# THE ACOUSTICS SECTION: A PROFILE OF THE LABORATORY

by

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When Editor Deirdre Benwell invited me to open this series, my first inclination was to offer a simple account of our tasks and responsibilities. On reflection, however, it became apparent that a narrative which failed to bring out the philosophy and style of a scientific institution would miss the mark. That is why I have gone back to our roots and provided some context to frame the diverse activities in which we have engaged over the years.

The first Director of the Division of Applied Physics was Dr. Robert W. Boyle who was born in Newfoundland and educated at McGill University where he was the first recipient of a Ph.D. in physics from that illustrious institution. In 1929, when he gave up his position as Dean of Applied Science at the University of Alberta to join NRC, he brought with him a strong interest in ultrasonics thereby opening a line of research activity in acoustics which has continued unbroken ever since. One year later his young assistant Dr. George S. Field (later Chief Scientist of the Defence Research Board) was invited to form the Acoustics and Ultrasonics Section which developed slowly during its first decade and made important contributions to the war effort between 1940 and 1945 (See W.E.K. Middleton, Physics at the National Research Council of Canada 1929-1952, Wilfrid Laurier University Press, 1979). Dr. Thomas D. Northwood joined the Section in 1940 and later headed a new laboratory within the Division of Building Research devoted to building acoustics. This will be the subject of a later article.

It was Dr. George J. Thiessen, Section Head from 1950 to 1975, who rebuilt the AcousticsSection during the post-war years and charted the course we follow today. It is a course which has crossed many areas of acoustics over a thirty-year period including, for example ultrasonic absorption and hypersonic light scattering in liquids, radiation pressure, elastic waves in solids, sound-generating mechanisms in machinery especially suction rolls, blowers and compressors, the effects of sound on birds, hearing protector design, the acoustics of circumaural earphones, the design of acoustical instruments, hearing threshold measurements and physiological noise. Throughout this period the primary purpose has been to direct attention to scientific areas and specific problems in acoustics which are of substantial economic or social significance in Canada. In terms of the National Research Council mandate this means acoustics related to health, the environment, industrial technology and standards. The predominant style of research in the laboratory is strongly rooted in physics, interweaves experiment with theory, focusses on strategic scientific questions, searches for underlying mechanisms and emphasizes economy of method.

The major health effect of sound is, of course, noise-induced hearing loss. Unfortunately, the ability to detect the onset of this insidious occupational disease is severely limited by the accuracy of conventional audiometric measurements in the critical high frequency region. Our work on the ear was initially inspired by this problem but has proved equally relevant to the measurement of noise exposure, the spatial perception of sound and the design of hearing aids. The tasks undertaken during the past decade include the "decoding" of the external ear in terms of its normal modes, directionality, radiation impedance and diffuse-field response, the building of physical models of the ear, the simulation of eardrum impedance, the calibration of high fidelity earphones and the measurement of noise-exposure with an "in-ear" microphone. Our current work in this field is concerned with the role of the eardrum and the flow of energy through the middle ear. We are also hoping to start new work on hearing protection inspired by contemporary industrial needs.

Another important health effect, vibration-induced white finger, is an industrial disease associated with occupations requiring the use of hand-held vibrating tools such as chain saws and grinders. For several years our laboratory collected, sifted and analyzed scanty data from several countries in an attempt to establish a firm relationship between the sensation-weighted vibration level, the years of occupational exposure and the incidence of selected symptoms. This goal has now been reached clearing the way for an attack on the sources of vibration, the tools themselves. Some preliminary work on the behaviour of anti-vibration tool handles was in fact undertaken several years ago but a major effort is required if we are to bring the input of vibrational energy to the hands under adequate control. This field was reviewed last October in Montreal at a Seminar on Occupational Exposure to Noise and Vibration, jointly organized by the Division of Physics and the Radiation Protection Bureau of Health and Welfare Canada in Montreal, and is the subject of an International Symposium to be held in Ottawa in May 1981.

