of the Institute, Meyer planned to build a reverberation room. Because of little experience with such rooms, Meyer arranged for preliminary studies to optimize its shape and construction [160]. The room, with 342 m^3 also quite large, was again erected in a separate building and completed 1960. To isolate the room from air-borne noise, a double-wall construction was chosen, and the inner room was supported from steel springs as protection against ground vibrations. Reverberation room experiments assume a diffuse sound field. Therefore parallel walls were avoided (oblique-angled ground plan and sloped ceiling), and as diffusers 24 curved plexiglass shells of 2 m^2 size were suspended irregularly in the room. A detailed description was published in [172].

As an innovation in the reverberation room technique, the inner walls were lined with copper foil so that the room was reverberant also for electromagnetic waves. Figure 8 shows a view into the new room with the diffuser shells and with absorber wedges as test object on the floor, at bottom right a directional microphone with parabolic reflector. The joints of the copper strips were bridged by white conducting varnish. Since also the bottom was covered with the sensitive copper foil, people had to wear carpet slippers when entering the room.

The transfer of the acoustic reverberation room measuring technique on electromagnetic waves is described in [176] and [183].

The two special rooms were often presented to important visitors in Göttingen, e. g., in December 1960 to a delegation from the United Arab Republic (UAR), led by the Egyptian Prime Minister Kamaleddin Hussein (a close friend of president Nasser). In July 1965 the US ambassador in Germany, George McGhee, visited Göttingen and also Meyer's Institute, escorted by an impressive convoy of black limousines, see Figure 9.

Figure 7: In the new "Anechoic Room:" three students, Heinrich Kuttruff (violin), Wolfgang Westphal (flute) und Frieder Eggers (cello), recording echoless ("dry") music. From LIFE International [244].

Erwin Meyer was offered a chair at the Heidelberg University in 1956. The Göttingen University Archive possesses a letter of the University curator to the Minister of Education and the Arts in Hannover, dated October 2, 1956, in which he states that it is highly desirable that Meyer refuses the Heidelberg chair and stays at the Göttingen University. As a consequence of the negotiations, a greater extension of the Drittes Physikalisches Institut could now be realized. The University administration had bought a small house next to the "White House" (the left building in Figure 5) which now was demolished to get space for a three-level annexe to the older building, completed early in 1960. Figure 10 shows the new Institute.

The "Red House" was now left and used by the university for other purposes. The new building offered space for many laboratories, the practical courses, the electronics workshop, the library, a larger lecture hall (of course with excellent acoustics), the extensive collection of demonstration experiments, and in the basement a deep water tank with absorbent lining (7 m $\times$ 4 m, 4 m deep) for experiments on underwater acoustics. Figure 11 shows the tank with rib-type absorbers along the walls and on the bottom (shown is an installation for experiments on sound scattering from sound-soft spheres).

The Institute remained essentially in this state until Meyer's retirement.

The publication list of the Institute displays a great variety of subjects. Meyer felt obliged to publish research results rapidly – considering that the University depends on "public spending." But unlike many colleagues he did not insist on being co-author of many papers, although he as initiator and engaged supervisor had of course a rich share in the results.

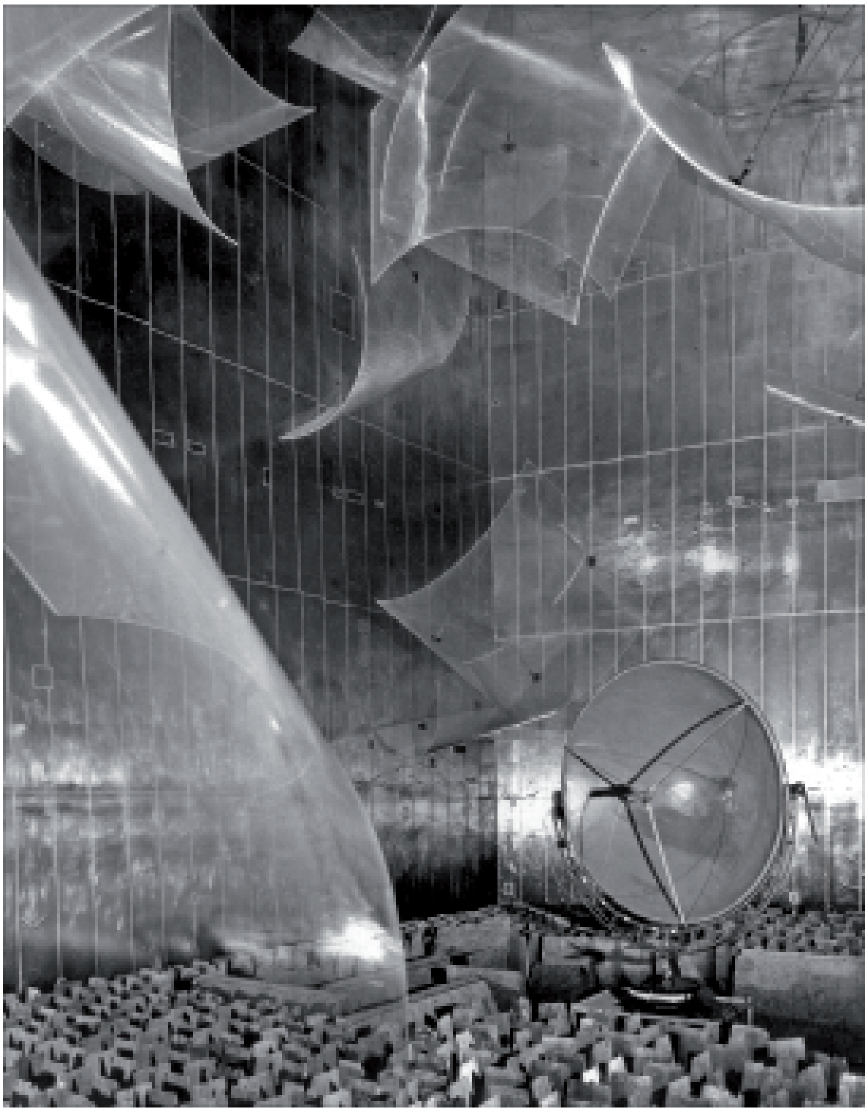

Figure 8: The new Reverberation Room.

Some of Meyer's reliable co-workers from his Berlin era had followed him to Göttingen and helped educate a staff of younger assistents. One of them was Konrad Tamm who completed his "Habilitation," the qualification as University lecturer, at the end of 1951 with a thesis on sound absorption in water and aqueous solutions of electrolytes [444] and headed an own working group at the DPI until 1961 when he was offered and accepted a chair at the University of Heidelberg.

