

The newsletter of
The Acoustical Society of America

ECHOES

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The Pickering Pickup

Most of us have grown up taking high-fidelity reproduction of recorded music, on phonograph records, magnetic tape, and now on CDs, pretty much for granted. We forget that hi-fi has not always been with us. One of the people who helped to make it all happen, engineer/inventor/musician/acoustician Norman Pickering is still hard at work in the basement laboratory in his home in Southampton, New York. Inventor of the Pickering pickup over five decades ago, Norman now devotes most of his energy to studying violins and violin strings.

During his high school and college years, Norman's favorite reading material was the Bell System Technical Journal, the Bell Laboratories Record, and any book having to do with musical acoustics. His heroes, he recalls, were men like Rice and Kellogg, Sivian, Dunn and White, Fletcher and Munson, and the great Helmholtz. He had been studying the violin since age 7 and was a competent French horn player as well. After finishing his electrical engineering studies at Newark College of Engineering, he received a scholarship to the Juilliard School. Embarking on a career as a performing musician, he quickly observed that recorded sound, while resembling music, was a far cry from the original stuff. In what he describes as his "youthful arrogance," he was sure he could do better.

In the nineteen thirties, most magnetic disc phonograph reproducers were massive devices built like the cutter heads used to make the records. A soft-iron armature mounted on elastic trunnions and surrounded by a coil was

provided with a strong magnetic field. Lateral movement changed a small air gap spacing, and the resulting flux variations through the armature generated audio-frequency voltages in the coil. As long as the motion of the armature precisely followed the undulations of the record groove, a voltage analog of the stylus velocity was passed along to the amplifier.

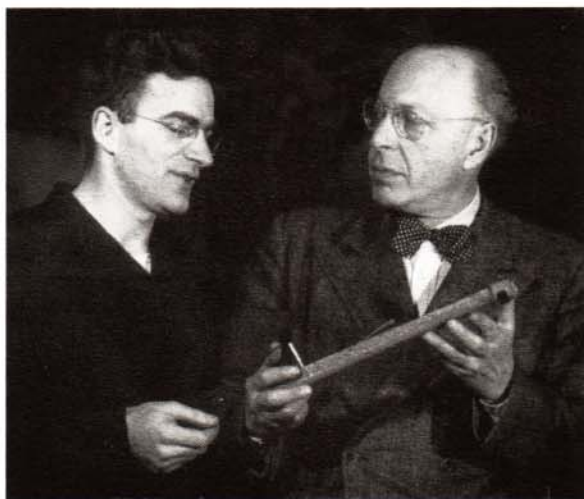
Because of the massive moving system (a gram or two), considerable vertical force was required to keep the repro-

ducing stylus in the V-groove of the record. Lateral accelerations of hundreds of g's were not uncommon in recordings, even in those days, and the shellac/clay material of the disc could not long survive the pounding in loud high-frequency passages. Neither could the stylus (then called the "needle.") Because of rapid wear it had to be replaceable, and the mass of the chuck and screw created a vicious circle of more mass, more wear.

A noble effort to circumvent these problems was launched by the Brush Development Company, Pickering recalls,

resulting in a piezoelectric design called the PL series. The moving mass was greatly reduced, and a jeweled stylus was permanently fixed. For professional use it failed because of its hum-prone high-impedance output and the necessity of equalizing its amplitude-analog signal to the velocity analog that more nearly matched the recording characteristics of the day.

During World War II, Pickering became a project engineer at Sperry Gyroscope Company in the development of aircraft azimuth instrumentation. He discovered that many



*Pickering presents a pickup to George Szell,
conductor of the Cleveland Orchestra in 1946*

(Continued on page 7)

We hear that...

Anthony Atchley is the new head of the Graduate Program in Acoustics at Penn State succeeding Jiri Tichy, who retired from that position recently.

Sadaoki Furui is the new Editor of the Journal of the Acoustical Society of Japan.

Howard F. Kingsbury, professor emeritus at Penn State University, has been named the 1997 recipient of the Wallace Waterfall Award given by the American Society for Testing and Materials.

Timothy W. Lancey, professor of mechanical engineering at California State University, Fullerton, has been named a Fellow of the American Society of Mechanical Engineers.

Michael Owren has moved from Reed College to the Department of Psychology at Cornell University, where he plans to do research on the evolutionary psychology of speech and sound.

