CASE STUDY

New Noise Measurement System
Rolls-Royce PLC

United Kingdom

Aerospace

PULSE™, Transducers, Noise Measurement

A new noise measurement system using state-of-the-art technology has recently been installed at Rolls-Royce's site at Hucknall, near Derby. Supplied by Brüel & Kjær, Denmark, the new installation enables noise measurements and analyses to be made simultaneously on up to 128-channels – the data is used to confirm compliance of Rolls-Royce engines to international noise standards and for extensive R & D investigations.

Fig. 1
A Rolls-Royce Trent 500 installed on the Noise Measurement Test Bed at Hucknall. The Turbulence Control Screen is mounted on its own trailer.

History

Back in 1927, Rolls-Royce decided to carry out its own flight development, but the airfield originally used was a long way from the main Derby factory, and it was too small. A suitable permanent site was necessary and Hucknall, some 15 miles from the Rolls-Royce factory, was chosen. Hucknall airfield, built in 1916 and originally home to the American Flying Corps, was subsequently used by the Royal Air Force, and it continued in this role for many years. The RAF stopped using the airfield in 1957.

In December 1934 two hangars were erected and Hucknall became Rolls-Royce's flight test centre. After nearly 40 years in this role, it was announced in 1971 that test flying would be transferred to Filton, near Bristol but Hucknall remained as a test site for Rolls-Royce engines.

Test Facilities

Using a wide range of technical expertise and test facilities, the Test Facilities Team of about 100 employees carry out a variety of tests vital to the integrity of Rolls-Royce aero engine throughout their development and certification programmes. The No. 11 Test Bed is designed to test engine noise and performance characteristics for all Rolls-Royce aero engines.

Fig. 2
Aerial view of Hucknall and the No.11 Test Bed – the runway is no longer used

A Turnkey Project

Rolls-Royce recently decided to replace its No. 11 Test Bed noise measurement system. The Test Bed, originally built in 1983, is the only rotating test bed in Europe and has been used to noise-certify all Rolls-Royce civil aero engines.

Michael Clarke, a Chartered Engineer who has worked at Rolls-Royce for 12 years, was appointed as the Project Manager.

Mike Clarke explains, “Noise measurement is vitally important. Our aim is to have as quiet an engine as possible. This benefits airframe manufacturers, airline passengers and the public in general. The noise measurement tests are carried out for both certification of an engine and for our own extensive R&D investigations”.

Fig. 3
Michael Clarke, is the Project Manager for the Noise Measurement System

Mike continues, “The new noise measurement system is a significant investment for Rolls-Royce. It must be reliable, stable, accurate and require minimum maintenance. We've used Brüel&Kjær analyzers, sound level meters, transducers and other products for many years and they offered us a cost-effective package. As the world leaders in the manufacture of aero engines, it was natural for Rolls-Royce to award the turnkey contract to the world leaders in noise measurement systems”.

The No 11 Test Bed is impressive! The whole structure weighs hundreds of tons but can be rotated through 360 degrees by a hydraulic motor. The position of the engine under test can therefore be adjusted according to the prevailing wind direction. It can take as little as two hours for an engine to be installed on the test bed.