About fifteen years ago a steady stream of enquiries from municipalities and provinces across the country persuaded us to shift much of our effort towards the support of community noise control. Since motor vehicle noise was known to be predominant in most cities, we began to collect statistical information on source strength for the various classes of vehicle and to develop mathematical models for the "ideal" city. It soon became apparent that the steady-state noise levels which we observed at our homes in Ottawa could not always be reconciled with the source data, a finding which foreshadowed the need to reexamine almost every accepted tenet of sound propagation outdoors. At the outset, to account for the absorption of sound in air at frequencies below 2 kHz, which are predominant in urban noise, we found it necessary to include the effect of the vibrational relaxation in nitrogen. This change in long-accepted theory was recently embodied in a new ANSI Standard which is a key document in the interpretation of aircraft noise measurements. Managers of mission-oriented research may note that this important discovery was inspired by the insights gained from our earlier activities in a very different field, ultrasonic absorption in liquids.

Our decade of work on sound propagation outdoors has embraced such major themes as the theory and measurement of sound propagation over an impedance boundary, the effects of refraction due to wind and temperature, the effects of atmospheric turbulence and the diffraction of sound by simple barriers. These themes have been tightly interwoven with a steady stream of applications such as the effect of sloping terrain on sideline noise at Vancouver International Airport, the variability of motor vehicle test site measurements and the performance of highway barriers. Our current work in this field is concerned with a fundamental limitation in diffraction theory which only came to light last year and seems to be associated with wave-front curvature.

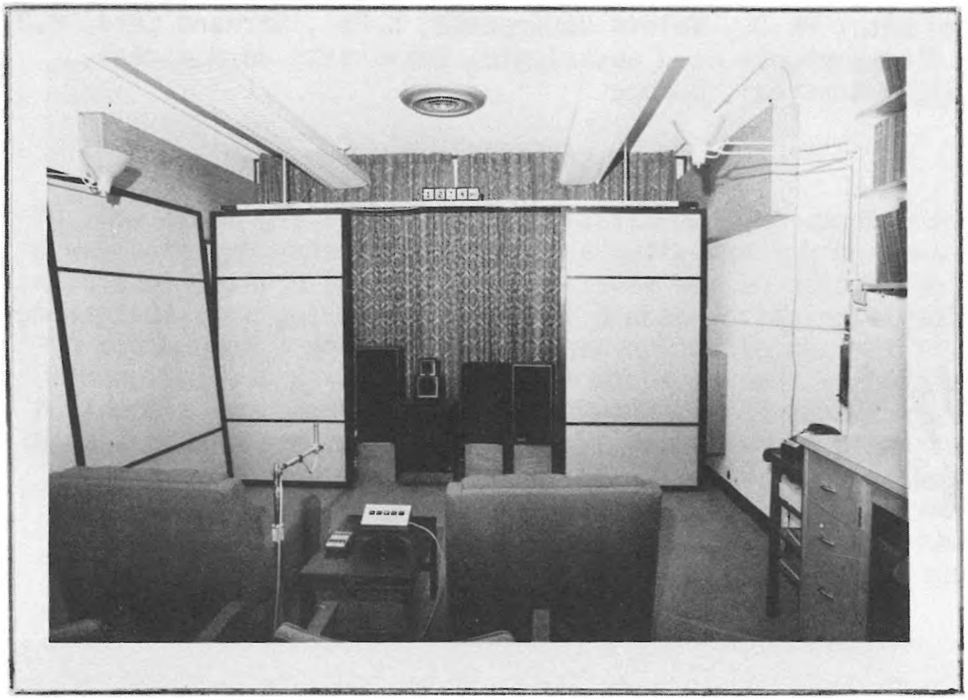
Fifteen years ago there was very little quantitative information about sleep disturbance which is generally recognized as one of the more important effects of urban noise. The sleep project was designed to fill this gap in a systematic way. Over a twelve year period (1968-1980) nearly 120 subjects participated in a series of experiments during which more than 1900 nights of sleep were measured in the laboratory. In all of these experiments the patterns of noise exposure were controlled and the sleep levels were monitored by means of electrical signals from the brain received by an electroencephalograph and recorded on magnetic tape. The results of this work are presented in a series of papers some which have already been published while others are in preparation.