The successful participation in one of the practical courses for advanced students ("Fortgeschrittenen-Praktikum") was a prerequisite to begin work for a diploma thesis (nearly equivalent to a Master's thesis). Meyer used to talk intensively with the students in his "Praktikum," and he had enough experience to judge who would fit to the efficient team of his Institute. The acknowledgements at the end of the theses reveal that it was almost always Meyer himself who proposed the topic of their research work. His wealth of ideas seemed to be inexhaustible, and the results of the theses were mostly important. On regular rounds through the laboratories, Meyer informed himself about the progress of his students' work and gave good advices. So he had always a profound overview of the typically 30 diploma theses and 15 PhD theses.

The working atmosphere in Meyer's Institute was very good – certainly a consequence of Meyer's style of leading the Institute, with authority, but always straight and fair, and

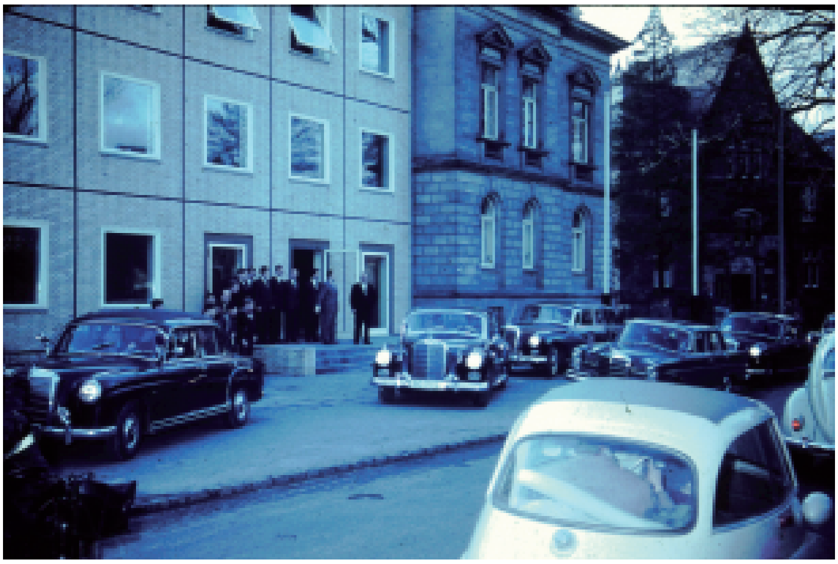

Figure 9: Important visit.

because of the many research fields so that the topics of the students did never overlap and no uncertainties of competence existed. And if it happened that a diploma student was unable to meet Meyer's expectations, the colleagues helped him in friendship so that "the boss" did not get a too bad impression. The pleasing – if also demanding – working atmosphere convinced many members to stay for their whole working life at the Institute, mainly in the non-scientific groups.

4.2. Main Research Fields

Meyer supported the investigations of H. Severin and his group on electromagnetic **microwaves**, e. g., diffraction, scattering, transmitters, receivers and measuring lines. He suggested the development of microwave absorbers [133, 135, 316, 317, 318] and the measurement of material properties of natural and artificial dielectrics [319, 320, 140], and he directed the interest to analogies with acoustics [127, 139, 159]. Meyer and Severin have reported on demonstration experiments with centimeter waves in [112].

After Severin's departure (1957), R. Pottel became head of the microwave group, initially in close cooperation with Meyer, but after his "Habilitation" 1965 more and more independent. A main research topic was the further development of absorbers with various principles [321] – [331], [194]. Meyer and Pottel published a comprehensive overview in 1960 [177]. Further topics were microwave propagation [334, 335, 187], diffraction [336] and scattering [337]. Another main topic were properties of dielectrics [338] – [342], later on mainly of liquids [343] – [350]. The Institute received financial support for these activities by a research contract with the U.S. Air Research and Development Command (European Office, Brussels), and the excellent laboratory equipment for a very wide frequency range was provided by the "Deutsche Forschungsgemeinschaft."

Microwave guiding by dielectric lines was the subject of E.-G. Neumann's research [351] – [358], and he developed an acoustic analogon of the Yagi antenna for microwaves, a microphone with a disc line in front which makes it a slim directional microphone [359]. Neumann completed his Habilitation in 1967.

Nearly one third of the Institute's scientific staff worked in the microwave department, the majority on the various aspects of acoustics.

Figure 10: The Third Physics Institute (DPI), Bürgerstraße 42–44, 1960. Right: the old building, left: the extension.

An important research field was **room acoustics**. The influence of "sound mirrors" at the sides of and above the stage of large halls was studied by geometrical room acoustics and often applied in practice [122].

An internationally much discussed problem was the characterization of the acoustic quality of rooms by significant coefficients. It was clear after the fundamental investigations of W. C. Sabine on reverberation [559] that reverberation time is the most important quantity, but it alone is not sufficient (a bathroom can have the same reverberation time as a concert hall). After earlier work, R. H. Bolt and R. W. Roop [575] proposed the "frequency irregularity" as a further parameter, assuming that it was a measure of the non-uniformity of the sound field. But Meyer's student M. R. Schröder (later on, he spelt his name Schroeder) proved in his PhD thesis and a following investigation by statistical analysis that this quantity (except for very low frequencies) is fully determined by the reverberation time and therefore does not yield additional information on a room [360, 361].[2] This was experimentally confirmed by H. Kuttruff in his diploma thesis, and by R. Thiele in his PhD thesis [362, 363].

It was assumed that the acoustic quality or audibility of a room is determined by the reflections from walls and ceiling following the direct sound. Meyer initiated intensive measurements on the spatial sequence [364] and on the directional distribution [365, 154] of reflections after impulsive excitation in many rooms and at many seats in each room. The comparison with subjective judgements of the acoustic quality revealed that early reflections determine the "definition" or "clearness," defined by Meyer and Thiele quantitatively as the ratio of the sound energy during the first 50 ms of the impulse response to the total energy. In order that concert visitors feel immerged into the sound

[2]These two fundamental publications in German were translated into English for internal use at the Bell Laboratories in 1963 [360] resp. 1972 [361], and published in 1987.