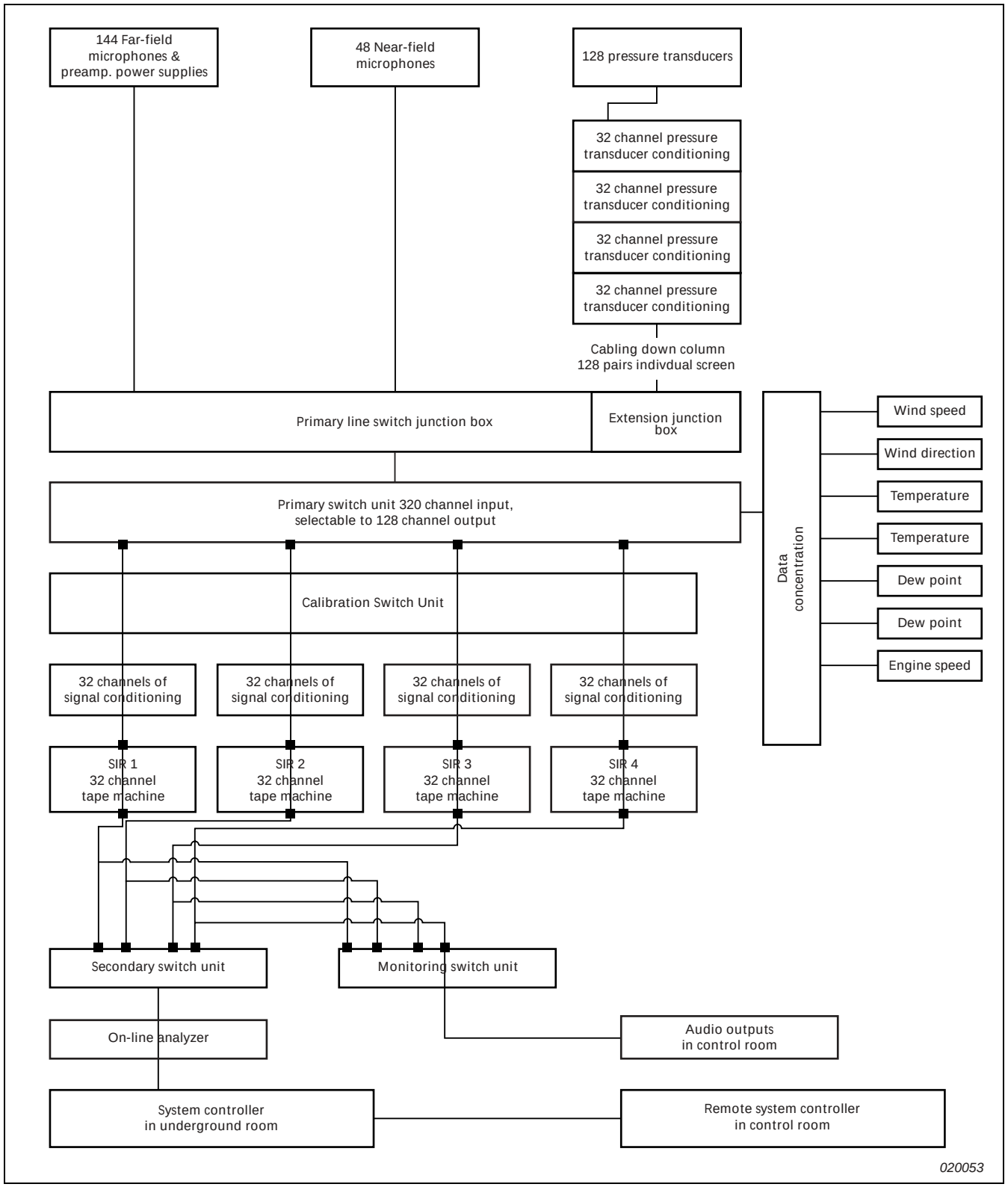
The Noise Measurement System – an Overview

Engine noise is collected by:

- 144 Brüel&Kjær far-field microphones – placed in pairs at ground level at 5 degree intervals around the perimeter of the test bed

- 48 Brüel & Kjær near-field microphones – placed at predetermined intervals at ground level, close to the engine
- 128 pressure transducers – mounted on the engine

Fig. 4 *Overview of the noise measurement system*



The cables from these transducers are routed to an underground room, located close to the test bed. Switching units are used to select up to 128 channels to be recorded from the 320 available transducers.

Placed in the underground room are:

- Eight Brüel & Kjær Type 2694 16-channel signal conditioning amplifiers
- Four Sony® SIR-1000 32-channel DAT recorders
- Brüel & Kjær 32-channel PULSE™ multi-analyzer
- Two computers – one is the PULSE master system controller; one is a data concentrator used to collect weather data
- Various channel switching units
- Brüel & Kjær calibration switch unit

