SOUND&VIBRATION

NOISE AND VIBRATION CONTROL DECEMBER 2010

University of Hartford's Acoustics Engineering Lab

Robert D. Celmer and **Michelle C. Vigeant**, University of Hartford
Alan Eckel, Eckel Industries, Inc., Cambridge, Massachusetts

The University of Hartford's Acoustics Engineering Laboratory was relocated and rebuilt as part of a new Integrated Science, Engineering and Technology (ISET) facility on campus. The new lab includes a reverberation room and an adjacent anechoic chamber. This new laboratory provides a wide array of acoustic and vibration testing capabilities that allow undergraduate acoustical engineering students to work on a variety of real-world acoustic design and research problems for industry, foundations, and the community. Projects include: loudspeaker and sound system design, architectural acoustics, acoustic material testing and development, musical acoustics, environmental acoustics, hearing and psychoacoustics, as well as noise and vibration control of machinery.

Facility Description. The facility includes a 125 m^3 reverberation room and an adjacent 100 Hz full anechoic chamber, each supplied by Eckel Industries, Cambridge, MA. Both chambers were independently tested for diffuse and free-field compliance with applicable ISO standards. Using the procedures reported in ISO 3741, Annex E, the reverberation room qualified for diffuse-field testing in all one-third octave bands, from 100-10,000 Hz.[1] An array of diffusors was subsequently added using the process described in Appendix X1 of ASTM C423-2002.[2] The anechoic chamber qualified for free-field measurements for one-third octave bands of 100 Hz and above per ISO 3745-2003.[3]

Both chambers are vibration isolated on 3 Hz springs and utilize inlet/outlet silencers that achieve background noise levels < NC 10). In addition, both chambers feature removable hatches along their common walls, enabling the facility to perform sound transmission loss tests using the sound intensity method described in ASTM 2249-02(2008).

Design of Test Chambers. Acoustical consulting services for the ISET facility were provided by Cerami & Associates, Inc. of New York City. A unique location for the new laboratory was found early in the ISET schematic design process. A high-bay, ground-floor area originally used for the building's air handlers became available, since the renovation called for the use of rooftop units. This became the preferred site for the new lab due to the larger chamber volumes possible thanks to the additional two feet of floor-to-ceiling height and its location at the far end of the corridor from the building's boiler room.

During the ISET renovation, Bob Celmer, director of the acoustics program and laboratory, developed the technical requirements for the laboratory's design that would meet the specific needs of the program's undergraduate acoustics engineering program. In addition to the architects and consultants, he worked closely with Jeff Morse, vice president of engineering at Eckel, who coordinated Eckel's design team. Morse offered suggestions that would take advantage of the chamber's unique location. Since the floor of the acoustics engineering lab itself would be 2 feet higher than the base of each test chamber, Morse suggested using Eckel's patented E-Element anechoic absorption units for the floor surface instead of a more conventional wedge. This enabled the completed chamber to be accessed by less than a 6-inch vertical step up while maintaining the same cut-off frequency as the wedges used for the walls and ceiling.

Instrumentation Systems. The Acoustics Engineering Laboratory uses a comprehensive array of Brüel & Kjær equipment, including a 4-channel Pulse measurement system, sound intensity wand, rotating boom microphone, reference sound power source, sound quality binaural head, diffuse and free-field microphones, accelerometers and a modal hammer, along with three Type 2250 portable sound analyzers. All engineering students enrolled in one of the two acoustic degree programs begin using the equipment for project work in their sophomore year.

Software-based analysis packages include current versions of ODEON, CATT, and StarSTRUCK (for modal and ODS analysis), which run on Windows 7 workstations. The lab has also acquired B&K Pulse projects, such as ISO 3741 Sound Power, ASTM C423 Sound Absorption, ASTM 2249 Transmission Loss by the sound intensity method, SAE J1400 Transmission Loss, as well as TL by the four-microphone, two-load impedance-tube approach.

Undergraduate Programs in Acoustics. The University of Hartford has two undergraduate engineering programs in the area of acoustics – bachelor of science in mechanical engineering with acoustics concentration and bachelor of science in engineering with a major in acoustical engineering and music. The first curriculum is part of a BSME degree program that has required courses in vibration as well as engineering acoustics since the 1960s. The acoustical engineering and music degree is a unique program that was instituted in 1976, where applicants must have the equivalent math and science background required of all engineering students and also must successfully pass the entrance requirements of the Hartt School (University of Hartford's music conservatory), including the audition.

Adam Clark BSME/Acs '12 calibrating a diffuse field microphone on a rotating boom. Transmission Loss pass-through hatch and fixed diffusors are visible behind the student.

Caitlin Ormsbee, BSE Acoustical Engineering & Music '12 participating in a psycho-acoustic study in the anechoic chamber.

Both programs encompass the same engineering vibrations and acoustics courses, as well as the same sequence of acoustic projects beginning in the second year. One of the transitions that engineering students must make as they enter the work force is the progression from theoretical concepts, or "book learning," to applied or "real-world" applications. At the University of Hartford, engineering design courses serve as culminating experiences devised to bridge this passage. The acoustic design projects challenge our students to apply their conceptual courses to a problem-solving opportunity replete with actual scenarios encountered in industry or consulting. Each year, architects, engineers, and members of the community approach our laboratory for design assistance. Projects are negotiated not only for their appropriateness but also for their starting times and scope, enabling the task to work within the confines of a semester course.