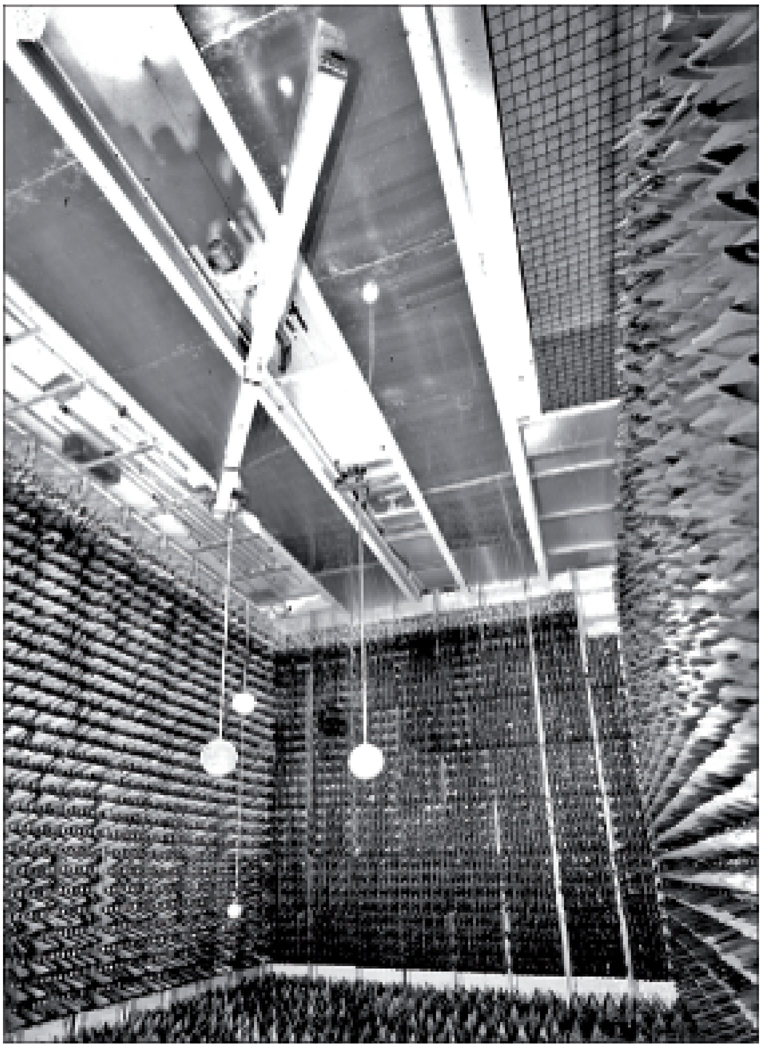

Figure 11: The deep water tank with absorber lining (without water).

field, it was believed that the reflections should arrive at the ears from all directions with equal strengths, i. e., the "directional diffusivity" should be as high as possible [141]. It was defined in such a way that it equals zero in an anechoic sound field, and unity in a perfectly diffuse field. Experimentally, the diffusivity was measured with a directional microphone (parabolic mirror with microphone in the focus, see Figure 8, p. 13) [365] and visualized by a "sound hedgehog," a sphere or hemisphere with radially inserted rods the length of which is proportional to the sound energy incident from the respective direction (Figure 12). Meyer's first talk about these new findings in the USA [134] raised much interest, as well as later presentations in 1956 [142] and 1958 [157]. M. R. Schroeder proposed, after theoretical analyses, a measuring method for the diffusivity in reverberation rooms which does not require the clumsy parabolic reflector [579]. M. Barron proved later on by sound field simulations in an anechoic room [582] and M. R. Schroeder with his students by dummy head recordings in many concert halls [366] that early *lateral* reflections are important for a good spatial impression.

Meyer and his co-workers, primarily H. Kuttruff, have used their new knowledge as acoustic advisers for a lot of festival halls, studios, conference rooms etc. Some of them have been documented [367, 168, 180, 192]. The latter, the "Jahrhunderthalle" in Höchst (near Frankfurt), is provided with one of the biggest electro-acoustic delay installations for artificial reverberation ever built. Meyer's competence was also requested in USA. In order to reveal the reason for acoustic deficiencies in the Philharmonic Hall at the

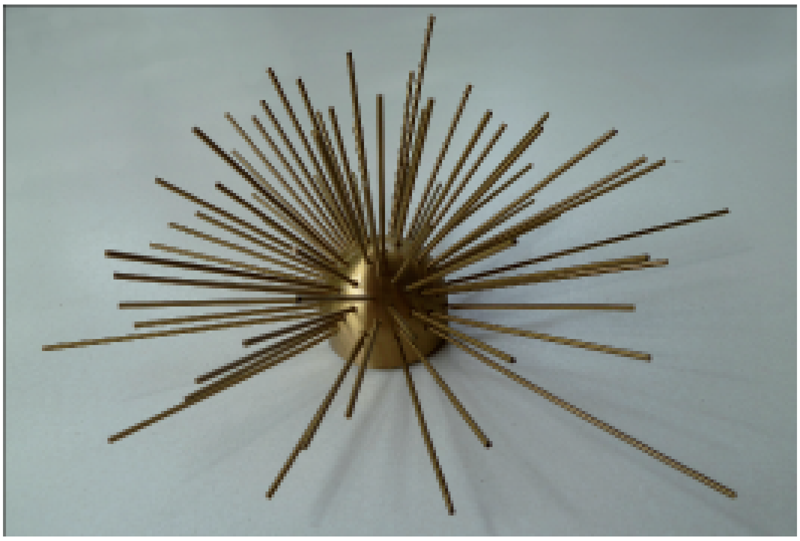

Figure 12: “Sound hedgehog” after Meyer and Thiele. Sphere diameter: 4 cm. Here for a sound field with good diffusivity.

Lincoln Center in New York, Meyer started measurements at a small-scale model of the suspended ceiling reflectors whereby the problems could partially be solved (besides an unfavorable ground plan) [188]. In the fall of 1962, Meyer gave at American Universities – upon invitation by the American Institute of Physics – a series of lectures on the research fields of his Institute in Göttingen [1].

The British acoustician E. G. Richardson had edited a handbook on Technical Aspects of Sound. The first volume [576] appeared in 1953, covering the audible frequency range under various aspects. For the second volume [577] on ultra and underwater sound, Meyer contributed two chapters [150, 151]. Richardson died during the preparation of the third volume on recent progress in acoustics, and the publishers asked Meyer to serve as co-editor and complete the volume [185]. Meyer, together with H. Kuttruff, contributed a chapter on room acoustics to this book [186].