Fig. 5 *Diagram of the noise measurement system*

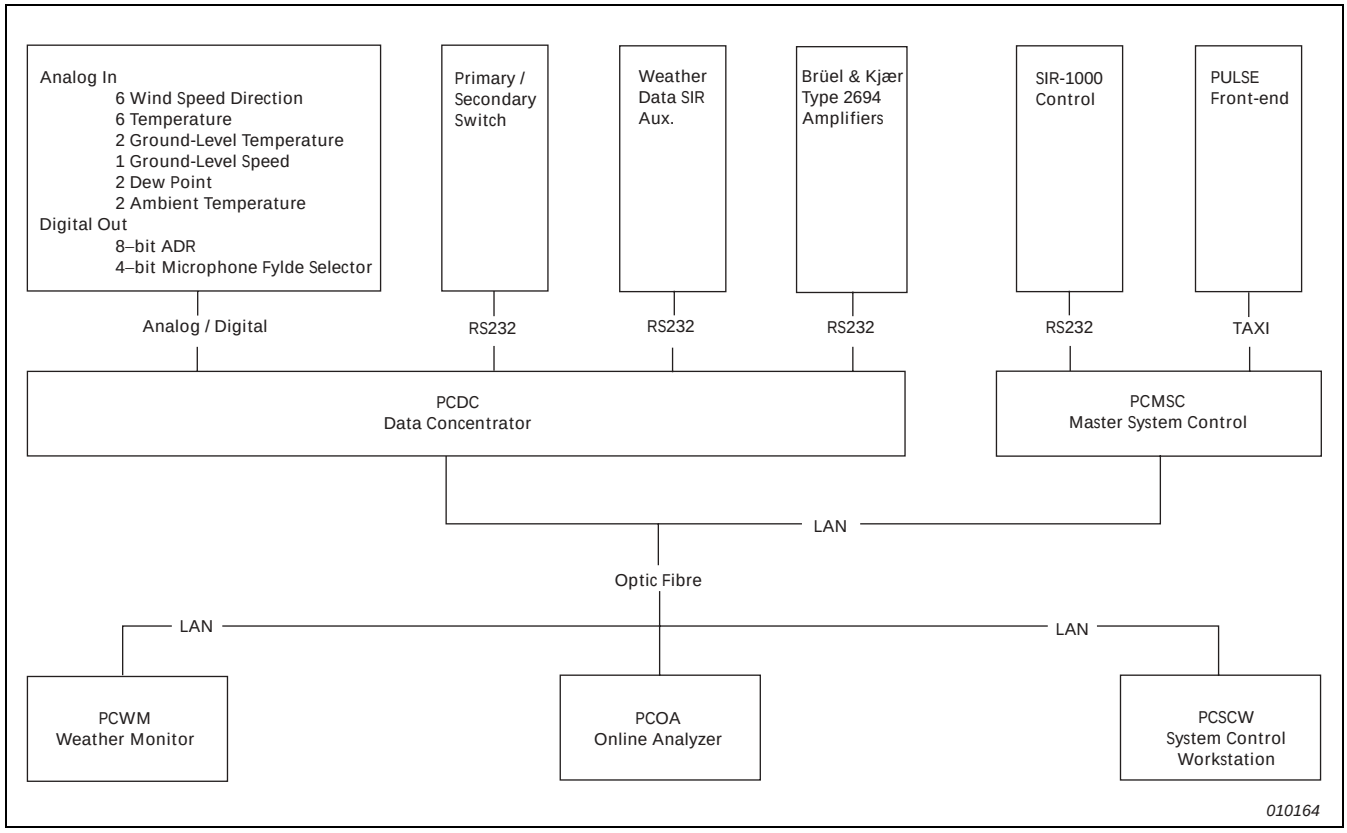


Fig. 6
Some of the equipment racks in the underground room

It's essential to carefully monitor the prevailing weather conditions during a test. There are sensors to measure:

- Wind speed and direction
- Air temperature
- Ground-level temperature
- Dew point
- Ambient temperature
- Atmospheric pressure

The analogue information from these sensors is routed to the underground room, converted to digital format and recorded together with the noise measurement data.

The complete noise measurement system is controlled from a room located in what was the airfield control tower. It's located about 200 metres from the underground room and a fibre optic cable connects the two. The noise measurement system has its own local area network.

All functions and selection parameters for recording data and calibrating the transducers are controlled from three computers located in the control room. These are:

- System Control workstation – to initiate and control the noise measurement system and all individual processes
- Weather Monitoring computer – displays the prevailing weather conditions
- On-line Analyzer computer – data saved on the network can be browsed, plots can be built, viewed and printed. pcAnywhere™ is used to enable the PULSE multi-analyzer to be remotely controlled from this computer.