During the late sixties the snowmobile, a spectacular new noise source with a strong attachment to Canada, appeared on the scene and soon achieved notoriety in environmental acoustics. In a few short weeks the laboratory took note of this problem, analyzed the noise-generating mechanisms in a typical machine, measured the levels from many others and issued a report outlining the measures needed to produce quieter vehicles. This document, which included a salutary appendix on noise-induced hearing loss, was clearly a landmark in the field.

It was by then apparent that machines powered by small internal combustion engines, such as motorcycles, lawnmowers and chain saws, accounted for a significant component of community noise in suburban areas. They were also more difficult to quieten than larger machines due to limitations in weight and size. In response to this problem, one of our current tasks is concerned with the fundamental mechanisms of exhaust noise generation and radiation in small single-cylinder engines of the types and sizesused in chain saws.

Ten years ago it would have been hard to find a Canadian-made high-fidelity loudspeaker system. Today more than half of the market is served by Canadian manufacturers. Whatever the reasons for this dramatic change, there can be no doubt that the industry is strongly supported by the studies of auditory processes, and physical factors related to the quality of reproduced sound, and the development of physical measurements, listening tests, interpretive methods and design techniques undertaken in the Acoustics Section during the past fifteen years. These activities also encompass the design of listening rooms, the reproduction of sound in centres for the performing arts, and the development of measurement techniques for earphones, phonograph pickups and turntables. In 1979, as a contribution to the work of the International Electrotechnical Commission, the laboratory assumed a major role in the development of draft standards on loudspeaker measurements and listening tests. The room shown in the photograph which accompanies this article is, in fact, the prototype international standard listening test room. Superficially, it resembles a conventional living room, but it is distinguished by exceptional control over the frequencies, pressure distributions and damping factors of the room modes without which consistent testing would be exceedingly difficult.

Increasingly statutes, regulations and international contracts require acoustical measurements which are traceable to the national laboratory. To meet such needs a highly accurate microphone comparison system has been built and a primary calibration system of exceptional quality is nearing completion in our laboratory. At the same time we are closely examining the performance of conventional sound level meters and various kinds of integrating instruments which are now coming into general use. It is now clear that factors such as the detector characteristics, (e.g. crest factor), the instrument time constants and the tolerances on the weighting networks and overall frequency response can cause errors which are much greater than those which would be inferred from the instrument specifications. To help solve these problems we are working closely with the IEC and ANSI Committees which are active in this field. More generally, we are finding it necessary to devote an increasing proportion of our effort to the scientific support of national and international standards activities which often provide the channels through which ideas and discoveries are translated into action. It should perhaps be added that the study of sound level measurement techniques has yielded several bonuses especially the development of a miniature sound level meter, now in production on a small scale, and a precision measuring amplifier with a remarkably large dynamic range.



NRC International Standard Listening-Test Room

Looking into the future, it is safe to predict that a higher proportion of our work will be associated with the needs of Canadian industry. These include the need to design quiet and vibration-free machinery meeting acceptable health and environmental goals and, incidentally, securing competitive positions in international markets, the need for innovative products and services related to fields such as speech communication, image formation, control systems, industrial processing and non-destructive testing, and the need for highly sophisticated measurement techniques commensurate with the wide variety of problems which can be anticipated during the nineteen eighties.

The Acoustics Section enters 1981 with a permanent staff of eight scientists (A.J. Brammer, R.J. Donato, T.F.W. Embleton, J.E. Piercy, E.A.G. Shaw, M.R. Stinson, F.E. Toole and G.S.K. Wong) and four technical officers (A. Hellard, A.C. Lapointe, R. St. Denis and M.M. Vaillancourt). Also, our effort is frequently augmented and the laboratory enriched by the presence of one or two visiting scientists, research fellows and students.

In addition to the listening room already mentioned, our special facilities include a sound-insulated anechoic chamber and a recently-completed measurement laboratory which features a clear space with principal dimensions exceeding 7 m. Measurements in this space will be made with advanced techniques such as time-domain spectrometry, impulse and correlation methods. With these techniques we expect to be able to make measurements which, in an earlier day, would have required a very costly and less convenient anechoic chamber.