Meyer gave an impressive overview lecture with experiments on the acoustics of large halls at the 1965 meeting of the German Physical Society [201, 281]. He was often invited to give talks on modern electroacoustics [120, 129, 145, 196, 204]. In Venice (Italy) he reported on model experiments on diffuseness in rooms with optical, electromagnetic and ultrasonic methods [149].

The sound absorption by and propagation above an audience was measured upon Meyer’s initiative in his reverberation room [191] and in the free field [195]. The spatial sound pressure drop was scanned with a microphone drawn above the people with a cable pull. Figure 13 shows how Meyer tried to loosen the microphone when the cable got stuck. Model experiments were performed to clarify some problems [368].

The measurement of absorption coefficients in the reverberation room assumes diffuseness of the sound field, but this is violated by the insertion of absorber samples. How far this influences the measured data was investigated upon Meyer’s initiative [189, 206]. The latter paper presents results from W. Lauterborn’s diploma thesis, among others a new method for direct displaying the reverberation time which permits faster measurements. Correlation measurements in room acoustics, e. g., to determine diffuseness, are reported in [369] – [371].

In order to study the influence of wall and ceiling reflections on the impression of spaciousness, the anechoic room was equipped with 80 suspended loudspeakers so that

Figure 13: Measurement of sound propagation above people.

they surrounded a test seat hemispherically (Figure 14). A crossbar distributor and an amplifier and filter bank permitted up to 20 loudspeakers to be fed independently. A tape loop with several movable pick-ups allowed a primary signal to be delayed so that a number of attenuated (or amplified) echoes could be transmitted from nearly arbitrary directions. The signals could also be provided with reverberation [200, 215].

These investigations were concerned with subjective impressions of sound signals; they can therefore also be considered as contributions to **psychoacoustics** [126, 200], [373] – [379]. New developments in acoustic measuring techniques can be quoted here, too [380] – [383].

Meyer arranged for a series of diploma and PhD theses studying the subjective impression of synthetic sound fields generated by the hemispherical loudspeaker array. It was found that the auditory spaciousness broadens when the coherence of (a few) loudspeaker signals is reduced [384]. Concerning directional hearing, it was known since long that in the horizontal plane (left – front – right – back) the intensity difference and

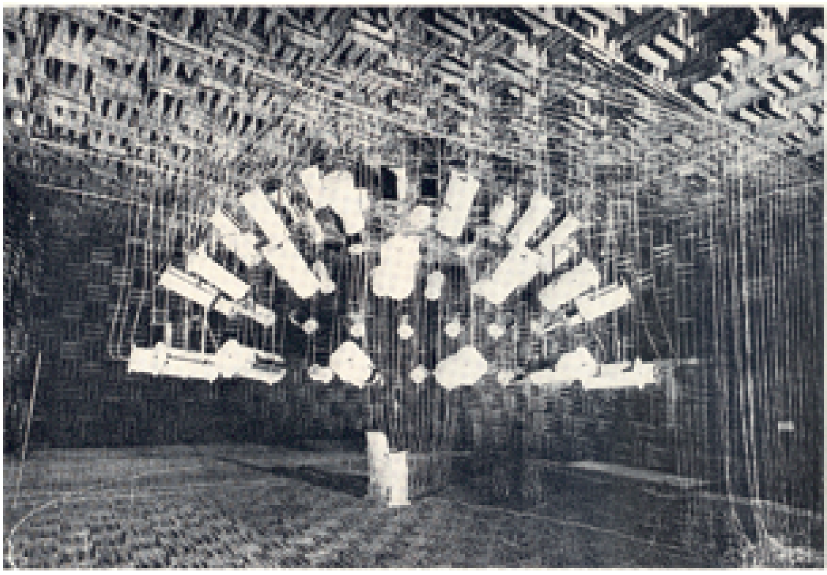

Figure 14: Loudspeaker-hemisphere in the anechoic room.

the time delay between the two ear signals is essential. But this does not explain how source localization in the median plane (front – top – back) is possible. In-depth experiments with a dummy head and with test persons revealed that the brain obviously utilizes slight spectral variations of well-known signals such as speech [385, 386]. In sound field reproductions with direct sound and few echoes, added reverberation is important for the directional impression [387]. Meyer also initiated research on "head-related stereophony." It allows to realize, by cross-talk cancellation, true three-dimensional spatial impressions with only two loudspeakers, not only between the loudspeakers as in conventional stereophony [388, 389, 390].

Several aspects of **building acoustics** were studied in Meyer's Institute: insulation from [391] – [394] and attenuation of structure-borne sound by granular materials such as sand and gravel [113], [395] – [398], propagation of structure-borne sound [118, 147, 148], [399] – [401], sound transmission through and sound radiation from plates [402] – [404], also for ultrasound [405, 406], and also here new measurement techniques were developed [407] – [411].

Already in Berlin Meyer had worked on **ultrasound** (frequency range from 20 kHz through 1 GHz) [88, 98]. In Göttingen he developed new experiments for his practical course [116], and he liked to apply ultrasound for model experiments [125, 136, 170]. A handbook article on ultrasound was published in 1957 [150]. Also hypersound (frequencies above 1 GHz) was a research field at the DPI, in the working group of W. Eisenmenger [412]. Attenuation measurements on quartz are published in [202, 413]. Eisenmenger made novel experiments with phonons in superconductors during a later research stay at the Bell Laboratories in USA [414].

An important research field at the DPI was **underwater sound (hydroacoustics)** – in continuation of the former work at the HHI in Berlin during WWII. Besides the development of new experimental techniques [415] – [422], Meyer arranged for further development of absorbers of underwater sound. The idea to improve the former absorbers (with special rubber mixtures) by modern highpolymers [137, 193, 211, 423] had finally to be abandoned. Very high loss factors are easily obtained, but due to the Kramers-Kronig relations (e. g., [221]) they are inevitably related to strong temperature and frequency dependence of the corresponding dynamic moduli so that effective absorbers of this type are constrained to narrow temperature and frequency intervals. Instead, absorbers with viscous loss of liquids streaming through narrow slits were constructed

[190, 207, 210, 212, 424, 425, 426, 219]. Since the dynamic properties of viscoelastic materials, the elastic moduli and their loss factors, are also important for the insulation and damping of structure-borne sound in buildings and mechanical engineering, the work on highpolymers was continued, mostly with new experimental techniques [109, 427]. The experimental data provide also information on the structure of materials, particularly relaxations [163], [428] – [433].