Larry Royster received the Industrial Hygiene Association Distinguished Service Award at the AIHA Conference in Dallas in recognition of his significant contributions to the field of hearing conservation.

John Ffowcs Williams will receive the Per Bruel gold medal for noise control and acoustics at the annual meeting of ASME International (The American Society of Mechanical Engineers) in Dallas on November 17 in recognition of his contributions to the understanding of aeroacoustic phenomena and the application of theoretical acoustics to practical problems of noise control.

ASA mousepads available

A unique mousepad for ASA, with its own logo, is available for \$6 postpaid from ASA, 500 Sunnyside Blvd., Woodbury, NY 11797.



Newsletter of the Acoustical Society of America
Provided as a benefit of membership to ASA members

The Acoustical Society of America was organized in 1929 to increase and diffuse the knowledge of acoustics and to promote its practical applications.

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Practical Applications of Acoustics

by Charles E. Schmid

The stated purpose of the Acoustical Society, when it was founded in 1929, was to: 1) "increase and diffuse the knowledge of acoustics" and 2) "promote its practical applications." The first goal seems to be well satisfied today if we just look at a few statistics: we now hold about 7 parallel sessions at our meetings compared to a single stream of sessions fifty years ago; we publish around 8,000 pages in the Journal each year compared to 600 pages in 1929-30; we have a Web page that receives thousands of hits each month; we will be going online with the Journal in 1998, and are experimenting with e-prints and on-line rapid communications.

The second goal is harder to measure, and we must rely more on inference. The articles in this and the next issue of *Echoes* deal with past, present, and possible future practical applications of acoustics (phono cartridge, land mine detection, and sonoluminescence, respectively). In addition to publishing articles on practical applications, we recognize those who have promoted these applications, such as Silver medallists Gerhard Sessler and Jim West, who invented the foil electret microphone, 600,000,000 of which are manufactured every year! And ASA's satellite meetings seem to be oriented to the practical side. Dick Lyon's Product Sound Quality workshop was held last month, and ASA has organized a Classroom acoustics workshop for December. Two workshops next year will be on hearing aids and musical instruments. Last year a meeting on the Entrepreneur in Acoustics attracted around 50 participants.

A final note: It appears that the Congress, under pressure from the American public, is asking for more practical applications from scientific research. As James Sensenbrenner (R-WI), chair of the House Science Committee, recently stated, "I feel like the future of science rests on...convincing the public it's getting its money's worth." Such demands are probably based on the end of the Cold War (much of our research in acoustics is supported by DOD), consumer priorities, and concerns about taxes. Whatever the causes, it is important for us to emphasize that basic research still provides the foundation for future applications. But at the same time, it also helps when we can describe what the practical applications of acoustics are, or might be in the future.

Charles Schmid is Executive Director of the Acoustical Society of America.

Reusing JASA

Are you moving or retiring? Would you like to donate back copies of *The Journal* to a deserving newer member? Are you a new member who would like to receive back copies?

Interested parties should contact Elaine Moran at the ASA office (516/576-2360); she keeps lists of potential donors and recipients and tries to pair them according to geographical proximity. Each pair makes its own arrangements for shipping and postage.

Acoustics Workshops For Teachers

by Uwe J. Hansen

Musical acoustics is an effective vehicle for communicating science to students as well as to the general public. Therefore when technical initiatives were first discussed, the Technical Committee on Musical Acoustics proposed a series of workshops for science teachers. Since 1991, we have conducted 9 teachers workshops, some in conjunction with ASA meetings, some held at universities, and some in local school districts.

The first two workshops were organized following the Baltimore ASA meeting in 1991. A workshop for elementary school teachers, organized by Richard Berg (U. of Maryland), was held at the University of Maryland. This workshop was supported by funds from an Eisenhower grant, and it included follow-up support for teachers. Concurrently, a workshop on acoustics demonstrations and laboratory experiments was organized by Thomas Rossing.

The following Fall, a teacher workshop was organized following the Houston ASA meeting by Tom Rossing and me. Three subsequent workshops for elementary and secondary science teachers were conducted at Brigham Young University in Provo, Utah and at Indiana State University in Terre Haute. In organizing these workshops, we drew on the experience of summer courses we had offered at Indiana State, also supported by Eisenhower grant funds (which are handled in each state by the departments of education).

