CASE STUDY

Caterpillar Inc.
Noise and Vibration Testing

United States of America

Automotive, EU Directive, Consultancy

PULSE, Transducers

A new Noise Control Research Laboratory was commissioned in December 2001. It provides extensive test and analysis facilities that are used in new product development and for verification of compliance of Caterpillar products to international standards. Caterpillar's test facilities and expertise are also available to external customers.

Caterpillar is the world's largest manufacturer of construction and mining equipment, diesel and natural gas engines, and industrial gas turbines. The first Brüel & Kjær PULSE™ analyzer was bought in 1996 and PULSE forms an integral part of the AudiBel Dynamic Sound Test System.

PULSE

A major benefit of PULSE is its OLE interface – it integrates with other software enabling customised user interfaces to be developed. The PULSE LabShop software runs in the background and, when once set up, requires no further attention.

AudiBel

Fig. 1
The Dynamic Sound Test System performs dynamic and static sound testing on earth-moving machinery according to ISO standards. Due to an advanced system design, only one person, the machine operator, is required to perform a complete test

In order to comply with the requirements of the ISO 6395/6396 standard for static and dynamic sound testing, Caterpillar improved its testing facilities. The implementation of ISO 4871, which outlines statistical documentation requirements, had a significant impact on sound power compliance levels and manufacturers' labelling practices – compliance that would increase the number of necessary tests, making the time needed per test a critical factor.

Due to the advanced system design of the AudiBel system, a complete test can be performed by a single person compared to two or three people involved in manual testing. Furthermore, testing with the AudiBel system meant an eight-fold reduction in the overall test time due to the elimination of lengthy setup and dismantling time, fast calibration and on-line calibration validation, plus simultaneous exterior and operator noise measurements. This increases the number of tests per day.

Based on calculated time savings, Brüel & Kjær worked with Caterpillar in developing the automated AudiBel solution.

The facility is used to verify that complete machines conform to international standards such as the new EU directive. There are also noise standards for outdoor machinery in other countries such as Japan and Australia. The complete machine is rolled out into the test site and goes through all operational cycles, including operation of all tools, loaders, hydraulics, etc.

New Noise Control Research Laboratory

Fig. 2
Caterpillar's Technical Center at Mossville, Illinois

To meet the need for noise and vibration testing in product research and development, in December 2001, Caterpillar commissioned a new noise control research laboratory at its Technical Center in Mossville, Illinois. The new laboratory includes two sound chambers – a reverberation chamber and a hemi-anechoic chamber – state-of-the-art instrumentation, and a spacious analysis/control room.

Fig. 3
David Copley is a senior research engineer – he has worked at Caterpillar since 1995

Some of the critical requirements were for a hemi-anechoic chamber large enough to test a variety machines and components, including some that would require exhaust ventilation. Low-frequency capability was identified early on as a requirement, and it was decided that both chambers would be capable of measurements down to 80 Hz.

Due to the variety of possible research, a very low noise floor was required, and set to be no louder than NC20, with a HVAC (heating, ventilating, air-conditioning) system running. Requirements for the reverberation chamber also included a NC20 noise floor with HVAC, and capability down to 80-100 Hz for sound power and sound absorption tests. In addition, a transmission loss aperture was required between the two chambers in order to conduct noise barrier performance tests such as SAE J1400.

Lab Features

The chambers are built on separate isolated concrete slabs, each resting on fibreglass pads, in turn resting in separate concrete basins structurally isolated from the buildings' concrete foundation, which is in turn structurally isolated from the existing building.

Hemi-anechoic Chamber

The interior dimensions of the hemi-anechoic chamber are 30 × 30 × 16 feet (9.1 × 9.1 × 4.9 m) – large enough to test major components or complete machines.

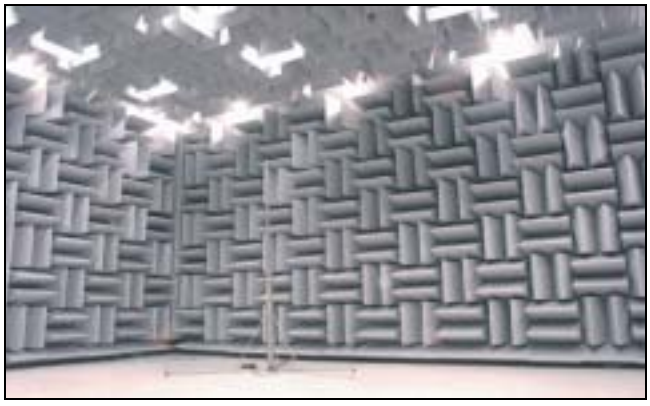

Fig. 4
An inside view of the hemi-anechoic chamber at Caterpillar's noise control research laboratory

The hemi-anechoic chamber walls are made from 12 inch (305 mm) thick panels, made from 11 gauge steel and filled with fibreglass.

The interior of the hemi-anechoic chamber is lined with more than 1500 melamine foam wedges, each 2 feet (610 mm) deep, 2 feet (610 mm) wide and 12 inches (305 mm) thick.