PULSE

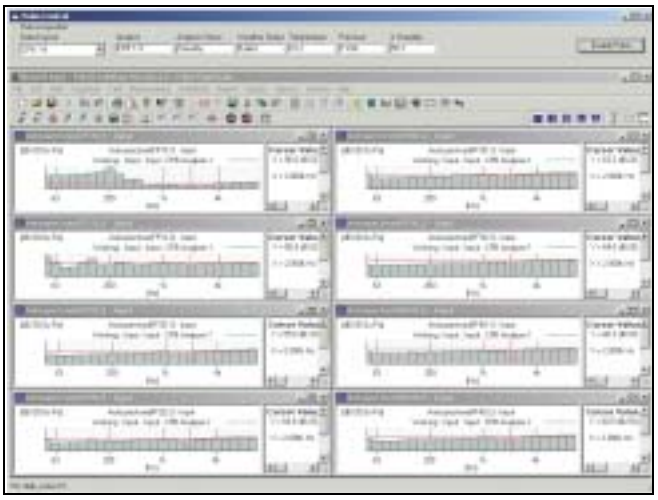


Fig. 7
An example of the main PULSE acquisition display

Up to 32 channels of PULSE data (CPB or FFT) can be viewed in real-time while a noise measurement test is made. Additionally, a loudspeaker in the control room can be remotely connected to any of the microphones in use and so provide audio from the selected source.

Mike says, “When tests are being conducted, we send the tapes to Derby each day for detailed post-processing, but, as a first step, the ability to view up to 32 channels of data in real-time while a test is being made gives us a good impression of the likely result”.

Certification Testing – R&D Investigations

A small, highly experienced team operates the noise measurement system. Noise measurement testing is basically of two types. The first is certification testing where the data is used to prove to authorities such as the CAA or FAA that the engine does what it should and performs as specified, and in accordance with the required standards. The parameters for these tests are laid down in Annex 16 of the ICAO regulations (these are the international standards which are adopted by ICAO members into their national regulations) or Part 36 of the Federal Aviation Regulations for the US. The European authorities use JAR-36 which will become the universal European requirement with the phase-out of the individual members regulations. Rolls-Royce’s No. 11 Test bed is fully approved.

Mike explains, “The test requirements and parameters are given to us by the Noise Engineering Department at Derby. They specify such things as the power settings for the engine and which arrays of transducers are to be used. The tapes on which the noise data has been recorded are sent to this department for evaluation and the official report is then prepared. Our aim is to achieve at least a 95% confidence level and we take three sets of data. We use 20 power points, from idle to full thrust, and record data for 35 seconds from each power point. The total test takes about three hours. Other types of noise testing are for R&D investigation”.

About twice as many R&D investigation tests as certification tests are performed. All noise measurement data is placed on Rolls-Royce's main frame database.

Peter Hopkins is a noise specialist in the Noise Engineering, Performance and Engine System Department at Derby. “The parameters for noise investigations are specified either by us or by the airframe manufacturer”, says Peter. “The transducer array and positions are defined according to what is being measured and based on experience”.

Peter continues, “A lot of planning is required although the actual testing may only take a couple of weeks. The R & D data is essential for future design and development and can take place 2 or 3 years before a new aero engine goes into production. We have about 20 employees at Derby who are solely involved with noise matters – it's a vitally important area for us. The post-processed data is passed on to our design engineers and enables noise modifications to be incorporated in new engines.”

The Future

Mike Clarke concludes, “Airline customers and passengers worldwide rely on these essential tests to ensure the certification and integrity of Rolls-Royce aero engines. The testing process is constantly being developed and, for example, in the future we intend to measure on up to 124 channels using pressure transducers. We will use the data to identify the detailed source of the noise using modal analysis techniques, and to continuously develop and test those features to reduce the overall engine noise. In the end, this will benefit everyone.”

Key Facts

- Rolls-Royce have used Brüel&Kjær analyzers, sound level meters, transducers and other products for many years
- A new Brüel&Kjær noise measurement system using state-of-the-art technology has recently been installed at Rolls-Royce's testing site at Hucknall, near Derby
- Noise measurements and analyses to be made simultaneously on up to 128-channels
- The data is used to confirm compliance of Rolls-Royce engines to international noise standards and for extensive R&D investigations
- The new noise measurement system must be reliable, stable, accurate and require minimum maintenance
- Up to 32 channels of PULSE data (CPB or FFT) can be viewed in real-time while a noise measurement test is made
- The data is used to prove to authorities, such as the CAA or FAA, that the engine does what it should and performs as specified, and in accordance with the required standards
- R&D data is essential for future design and development
- Airline customers and passengers worldwide rely on these essential tests to ensure the certification and integrity of Rolls-Royce aero engines
- “As the world leaders in the manufacture of aero engines, it was natural for Rolls-Royce to award the turnkey contract to the world leaders in noise measurement systems”

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