Although the workshops have employed different formats and programs, they all emphasized acoustics laboratory and demonstration experiments with simple apparatus, often constructed by the teachers themselves. For example, teachers built their own monochords and air column resonators, using pre-cut lumber, then did experiments with this equipment and took it home for use in their own classes. Self-resonant tuning forks were constructed at low cost in a university shop, and conventional tuning forks were supplied by scientific apparatus manufacturer. In one workshop, the teachers used computer-based data acquisition systems to do spectral analysis of sounds.

Our most recent workshops, conducted in the Spring of 1997, took place at regional conventions of science teachers. A workshop at the Hoosier Association of Science Teachers convention in February was attended mainly by elementary school teachers. Basic acoustical principles were presented, followed by a session on practical classroom applications using tools given to the teachers to take back to their schools. The tools consisted of a spring and a slinky for wave demonstrations, a monochord to relate the harmonic series to audible tones, an air column resonance device, a self-resonant tuning fork, and a corrugated whirling tube resonator. The second workshop was conducted at a meeting of the Indiana Section of the American Association of Physics Teachers at Purdue University in April. In addition to a review of acoustics principles, the demonstration and laboratory experiments for high schools were discussed.

The Technical Council is exploring the possibility of expanding the ASA educational outreach efforts, seeking outside funds, and possibly launching a national workshop program conducted by interested ASA members in various parts of the country. Anyone who is interested should contact me at Dept. of Physics, Indiana State University, Terre Haute, IN 47809. Telephone: 812/237-2046, email: phhanse@scifac.indstate.edu.

More on Change Ringing

Readers who enjoyed the session on bells at the Penn State meeting, and the paper by Ron Edge on change ringing in particular, will enjoy the article "Factorial Mathematics and the Art of Change Ringing" in the Sept. 19 issue of *The Chronicle of Higher Education*. The article features retired math. Professor T. Jefferson Smith, who has promoted change ringing at Kalamazoo College in Michigan. The sounds of the Kalamazoo bells can be heard on the Web at: <http://chronicle.com>.

Mystery of the Copenhagen Hum

To the Editor:

I have, with interest, read the article in *Echoes* 5(3), 1995 "The mystery of the Taos hum." A similar hum is known in many parts of the world, including an area with a diameter of 50 kilometers northwest of Copenhagen. Many persons (maybe 2% of the population) can hear a low-frequency sound, like the sound of an idling diesel engine or a bus at a bus stop. The sound often continues for weeks, but does change and stop. The sound differs from place to place. It is mostly noticed at night and inside homes where other noise is reduced. Some hum hearers are not bothered, but for most, sleep is disturbed and there are physiological and medical effects which severely affect the life of the victim.

Environmental branches of local government doubt that the hum is acoustic, and suggest mental illness or tinnitus as the cause. I have, however, researched the phenomenon in cooperation with a local organization of hum victims.

The hum can be tape recorded and replayed to the hum sufferer, who will recognize the hum provided that the sound reproduction system has a flat frequency response down to 10 Hz. If frequencies below 30 Hz are filtered out, the hum hearer will no longer recognize the hum from the tape. If the sound from a low frequency microphone near the sufferer is amplified and replayed in headphones with a phase 180 degrees different from the surrounding sound, the hum experience can be nullified, proving that the hum is caused by sound in the 5-30 Hz range.

A typical sound spectrum recorded in the home of a hum sufferer has peaks between 10 and 20 Hz, and the LFA weighted noise-energy sum is around 20 dB. The G-weighted noise-energy sum is around 60 dB. This is considered to be below the hearing threshold of the average person, who indeed cannot hear the hum. The low-frequency hearing thresholds of the hum hearers have not been systematically measured. The hearing threshold at higher frequencies is often impaired in hum hearers, and low-frequency hearing threshold appears to be sometimes average, often more sensitive than average.

The ability to hear hum seems to be hereditary, because the numbers of sisters, mothers, and daughters who can also hear it is above average. There are not so many brothers, sons, and fathers who can hear it, however. When the low frequency hum is replayed at increased volume most people can hear the hum and recognize the description given by the hum sufferers.