Melamine resin is the basis for FORMICA® and being quite inert, does not deteriorate with exposure to acids and alkalies like urethane foams. Also, melamine foam does not burn under normal atmospheric conditions and has a high flash point. Acoustic performance is achieved when these wedges are coupled with the cavity-wall construction as implemented in this chamber for maximum sound absorption down to 80 Hz.

One drawback of the melamine foam wedges is that they are brittle and somewhat fragile. However, because this facility is primarily used for research purposes it was decided that the benefits of acoustic performance outweigh the risks of damage.

Fig. 5
The chamber is large enough for complete machines to be tested

To meet access requirements, there are large double doors with accompanying wedge-basket doors, a double personnel door with a wedge basket door, a transmission loss aperture, wall plugs covered by wedge baskets, and many 3inch (76 mm) diameter pass-throughs. A ceiling plug is in the ceiling, and when removed, exposes a telescoping vent which leads to an exhaust fan.

The doors and plugs are all high Sound Transmission Class (STC) design and are magnetically sealed. Door frames are caulked or otherwise sealed to the chamber structure. The passive leaf of the large exterior door has a cane bolt to ensure a tight fit when both leaves are shut and the large exterior doors have an innovative, adjustable drag seal that ensures a tight acoustic seal to the floor and door threshold.

There is a layer of fibreglass between the inner shell of the chamber (metal panels) and the outer shell (concrete block). In the region above the large doors, a pressure-relief channel through the fibreglass layer was necessary to permit the doors to open and close due to such tight sealing conditions.

Reverberation Room

The reverberation chamber walls are 4 inch (100 mm) thick metal panels, made from 11 gauge steel and filled with fibreglass. The chamber is large enough to test components or complete machines.

Fig. 6
David Copley adjusts a microphone inside the new reverberation chamber

Six stationary metal panel diffusers are suspended by adjustable chains. The diffusers establish a diffuse acoustic field at low frequencies. To meet access requirements there are large double-leaf doors, double personnel door with transmission loss aperture and wall plugs, and 3 feet 3 inch (76 mm) diameter pass-throughs.

Interior lighting is provided by five fluorescent light fixtures. The ballasts were mounted remotely above and away from the chamber, in order to minimize buzzing noises within the chamber. Sprinklers and emergency lighting are provided for safety.

The doors are high STC design and are magnetically sealed. Door frames are caulked or otherwise sealed to the chamber structure. The passive leaf of the large interior door has a cane bolt to ensure a tight fit when both leaves are shut. There is a layer of fiberglass between the inner shell of the chamber (metal panels) and the outer shell (concrete block). Storage areas are provided to either side of the large double doors.

HVAC Systems

The hemi-anechoic chamber has two independent HVAC systems, one used for environmental or personnel comfort air, the other used to ventilate the chamber during engine operation. The reverberation chamber has its own separate HVAC system to minimise cross-talk between the chambers.

To minimize HVAC noise, several key noise control techniques were employed, including:

- Remote placement of air handling unit (more than 100 feet (30.5 m) away in a different part of building)
- Long, acoustically lined ducts
- Ducts with large cross-sectional area
- Multiple silencers
- Guide vanes at turns
- Caulk around wall penetrations (vents, conduit, pipes, lighting fixtures, etc.)

Analysis/Control Room and Equipment

A spacious, brightly-lit analysis/control room provides workspace for primary and secondary control stations, two analysis stations and a conference table. In addition, there is ample room for supply cabinets and resource materials. Miniature TV cameras are mounted in each chamber so the test engineer can monitor activity.

Two 16-channel Brüel & Kjær PULSE systems provide primary data acquisition and signal control for both chambers. These multi-analyzers use standard PULSE LabShop software.

Performance Specifications Obtained Through Qualification Testing

Before use, the acoustical performance of each chamber was tested for compliance with the original specifications by a third-party acoustical consultant.

Benefits

Following the commissioning of the new Noise Control Research Laboratory, Caterpillar can make noise and vibration tests in the hemi-anechoic and reverberation rooms on both complete machines and individual components such as diesel engines, electric motors, hydraulic pumps, etc. Owing to the minimal noise from the HVAC system, testing can be made even with the engine running. The machines can be remotely controlled during this type of testing.

An additional 16-channel PULSE analyzer coupled with a laptop PC will enable a user to make tests, especially vibration and modal analysis, wherever they're needed – on the various production lines, at external customers premises. Many of the measurements are directly connected to compliance with the various international standards.

Reporting and Data Handling

Test data is archived on a database – Caterpillar has developed a number of in-house analysis tools to post-process the data. Reports are made using the Microsoft® Office suite (Word and Excel). The reports are also placed on the database enabling R&D, production departments, etc., all over the world to access the test results.

External Customers

Caterpillar plans to open up the Noise Control Research Laboratory to external customers.

Key Facts

- Brüel&Kjær products have been used by Caterpillar for more than 20 years
- The AudiBel system uses PULSE for data acquisition
- Caterpillar uses Brüel&Kjær transducers
- A new Noise Control Research Laboratory was commissioned in December, 2001 – two 16-channel PULSE systems are used for data acquisition
- The Noise Control Research Laboratory facilities and expertise are available to external customers
- The company is the world's largest manufacturer of construction and mining equipment, diesel and natural gas engines, and industrial gas turbines

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