Sound propagation through (narrow) water-filled tubes was studied [313, 434], as well as scattering of underwater sound from various objects in three-dimensional (deep water tank) [435, 436, 437] and two-dimensional sound fields (in shallow water basins) [438, 439].

The sound velocity and damping in liquids were measured quite intensively with various methods and in a wide frequency range, financially supported by the above-mentioned DSIR/DNPR research contract. Besides water [440, 441, 442] and aqueous solutions of electrolytes [443] – [449], some other liquids were studied [450] – [453]. In cooperation with Manfred Eigen (University Institute for Physical Chemistry) some findings were understood as relaxations, which often are extremely fast (up to 10^{-9} s) [454]; Eigen was 1967 awarded the Nobel prize in chemistry for the investigation of fast reactions.

Studies on the influence of gas bubbles on the acoustic properties of water, formerly in Berlin, were continued in Göttingen, not only concerning sound propagation and damping in water [455] – [458], but also on bubble formation [459] – [462], their nonlinear vibrations [463] – [468], cavitation [144, 152, 161], [469] – [480] and sonoluminescence [166, 167], [481] – [486]. These activities were performed in the working group of W. Lauterborn with his co-workers. Upon Meyer's initiative, the relevance of cavitation for surface cleaning with ultrasound was investigated in a wide frequency range [487]. Meyer wrote 1957 a handbook article on gas bubbles in liquids [151], and in 1962 he gave a lecture on "High-Intensity Sound in Liquids" [184].

Upon Meyer's suggestion, G. Sessler studied **sound propagation in gases** at low pressures p and high frequencies f (f/p–values from 10^6 to 10^{11} Hz/atm, frequencies from 100 to 600 kHz) – relations which had not been reached by other research groups. This was possible by applying electrostatic transducers ("Sell type transducers") [116, 488, 489, 490]. While in monoatomic gases only "classical" damping by internal friction and heat conduction occurs, in 2-atomic gases also rotational excitations of the molecules play a role. This was confirmed by measurements with argon, air, oxygen, nitrogen and hydrogen [153, 491, 492]. At the highest frequencies the sound path between transmitter and receiver must be smaller than the free wavelength of the gas molecules because of the high damping – the transducers "play ping-pong with the gas molecules." Meyer and Sessler have derived the theory for these phenomena [153]. This paper became Meyer's most often cited publication [3]. Polyatomic gases exhibit further effects, e. g., a relaxation at CO_2 [116] and a dissociation at $NO_2 \rightleftharpoons N_2O_4$ [493], which was not understood since early investigations (also by Albert Einstein) and could now be explained by Sessler's experiments [494]. Further experimental results and theoretical explanations on ultrasonic absorption and dispersion in polyatomic gases and vapors with Sell type transducers at high frequency/pressure ratios were published in [495] – [500]. Sell transducers need a high bias voltage (e. g., [221]) to linearize their performance; later on, Sessler and his colleague J. E. West invented the electret microphones where this bias is produced by a "frozen" charge on special polymer foils [580].

As a new research area for his Institute, Meyer started **flow acoustics**, the mutual influence of sound propagation and air or water flow. To sponsor the air flow activities, he placed a research contract with the US Air Force, while the research on water flow was performed within the DSIR/DNPR contract. When in 1960 the Institute's extension building was completed, Meyer installed a wind tunnel in the basement. Earlier experiments on the measurement of sound attenuation in turbulent flow were performed in a small wind tunnel with rectangular cross-section and various absorber linings along the wider tunnel walls [158, 501]; the results help design mufflers. Detailed later investigations on this subject were documented in [502] – [506]. Some projects were concerned with the influence on the flow boundary layer in air by sound [507, 508] and by wall vibrations [509]. The influence of air flow on sound radiation and impedance of a muzzle was studied by experiment and theory in [510, 511]. The air-borne sound propagation in a flow channel was studied with striation optics [512].

Comparatively simple laboratory experiments allowed to study flow noise of water in thin-walled narrow tubes, intermittencies between laminar and turbulent flow, and the influence of cross-section steps [175, 513]. Improved measurement methods to investigate boundary layer disturbances in water by a hot-wire sensor were described in [514].

Meyer's assistent F. P. Mechel supervised the flow acoustics group. But he chose for his Habilitation (1965) the theoretical treatment of plane wave scattering from cylinders and spheres with complex surface impedance. Partial results were published in [515, 516, 517]; the complete Habilitation thesis with hundreds of calculated scattering diagrams was, however, too long for a journal publication. Such theoretical work did not appeal to Meyer; but he familiarized himself with this matter (with admitted trouble [1]) to present a talk at the Göttingen Academy of Science and so got Mechel's Habilitation thesis published by the Academy [518]. After Mechel's departure (1965), D. Ronneberger headed the flow acoustics group with great success [519] – [522], in close cooperation with the Max-Planck-Institute for Flow Research and DLR Institutes in Göttingen.

To illustrate the broadness of subjects treated in Meyer's Institute, a few **special projects** shall be mentioned. The oscillations of air particles near boundary layers were measured in front of absorbing walls [119] and in front of a rigid wall [130], in both cases with small floating particles and optical observation. In the same way the particle velocity transformation by the pressure chamber of a horn type loudspeaker was tested in a model experiment [178]. – The absorption of ultrasound by animal tissue and plastics was studied with industrial sponsoring [523]. – A flat room for air-borne sound was used to measure the absorption coefficient of standard absorber materials and resonators at oblique incidence in the lower kHz range [524]. – A very capable student of Meyer's was Marie-Luise Exner [455, 391, 393, 396, 456, 525]. Meyer suggested her to apply for Habilitation, but she refused in favor of having enough time for her family [1]. – The German Federal Railways supported measurements on railroad tracks [526, 527]. – K. Tamm and G. Kurtze invented 1954 a directional microphone with a slotted tube in front of the sensor as it is used now routinely for TV recordings etc. [528, 529]. – H.-G. Diestel used a 55-fold enlarged ear model for acoustic measurements which helped understand the hydrodynamics of the cochlea [530]. – W. Güth investigated the propagation of sound impulses in metal rods experimentally with striation optics, and also theoretically; he found relations to riffle formation on tracks and in bearing shells [531]. – The radio manufacturer Telefunken sponsored measurements of the nonlinear distortion of piezoelectric phono pick-ups at low frequencies which turned out to be caused by the high mechanical input impedance [532]. – Several institutions financed subjective and objective loudness measurements with many noise patterns in order to clarify discrepancies [533]. – A research contract with the German Federal Ministry for Housebuilding supported the investigation of sound insulation of various wall constructions by electrical filter models, thereby drastically reducing the experimental effort [534]. – M. R. Schroeder developed a new method to measure permittivity by split degenerate natural frequencies of cavity resonators [535]. – Attracting and repelling forces between two spheres in a standing sound wave (Bjerknes forces) were studied in the scope of a diploma thesis [536]. – Dielectric properties of various building materials were measured as function of water content [537]. – Relaxation phenomena span a wide frequency range so that their measurement with sinusoidal excitation over about four octaves is quite involved. It has been tested in [538] how the relaxation parameters can be determined directly from the deformation of rectangular impulses. – In his diploma thesis, F. Eggers, an engaged cellist, measured the vibrations of a loudspeaker membrane with a capacitive method more precisely than it was possible before [539]. He refined the technique for his PhD work to exactly measure the corpus vibrations of a violoncello and has, among others, found a simple way to suppress the "wolf," an ugly resonance [540]. – K. Tamm and O. Weis applied photoelastic methods to study flexural waves, including near-fields [541, 542], and the various wave modes in lossy solids [543, 544]. – The radar backscatter cross section of metal cylinders was measured in the electrically semi-anechoic room [164].