Using directional finding, the low frequency noise in the home of hum hearers could readily be traced to industrial plants, including power plants, a steel mill, an oxygen factory, a semiconductor plant, and a timber store. I feel that the mystery of the Copenhagen hum has largely been solved.

Anders Heerfordt

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San Diego and Seattle: two exciting meetings in the West

The Pacific shores are the where action will be for acousticians! Two exciting ASA meetings, as well as several symposia, are scheduled for San Diego and Seattle.

The 134th meeting of the Acoustical Society, at the Town and Country Hotel in San Diego, December 1-5, includes 35 special sessions on everything from ambient noise inversions in the ocean to computer jazz improvisation. A tutorial on "The Dolphin Echolocation System" (see article by Whitlow Au in this issue) and 3 short courses are scheduled. In addition to the information in the Call for Papers and the Program distributed with the Journal, information about the meeting is available on the ASA web site at: <http://asa.aip.org>.

The 135th meeting will be a joint meeting with the 16th International Congress on Acoustics (ICA) in Seattle, June 20-26, 1998. This will be a large meeting, with many special sessions, and in addition to the Call for Papers and the ASA web site, meeting information is available at <http://www.apl.washington.edu/ASA/asa.html>. Two satellite symposia are scheduled to follow the ICA/ASA meeting: one on Musical Acoustics (ISMA98) in Leavenworth, Washington, and one on Phonetic Sciences (IPS-98).

Home page for ISMA98 is: www.boystown.org/isma98, and home page for IPS-98 is: www.wvu.edu/~linguist/IPS-98.html.

Science Centers: Informal Education for Millions

by Thomas D. Rossing

Informal science education probably reaches a larger percentage of our population than formal science education in schools. Informal science education depends on television, newspapers, books, museums, and science centers to reach the public, young and old. While acoustics has not penetrated television nearly as much as we would like to see, museums and science centers appear to be prospering like never before.

At the San Diego meeting, the Committee on Education in Acoustics will sponsor a special session on Informal Science Education in Acoustics. We will hear from educators at three large science museums on the West coast: The Exploratorium (San Francisco), The Pacific Science Center (Seattle), and the Reuben Fleet Science Center (San Diego). In addition, we will hear from physics teachers who have active in "outreach" programs to schools and the general public.

I am a science museum "junkie." I rarely miss an opportunity to visit a science museum when I visit another city. The Exploratorium in San Francisco is a particular favorite. Reflecting the philosophy of physicist Frank Oppenheimer, its founder, it has had a tremendous influence on other science centers. Its interactive exhibits have been copied by many other museums with the blessings of the Exploratorium. In fact, so eager are they to have their exhibits replicated, that they have published a series of "Exploratorium Cookbooks" with useful ideas for science teachers at all levels.

The *IEEE Spectrum* published an interesting series of reports on science and technology museums. "WANTED: EE's WITH CHILDREN" was the headline of a call for volunteers to visit science and technology museums and write a report. Every report includes subheadings such as

"highlights," "what kids thought," "what adults thought," and "recommend it?" Science and technology museums, arranged by state are reviewed in the September and October 1995 issues. International museums are reviewed in the April 1996 issue.

Christopher Chiaverina is an extraordinary high school teacher, who has created interactive science exhibits at several schools. At Barrington (Illinois) High School, he teamed with a biology teacher and with students to create "The Science Place," which found a temporary home in an unused gymnasium in one of the elementary schools in his district. At New Trier High School, he has teamed up with other physics teachers to create an Interactive 3-D Physics Library, a collection of interactive exhibits designed to encourage exploration and generate a positive attitude toward physics. During the years, he has received support from both the Acoustical Society of America and the Optical Society of America for these activities, which he will describe in San Diego.

My many conversations with leaders in informal science education has conveyed the message loud and clear: while science centers are going strong, they depend upon volunteers and especially on knowledgeable scientists and engineers who are willing to pitch in and help with this important endeavor. Dick Crane, a retired University of Michigan physics professor (now in his mid-eighties), still produces hands-on exhibits in his basement shop for the Ann Arbor Science Center! Ernie Malamud, a high-energy physicist, took a year's leave from his position at FermiLab to serve as founder of the SciTech science center in Aurora, Illinois. Attendees at the Informal Science Education session in San Diego meeting should be warned: you may catch the "bug" yourself and end up volunteering to help your local science center!