Sample senior projects include:

- Muffler Design for NASA Orion Space Crew Module
- Just Noticeable Difference of Clarity Index (C80) Study
- Room Acoustic Design for Hartford Symphony Orchestra
- Rehearsal Space – Modal Analysis and Audio Performance Testing of an in-wall sub-woofer system.

Students have not only completed these

projects successfully but have also gone on to present their results at national meetings of the Acoustical Society of America and Institute of Noise Control Engineers. They have also won awards for best student paper, best student design, as well as the Robert Bradford Newman Student Medal for Merit in Architectural Acoustics.

Alumni of both undergraduate programs have successfully obtained positions in consulting (architectural and environmental), audio product and A/V design, musical instrument design, hearing and psychoacoustic-related design, noise control, as well as to pursue graduate degrees.

Faculty. Celmer is the director and also an alumnus of the acoustics program at the University of Hartford. He graduated from UH with a bachelor of science degree in mechanical engineering with acoustics concentration in 1978. He went on to the Pennsylvania State University, where he earned his masters and doctorate degrees in acoustics in 1980 and 1982, respectively. Since 1982 he has been in the Mechanical Engineering Department of the University of Hartford's College of Engineering, where he currently holds the rank of professor. He is director of the Acoustics and Vibrations Laboratory at the College's Engineering Applications Center, and his major areas of applied research include: architectural acoustics, acoustics of musical instruments, noise and vibration control, hearing loss and hearing aid design, sound quality, transducer design, environmental acoustics, modal and ODS analysis. He is a member of the Acoustical Society of America, Institute of Noise Control Engineering, Audio Engineering Society, American Society of Mechanical Engineers, and American Society of Engineering Educators. Celmer is also a registered Professional Engineer.

Michelle Vigeant is the second member of the U H acoustics program. She completed a bachelor of science degree in mechanical engineering co-op at the University of Alberta in 2003, during which she spent two of her three co-operative work terms in the field of acoustics. Immediately following her undergraduate degree, she pursued her doctorate degree in architectural engineering at the University of Nebraska. Her dissertation research was in the area of room acoustics computer modeling and auralization, as related to source directivity, and she graduated with a Ph.D. degree in engineering. Her major area of applied research is architectural acoustics, specifically in the topics of listener envelopment and the just noticeable difference of clarity index (C80). She is a member of the Acoustical Society of America, American Society of Mechanical Engineers, and American Society of Engineering Educators.

Summary. The University of Hartford has designed and constructed an Acoustics Engineering Laboratory that includes both a reverberation room and full anechoic chamber and provides its acoustical engineering students access to state-of-the art facilities and equipment. The students are provided extensive training in the procedures to make accurate and repeatable sound measurements as well as achieving analysis and design capabilities for a wide variety of acoustic topics. This prepares them for successful careers in the field.

The anechoic chamber was dedicated in October 2010 as the Paul S. Veneklasen Research Foundation Anechoic Chamber, in recognition of financial support of award-winning student research projects in the laboratory over the past four years. For more information about the program and/or to see photos from the dedication, please visit our website at http://uhaweb.hartford.edu/acoustics.

1. International Organization for Standardization, Acoustics: Determination of sound power levels of noise sources using sound pressure – Precision methods for reverberation rooms. ISO 3741-1999.
2. International Organization for Standardization, Acoustics: Determination of sound power levels of noise sources using sound pressure, precision methods for anechoic and hemi-anechoic rooms, ISO 3745-2003.
3. American Society for Testing and Materials, Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method, ASTM C423 - 09a.

OUR AUTHORS

David L. Bowen is the author of "Sound Quality Studies of Front-Loading Washing Machines." He is currently supervisory consultant at Acentech Incorporated in Cambridge, MA. His areas of expertise include product noise, sound quality, signal processing, transducer development, active control, vibration transmission, and machinery diagnostics. Prior to Acentech, he spent 17 years at the consulting firm RH Lyon Corp., where he also focused on these same general areas. Bowen has over 25 years of experience in the acoustics and vibration field, and holds degrees in mechanical engineering from North Carolina State University and the Massachusetts Institute of Technology.

The article "Small Deviations and Big Failures in Vibration and Noise Isolation" was coauthored by **J. Byron Davis** and **Ahmad Bayat**. Davis and Bayat operate Vibro-Acoustic Consultants in San Francisco, CA.

Davis received his B.S. degree in materials science and engineering from MIT in 1998, with special background in semiconductor processing and high-end metrology technologies. He has spent about 12 years working on vibration and noise design for highly sensitive advanced technology facilities.

Bayat received his M.S. degree in civil engineering from the University of Houston, with specialization in soil dynamics. He has worked on vibration design of fabs and labs since the early 1990s. Together, their broad background offers a unique capability in creating cost-effective and highly productive laboratory and precision-manufacturing environments.