Experiments on sound scattering from phase gratings served to find methods for improving the diffusivity in rooms by fanning out the mirror reflection from the walls [182]. M. R. Schroeder has optimized this technique later on [583]. – Ruby laser flashes were synchronized by exciting longitudinal resonance vibrations of the ruby rod [197]. – The acoustic design of rooms demands often to "hide" acoustically effective elements optically. This is possible with grid-like perforation of panels as was shown experimentally and theoretically in a diploma thesis [198]. – The reflection and transmission behavior of porous absorbers was explored with models of bundles of parallel thin tubes ("Rayleigh-Absorbers") [203].

Two assistent professors stayed exceptionally long at Meyer's Institute: Heinrich Kuttruff and Wolfgang Eisenmenger (incidentally, both are tied by a life-long friendship). Both joined the Institute 1953 as students, applying for diploma theses. The subject of Kuttruff's thesis were the measurements on frequency irregularity (see p. 15) [362], Eisenmenger's theses was concerned with the electro-kinetic effect, from which a novel ultrasound probe for underwater sound resulted [550]. Kuttruff's PhD thesis comprised optical and acoustical model experiments on the creation of diffuse sound fields in the reverberation room [551], and he treated in experiment and theory non-exponential decay of reverberation curves [552]. Eisenmenger developed a method for measuring the surface tension of liquids by parametric excitation of standing capillary waves; he could correct and extend literature data for water and aqueous solutions [553]. For his Habilitation, Kuttruff investigated the relationship between cavitation and sonoluminescence [484]. Eisenmenger created, in the frame of the DSIR/DNPR contract, a novel source of sound impulses with a flat spiral coil and a close-fitting metal membrane. A high-current discharge through the coil excites eddy currents in the membrane which is thereby repelled and produces sound pulses in liquids up to 200 atm [554]. Eisenmenger applied this for his Habilitation thesis (1963) to measure shockfront thicknesses in liquids [555]. Both, Kuttruff and Eisenmenger, left the Institute in September 1969 to accept chairs in Stuttgart (Eisenmenger) and Darmstadt – later on Aachen – (Kuttruff). Eisenmenger took up the shock wave excitation with the flat coil transducer more than 30 years later for a lithotripter [586]. Wolfgang Eisenmenger died on Dec. 12, 2016.

Even longer than Kuttruff and Eisenmenger stayed H.-W. Helberg at the Institute. After his entry (1952) he worked on acoustics [176, 434, 459, 460, 549], then on microwave absorbers [194, 325, 327, 328, 330], before he turned over to solid state physics [331, 332, 333]. Meyer had realized that Helberg was very assiduous, reliable and responsible; he gave him first an assistent position, and since April 1964 a tenured position as managing director which he held until his retirement in 1993.

Figure 15: Erwin Meyer and Heinrich Henze (left) in the lecture hall preparing the lecture on Electronic Measurement Techniques on June 25, 1966.

4.3. Lecture courses

Meyer's main interest was focused on scientific (mainly acoustic) research, but he devoted also much time to his four semester lecture course. His lecture on "Physics of Vibrations and Waves" presented the fundamentals, followed by "Physical and Applied Acoustics," "Electronic Measurement Techniques," and "Physical Fundamentals of High-Frequency Technique." Highlights of Meyer's lectures were the impressive demonstration experiments which he updated constantly. Typical for Meyer's Institute in Göttingen was, as stated before, the manysidedness. Impressed by the basic idea of the HHI, Meyer always used the analogies between electrical and mechanical (or acoustical) vibrations. This was not only typical for the research directions, but also for his lecture demonstrations. A mechanical/acoustical experiment was usually followed by an analogous electrical one or vice versa. Eager to include modern developments into his lectures, Meyer designed many novel experiments. Some of them were published: on parametric (or rheolinear) excitation and amplification [171], both being principles which only recently had gained practical relevance; on the acoustic radiation pressure [547]; and on shock waves [548]. Meyer's lecture time was always Friday morning, 9^{15} – 10^{45}. The experiments were set up by H. Henze (see p. 8 bottom) and if necessary his workshop members. On Thursday morning, Meyer discussed all presentations with Henze, sort of final rehearsal, see Figure 15.

Meyer was manually somewhat unhandy and left it to Henze to exhibit the experiments. Figure 16 shows Meyer during and Figure 17 after a lecture giving attendance certificates.

Repeatedly, publishers had asked Meyer to publish his lectures as textbooks. Meyer agreed when he started his last four-semester term before retirement. Meyer did not have the time, and he was not "picky" enough to write the books himself, therefore he asked members of his Institute to serve as co-authors. Three books were published, that one on Acoustics also in English [205, 216, 220, 221]. A fourth book on Electronic Measurement Techniques was planned, but not completed. The author of this manuscript has finalized the book "Schwingungslehre" – fundamentals of vibrations and oscillations – after Meyer's death so that it became Meyer's last publication. The three books are estimated by many lecturers also because of the descriptions of the demonstration experiments.