Echolocation in Dolphins

by Whitlow W.L. Au

The echolocation system of dolphins has undergone millions of years of refinement under evolutionary pressures and has emerged as a sophisticated and finely honed system, with capabilities that are the envy of sonar designers. In a highly cluttered and noisy shallow environment, the dolphin can outperform any sonar in existence. The keen echolocation capabilities of dolphins can be attributed to several factors; (a) their sensitive and broad hearing range, (b) their use of broadband, short duration signals having high temporal resolution, (c) their high mobility coupled with good auditory spatial memory, and (d) their innate signal processing capabilities associated with a large brain much of which is devoted to processing acoustic signals. An example of an echolocation behavior that is rather remarkable comes from observations of Atlantic bottlenose dolphins foraging for prey buried in the sandy bottom in waters off the Grand Bahama island. In one mode of foraging, these dolphins swim about two to three meters from the bottom and scan the bottom, moving their heads in a circular motion emitting echolocation clicks that are audible to swimmers observing the behavior. Once locating and discriminating a prey, the dolphins often burrow about 45–50 cm into the sand, up to their pectoral fins, and emerge with a small prey in their mouth. Dolphins and bats have the broadest hearing range of any animals, some species having an upper limit of hearing to about 150 kHz. Their hearing sensitivity, frequency discrimination capabilities, binaural localization capabilities, intensity discrimination capabilities and their capability to detect and discriminate signals in noise are similar to humans. The major difference is that the dolphin's frequency of hearing is about 10X broader than humans, and the frequency at which dolphins have their best auditory capabilities are in the ultrasonic frequency range.

Echolocation signals of the Atlantic bottlenose dolphin are short duration clicks with durations of 50–70 μ s, bandwidths of 40–70 kHz and peak frequencies as high as 120–130 kHz. With this type of signal, the theoretical limits in resolving two echoes separated in time is between 12–15 μ s, which translates to about 0.9–1.1 cm. The signals are emitted in a conical beam having a width of about 10°. The peak-to-peak sound pressure level referenced to a distance 1 m from an animal, can reach up to 228–230 dB re 1 μ Pa, although levels around 220 dB would be more typical. In a noisy bay populated by snapping shrimp, a bottlenose dolphin can detect a 7.62-cm water-filled stainless steel target out to a range of about 113 m. For a 6.35-cm solid steel sphere laying on the bottom of the same bay, the dolphin can detect it at ranges up to 70 m.

Acoustic signals are processed in the dolphin auditory system very rapidly and this may in part explain the extremely fine temporal resolution capabilities of these animals. Brainstem transmission time in the bottlenose dolphin is considerably faster than in man or cat and is very similar to rats which have much smaller brains and shorter nerve pathways. In a range resolution experiment in which a dolphin had to determine which of two targets spatially separated by 40°, the dolphin was able to resolve range difference down to 0.4–0.5% of the absolute range (3 cm in 7 m and 1.5 cm in 3 m). These values translate to 40 μ s in 9,333 μ s and 20 μ s in 4,000 μ s. This fine temporal resolution capability coupled with the good theoretical temporal resolution limits of the echolocation signals play a large part in the dolphins' ability to discriminate the shape, structural composition, material composition and other features of targets. Echolocating dolphins are able to discriminate a copper plate 30-cm in diameter and 0.22 cm thick from aluminum and brass plates of the same diameter but slightly different thickness. In a wall thickness difference discrimination experiment using aluminum cylinders 8 m away, a dolphin was able to discriminate wall thickness differences down to 0.23–0.27 mm. This is such a small wall thickness difference that humans would have difficulty in performing the same task visually by looking at the cylinders edgewise from 1 to 2 m away.

Most of our knowledge of dolphin echolocation has come from experiments with captive animals. In these experiments, dolphins are trained to echolocate and perform detection and discrimination tasks that are not exactly natural, working with targets that are probably very alien, and in environments that are far removed from their natural habitat. Nevertheless, these experiments have been and continue to be extremely important in learning about echolocation, and there is still much to be learned. But the time is rapidly approaching when we will be able to take fuller advantage of the rapid technological advances in the computer field, especially with microcontrollers that are getting smaller physically but larger in memory capability and much faster in speed. We will then be able to pursue more studies with instrumented wild dolphins or trained dolphins in the wild, and to obtain better information on how, why and when echolocation is used for different species in different environments.

Whitlow Au is with the Marine Mammal Research Program at the Hawaii Institute of Marine Biology in Kailua. He will present a tutorial lecture on The Dolphin Echolocation System at the ASA meeting in San Diego.

NATO Advanced Study Institute on Sonochemistry and Sonoluminescence

by Nancy Penrose and Tom Matula

Physicists and chemists from 19 countries gathered at the Sleeping Lady Conference Center in Leavenworth, Washington in August for a NATO Advanced Study Institute (ASI) on Sonochemistry and Sonoluminescence. The purpose of the institute was to bridge the knowledge gap between disciplines by bringing together physicists, with their expertise in the physics of acoustic cavitation and bubble dynamics, and chemists, with their expertise in electron transfer, chemical reactions, and spectroscopy.

The institute, which included 10 days of tutorials and lectures, was organized by an international scientific committee comprised of Lawrence A. Crum, University of Washington, Chair; Timothy J. Mason, Coventry University; Jacques L. Reisse, Université Libre de Bruxelles; and Kenneth S. Suslick, University of Illinois. The institute was sponsored by the NATO Scientific and Environmental Affairs Division and cosponsored by the ASA. Additional support came from the Office of Naval Research and the Applied Physics Laboratory of the University of Washington.

The scientific program opened with tutorials on the fundamentals of acoustics, cavitation, and organic, inorganic, and physical chemistry, before moving on to more specific topics such as heterogeneous and homogeneous sonochemistry, bubble dynamics, and single bubble sonoluminescence.

Several papers focused on the use of sonochemistry in the polymer industry. Long polymer chains get caught up in the cavitation field where stress induced by cavitation can break the chains in a controllable manner that permits fine-tuning of the chain length and hence the polymer properties. Other papers described sonochemical synthesis of nanometer-sized particles which have properties different from bulk substances due to their relatively large surface area. Possible techniques for quantifying the acoustical parameters in cavitation fields, a difficult task in view of the complexity of the cavitation fields, were discussed.

In the "bigger is better" category, a large plate, about a meter in diameter, which could be driven by a piezoelectric transducer at more than a kilowatt, was described. This large plate can be used for defoaming, fine particle removal, and textile cleaning on a large industrial scale. High-speed photographic methods (up to 20 million

frames per second) for direct imaging of cavitation bubbles and bubble fields were described, as were methods for imaging cavitation fields in three dimensions.

New measurements of single-bubble sonoluminescence pulse widths as great as 300 ps were presented, while spectroscopic measurements of the temperature of sonoluminescence bubbles in cavitation fields were reported as ranging from 2000 to 5000 K. Issues including stability, chemistry, transport processes, shock waves, and even thermonuclear fusion were the subjects of lively discussions and debates.

The Sleeping Lady Conference Center proved to be an ideal venue for this intensive scientific program. Surrounded by the Cascade Mountains and set beside Icicle Creek, the Center is named for the mountain profile overlooking the area. The ASI's

73 participants found the nearby walking trails and forests conducive to pondering such scientific conundrums as the imploding shock wave theory vs. the jet theory of sonoluminescence. Few participants skipped any of the gourmet cuisine served in the Conference Center's dining lodge, where meal-time discussions often led to plans for future scientific col-

laborations. Informal evening sessions at the Grotto beer garden addressed topics ranging from how to boil water at 110 degrees F to the merits of genetic cloning. The Kairos Quartet, a string quartet in residence as part of the Icicle Creek Music Center, rehearsed and performed during the first week of the Institute, adding a high enjoyable musical acoustics contribution to the meeting.

The participants found the institute educationally and scientifically fruitful, inspiring many to return to their laboratories with renewed vigor and ideas for new directions in research. As participant Martti Salomaa of Helsinki University of Technology noted, in a thank-you note signed by all the participants and presented to Sleeping Lady owner Harriet Bullitt, "Sleeping Lady was wide awake during the NATO ASI! Extraordinary surroundings for a successful scientific meeting: peaceful, close to nature. Even with a relaxing sauna!"

Nancy Penrose, a manager at the Applied Physics Laboratory, University of Washington, served as coordinator for the NATO institute. Tom Matula is a research scientist at APL.



Left to right: Ken Suslick, Andrea Prosperetti, Werner Lauterborn, Robert Nigmatulin, Larry Crum.