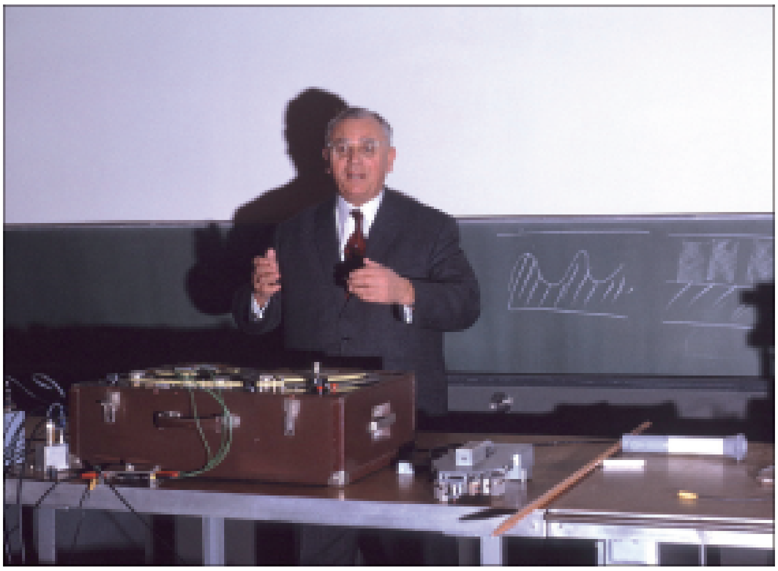

Figure 16: Erwin Meyer during his lecture on February 25, 1966.

Figure 17: Erwin Meyer giving attendance certificates after his acoustics lecture on February 25, 1966. The student to his right is Bernd Wagener, later on head of the computer center of the University of Oldenburg.

Also the lecturers at Meyer's Institute taught on various subjects, always illustrated by experiments. The lecture hall was also meeting point for the weekly Colloquium where each diploma and PhD student had to present, at least once during the work on his or her thesis, a talk usually on a subject not directly related to his or her work, followed by a vivid discussion. Subjects of the colloquium talks were recent developments in physics general, or physics related to the talker's hobbies (sailplaning, boomerangs etc.). The presentations should help overcome the nervosity to talk to a critical (but loyal) audience, and to train to familiarize oneself with a new subject within a reasonable time so that more than superficials could be presented. So the talks were a good Training program for later presentations at conferences, and for the audience a source of interesting information on news in science. Sometimes the colloquia motivated own projects; so P. Wille, who then headed the hydroacoustics group (and later on an oceanographic research institute in Kiel) developed, in analogies to microwave devices, an aspect-independent sonar reflector [556], and a flow-efficient directional hydrophone [557].

5. Patents

A number of patents are found in Meyer's publication list. The first one descibes an electronic sound analyzer [19], the second one a calibration method for condenser microphones [20]. Two patents filed in 1932 were related to magnetic sound recording [45] and reproduction [46]. 1934 followed the level recorder with logarithmic characteristic (see p. 4) [60]. A further patent described a certain coating for high-ohmic resistors to reduce their noise level [65]. To improve the sound insulation of double walls, Meyer proposed to apply absorptive material in the gap, e. g., in the corners of double windows [81].

Presumably Meyer's most important invention were the wedge-type absorbers for anechoic rooms [91] with the later supplement by resonator backing [92]. In 1949, Meyer applied for a patent on a siren with adjustable air flow at the exit [111], and for a noise reducing building construction by cavity bricks with sound absorbing filling, e. g., sand [113].

Together with H. Severin, Meyer developed a broadband wedge-type absorber for electromagnetic waves to be applied in front of walls [127]. The extension of wedge-type absorbers for airborne sound to absorb also electromagnetic waves by sucking in, e. g., graphite powder was patented in [128]. The disadvantages of large thickness of wedge-type absorbers and small bandwidth of resonance absorbers can be circumvented by appropriately constructed two-circuit resonance absorbers. Realizations for electromagnetic centimeter waves are described in [135].

The research work on absorbers for underwater sound led to Meyer's late patents. An inhomogeneous wall lining is disclosed in [137] where the water-facing surface is well matched, and energy dissipation occurs further inside the viscoelastic coating. Broadband sound absorption in water-filled narrow tubes within a polymer coating was proposed in [190], and by particle velocity transformation in undercrosslinked (and therefore lossy) polymers with compressible inclusions [193]. Several types of thin-layer absorbers for waterborne sound based on alternating flow in narrow liquid layers are described in [210]. Also Meyer's last invention presented an absorber for underwater sound consisting of small absorption cells embedded in an elastomer layer [212].

6. Conclusion

Erwin Meyer retired at the end of the summer semester 1967 when he reached his 68th year. Since no successor was in charge, he could "serve as his own representative" for one more year so that he became an emeritus in the autumn of 1968. Many of his former students held important positions worldwide. One of them was Manfred R. Schroeder who was elected Meyer's successor (starting in the autumn of 1969, in the meantime H. Kuttruff managed the Institute). After completing his PhD, Schroeder had left the Institute in 1954 and started an impressive career at the Bell Laboratories in Murray Hill, New Jersey, USA. He made pioneering contributions, among others, to room acoustics and physical speech research – also after his return to Göttingen and so further enhanced the reputation of the Institute. The author of this paper was announced by the chairman of a session at one of the semiannual ASA meetings by saying "Dieter comes from the *legendary* Third Physical Institute in Göttingen."

Some of Meyer's early students in Göttingen were shaped by wartime experience and inclined more to practical problems than to theory, so they performed rather poor in theoretical examinations. Richard Becker, professor of theoretical physics in Göttingen, in Germany known for excellent textbooks, but internationally less renowned, got the impression that at Meyer's Institute no serious physics were performed, and he let Meyer feel this. This changed when Becker, during an information journey through the USA, repeatedly heard that he, as physics professor in Göttingen, was assumed to have to work for Professor Meyer [279]. Returning to Göttingen, Becker told his colleague Meyer frankly of this experience and changed his mind after a longer conversation with Meyer – the more so as the students meanwhile performed better in theory.

Erwin Meyer supervised in Göttingen nearly 150 diploma theses, 90 PhD theses, 10 theses for state examinations (to qualify for Highschool teaching), and 9 "Habilitationen." Since the early 1950s, Meyer always hosted guest researchers from abroad, for several months or years.