Pickering

(Pickering Pickup...continued from page 1)

fine musicians were working there, and he was instrumental in forming a company orchestra and became the conductor. He also began to give concerts of recorded music from his own collection, using audio equipment of his own design.

Having analyzed the commercial record reproducers then available and the dynamics of the disc recording process, he decided that the magnetic approach was the best, and that mass was the enemy to be overcome. Concentrating on magnetic efficiency, he made the moving armature of a hydrogen-annealed 4750 nickel-iron alloy drawn into a tube 0.75 mm in diameter with a 0.1-mm wall. It was spring-mounted, very much like a front wheel on a modern automobile. With the Alnico V magnet, the entire mechanism was slightly larger than a 1-cm cube (still large by today's standards), and the effective lateral mass was about 10 milligrams.

An important discovery arising from the equation of stylus force vs. frequency was that the mechanical resonance frequency in the lateral mode, where the forces due to the lateral stiffness and the mass balance, should be near the middle of the frequency range. It also became evident that vertical motion must be accommodated, but with much higher stiffness of the suspension. Having the correct amount of damping in both modes is important.

Norman built a number of models along these lines, prompted mainly by the desire to extend the life of his own record collection. Friends who listened to his record concerts were impressed by the sound quality, and one of them, an entrepreneurial recording engineer, told him, "If you can make these after the war, I'll sell all you can make!" And that is essentially what happened.

Radio stations at that time depended heavily on disc recordings, including 16-inch transcriptions, for their program material. The Pickering Pickup became popular in that market almost as soon as it appeared. Capitol Records adopted it for all of their studios, leading the incursion into that application. The photograph on page 1, made in 1946, shows the professional version of the pickup in the hands of George Szell, conductor of the Cleveland Orchestra. Shortly after, Norman was engaged as Szell's technical assistant in audio and acoustical matters.

In 1947, a consumer model of the device was designed to operate with record changers. Seeburg adopted a dual version of the pickup for their novel juke box that played 100 records on edge with the arm in a vertical position.

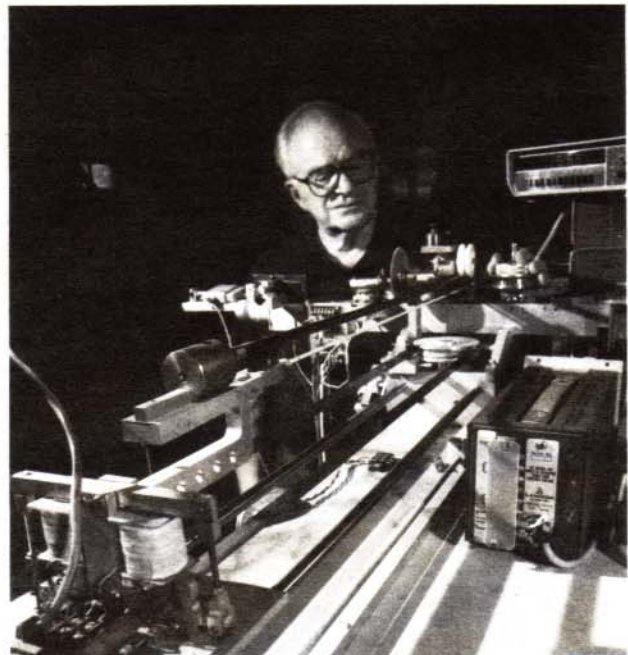
The development of the LP record system at the CBS laboratory took the audio world by surprise, and no information was initially available for use in designing new pickups. First guesses at recording characteristics were off the mark, but soon were rectified, essentially "by ear." The Pickering Pickup was adapted to LP records and later to

stereo discs, which required a completely new approach to pickup design. Norman remained a leader in audio pickup design, and he was one of the founders of the Audio Engineering Society, which is celebrating its fiftieth year at this time.

Having equipped his laboratory with the best available audio-frequency instrumentation, it occurred to Norman that it could be used to study the acoustics of the violin. What seemed to be a fairly straightforward problem, however, has turned out to be one of great complexity. During the past few decades, he has applied most of his creative energy to studying violin strings and particularly the bow-string relationship. He has made about forty violins and violas as part of his research, and he served as president of the Violin Society of America, of which he is still a Director. He is a Fellow of the Acoustical Society of America and a frequent contributor to its programs.

Using infrared sensors, he has carefully studied temperature effects during bowing, and especially how the frictional coefficient of violin rosin changes with temperature. Many of his results are described in his book *The Bowed String* (Amereon, Mattituck, NY, 1991). He has collaborated with a prominent string manufacturer, for whom he designed new types of bowed strings as well as computer programs for predicting string performance. The photograph below shows him with his violin bowing machine.

What Norman Pickering will focus his creative energies on next is anyone's guess. What is certain, however, is that this modern Renaissance man has left his mark as a musician, inventor, engineer, scientist, and an example of creativity to future generations!



Pickering's violin bowing machine

Acoustics in the News

● Sound normally travels at about 1400 meters per second in water and about 4000 meters per second in ice. Collective excitations are thought to be responsible for "fast sound" in liquid water, which has been observed to propagate at 2000 to 3200 meters per second, according to a paper in *Physical Review Letters* 77, 83-86 (1996). A group of researchers at the European Synchrotron Radiation Facility and the University of L'Aquila in Italy used inelastically scattered x-rays to generate fast sound waves in water. Their results suggest that at high frequencies, the dynamical response of liquid water becomes increasingly solidlike.

● While examining signals recorded by seismic stations in French Polynesia, seismologists Jacques Talandier of the French Atomic Energy Agency and Emile Okal of Northwestern University discovered mysterious signals in frequency range of 3 to 12 Hz, according to an article in *Scientific American* (August 1997). The first clue to their origin came after they determined the position of the source to be within a poorly surveyed region of the South Pacific known to have an underwater volcanic ridge. Although volcanic events can generate ocean-going sound waves, called T waves, those that do are generally in shallow water where the pressure is sufficiently low that bubbles can form in the water above the scorching lava. Bernard Chouet, a specialist on harmonic tremors at the U.S. Geological Survey, suggested that a cloud of bubbles sandwiched between the top of the seamount and the surface of the ocean was acting as a resonator, leading to the pure tones at low frequencies. Although this appears to be a plausible explanation, Talandier and Okal presented their observations to the Seismological Society of America under the heading of "Volcanological Speculations."

● "Towards a quantum loudspeaker" is the intriguing title of a note by Roberto Merlin, University of Michigan, in *Physics World* (August 1997). "Imagine that we could reduce the dimensions of a loudspeaker to the point where quantum effects became important," begins the article, "How would such a speaker sound and, in particular, how

would its energy dissipate?" The author goes on to describe experiments at CalTech that open the door to a "new world of calorimetry where we will be able to monitor the movement of single phonons carrying energies of less than a yoctojoule, or 10^{-24} J. Looking into the future, he sees a totally new field called "quantum sonics."

● An article in the September 1997 issue of *The Industrial Physicist*, entitled "Science and Art Converge in Concert Hall Acoustics," includes photographs of Symphony Hall in Birmingham and the Myerson Symphony Center in Dallas, as well as contributions from acousticians Ashley Goodall, George Izenour, John Bradley, and Christopher Jaffe. Surround halls, "designed to create an intimate, less formal musical experience with easier access between the performers and the audience" are discussed, as well as other contemporary concert hall designs. Subscriptions to *The Industrial Physicist*, published by the American Institute of Physics, are free to "qualified" persons who request them.

● Booming, squeaking, and whistling sounds from sand are discussed in an article entitled "Booming Sand" in the September 1997 issue of *Scientific American*. Squeaking sand produces sounds with frequencies between 500 and 2500 Hz, lasting less than a quarter of a second, whereas booming sand makes louder, low-frequency sounds (50 to 300 Hz), which may last as long as 15 minutes in large dunes. At least 30 booming dunes have been found in deserts and on beaches in Africa, Asia, North America and elsewhere, according to the authors, Franco Nori, Paul Sholtz, and Michael Bretz, at the University of Michigan. Walking on some sand produces the squeaks, whereas booms are associated with avalanches. Before an avalanche can occur, winds must build up a dune to a critical angle, generally about 35 degrees for dry desert sand. Then layers of sand can slip over layers below, like a sheared deck of cards. The multiple frequencies emitted by the booming sand are not yet understood, however. A more complete paper will appear in the Fall issue of *Contemporary Physics*.



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