Meyer cultivated relations to colleagues in Germany and abroad, to be informed about new developments and to discuss research topics. Occasional correspondence published in the Journal of the Acoustical Society of America with the editor of JASA, F. A. Firestone during wartime, when direct contact was impossible, proved the loyal connections between the scientists across the ocean [236, 237]. Meyer kept contact also to the acousticians in the German Democratic Republic (DDR), e. g., to Prof. W. Reichardt, in Dresden. Meyer and some of his co-workers visited Reichardt and his Institute several times, and also Reichardt came to Göttingen with members of his staff as long as the DDR government admitted such contacts. Meyer attended each congress of the International Commission on Acoustics (ICA) (every three years since 1953), and most meetings of the German Physical Society, from which the German working group for acoustics, DAGA, later on German Society of Acoustics (DEGA) separated. Meyer was essentially engaged in founding ICA and DAGA. He was the local chairman of the 3rd ICA Congress in Stuttgart 1959.

Very popular were scientific excursions to universities and major companies in which all Institute members could participate. Meyer liked to celebrate special events amidst his staff, the annual Christmas parties, and every five years his big birthdays. Meyer did not really have hobbies. He focused on scientific achievements, and obviously suffered 1968 from handing over the responsibility for his Institute, but he retained an office for the rest of his life.

He liked long walking-tours, particularly in the mountains, in earlier years also skiing. He recovered fast after the long winter semester term when he spent some weeks in the Swiss Alps, and he returned extremely sunburnt, so that his little granddaughter feared the "black man" and screaming rescued herself on mother's arm when they once met him at the train station.

Erwin Meyer was an impressive personality and possessed natural authority which all people felt meeting him. As an outstanding acoustician, he was esteemed and well-liked everywhere, and he was rewarded repeatedly. As early as 1933 he received the "Gauss-Weber-Denkmünze" of the University of Göttingen for his contributions to the advancement of telecommunication, and 1961 the "Gauss-Weber-Medaille." The Academy of Science of the University of Göttingen elected him an Ordinary Member in 1950 [302], and he was elected Dean of the Faculty for Mathematics and Natural Sciences on April 1, 1956 for one year. The Institute of Radio Engineers (IRE) appointed him 1957 "Senior Member," and the Technical University of Berlin awarded him an honorary doctorate (Dr.-Ing. E. h.) in 1958 [253, 254, 162]. The journal ACUSTICA published a special issue on the occasion of Meyer's 60th birthday with 16 contributions of his (former or present) co-workers and colleagues, all stating "Dedicated to Professor Dr. Dr. E. Meyer on his 60th Birthday" [263]. Also, Meyer's former co-worker M. Grützmacher wrote a congratulation address [263]. In 1964, the Acoustical Society of America honored Meyer by giving him the "Wallace Clement Sabine Award for internationally recognized contributions to all aspects of architectural acoustics. His published works include studies on sound propagation and diffusion in concert halls, theaters, and radio studios; investigations on sound transmission and insulation in buildings; and the design of anechoic

Figure 18: The first Lord Rayleigh Medal of the British Acoustical Society.

and reverberation chambers for both acoustic and electromagnetic waves. As teacher, writer, and research physicist, he has influenced the scene of acoustics in a broad manner. He has shown his administration abilities through the direction of such important activities as the International Congress on Acoustics in Stuttgart, his vital part in the creation of the journal ACUSTICA, and the establishment of an internationally renowned center of acoustic research at the University of Göttingen." (The photo of Figure 1 was made for the Festschrift issued by the Acoustical Society) [278, 279, 283].

On 21st November 1969 the recently founded British Acoustical Society presented the first "Lord Rayleigh Medal", see Figure 18, to Erwin Meyer, stating that he "has been recognized as a leading figure in international acoustics for a period of many years." Meyer was no friend of stiff and formal ceremonies. He had long looked for something humorous to present at his dinner speech, and finally found in a German popular newspaper (BZ Berlin, Oct. 31, 1969) a story reporting that the old Vern O. Knudsen had measured in his reverberation room in Los Angeles the sound absorption of ladies wearing mini-skirts in comparison to those with skirts of normal length. Of course, the mini-skirts absorbed less. Meyer started his address by asking for similarities between a mini-skirt and a dinner address, and added the answer himself: both should be short and attractive. After summarizing the contents of the amusing newspaper article and expressing his thanks to the British Acoustical Society [217], the conversations of the dinner guests livened up discussing Knudsen's experiments [1]. Incidentally, Knudsen had appreciated Meyer's merits on the occasion of his 65th birthday [275], in particular his invited paper on "novel analogies between acoustic and electromagnetic oscillations and wave fields" at the 4th ICA Congress in Copenhagen 1962 [181]. Further congratulations were published on Meyer's 70th birthday [286] – [288].

A students' tradition at that time was honoring popular professors on special occasions by a torchlight procession. Meyer was honored this way twice: at his 65th birthday on 21st July 1964, and after his final retirement on 18th October 1968 [284, 285].

Meyer's health was remarkably robust. He rarely caught a cold, and he never had headaches. A medicament against high blood pressure caused an icterus which enforced his single hospital stay. His plan was to receive the Wallace Clement Sabine Award in the USA at this time – which then was accepted by M. R. Schroeder for him. Meyer recovered rapidly from the icterus. More serious was a heart attack in England which he and his wife did not tell at home. A light cardiac infarction after his retirement tied him to his bed for several weeks, but he recovered well. His doctor had no objections when he wished again to spend his winter holidays in the Swiss Alps in spring 1972. Mrs. Meyer did not accompany him since she wanted to do some refurbishment in their house. Meyer's sudden death by a cardiac infarction during this stay in Pontresina (Switzerland) on 6th March 1972 was absolutely unforeseeable and terminated his still active work as acoustic consultant, e. g., for the rebuilt National Theater in Bucharest

Figure 19: Commemorative plaque for Erwin Meyer at his house in Göttingen, Otfried-Müller-Weg 6.

(Romania) which he had started together with H. Kuttruff who finalized this project alone. The new theater opened 1973.

Meyer's colleagues appreciated his great merits in obituaries [291, 292, 295, 294]. The city of Göttingen honored Erwin Meyer at his 100th birthday 1999 by mounting a commemorative marble plaque at his former house [301, 303], Figure 19 (the dates refer to the years which he spent in this house).

The author asks all readers to inform him about errors and suggestions for text improvement:

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(The following list enumerates in chronological order from [4] through [222] all publications of Erwin Meyer which the author has found. Publications about Erwin Meyer are listed thereafter: [223]–[305], followed by selected publications from the DPI [306]–[557], and a few further citations from [558] on. Not all of Meyer's publications are referred to in the text. The author has added in brackets English translations of the German paper titles [...])

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