

LDS APPLICATIONS



COMPANY PRESENTATION

Brüel & Kjær is a world leading manufacturer and supplier of sound and vibration solutions. We help our customers solve their sound and vibration problems – from measuring traffic noise and vibration in car engines to evaluating building acoustics and performing quality control. This combined business adds capability in offering complete vibration test solutions from a single source, providing our customers with a greater platform and an expanded team to service their needs and requirements.

LDS's experience and product portfolio of electro-dynamic shakers, vibration slip tables, fixtures, amplifiers and vibration controllers together perfectly complement the Brüel & Kjær product range of transducers and data acquisition systems.

COMPLETE VIBRATION TEST SOLUTIONS – WITHOUT COMPROMISE

Brüel & Kjær can help you perform the most complex vibration tests to ensure integrity and reliability of your products. LDS's comprehensive range of electro-dynamic shakers are designed for vibration testing of devices of practically any physical size – from a semi-conductor component to a complete satellite system.

ONLY ONE PC AND ONE SOFTWARE PACKAGE NEEDED

With LDS, your shaker, power amplifier, vibration controller and even the environmental chamber are not only controlled from one PC – they run under one software package. Combined with Brüel & Kjær's world-class data acquisition systems and analysis software suite, Brüel & Kjær and LDS offer the complete vibration testing solution. We also offer vital service and staff training to maximise the operation of your vibration test system.

"LDS continues over 50 years of experience as a world leading manufacturer of electro-dynamic vibration test systems. Now as part of Brüel & Kjær, a world leader in data acquisition, transducers and analysis software, we can better solve our customers' needs with a great range of solutions." -
LDS Test & Measurement's Vice President, Dr Lawrence Grasty



A member of the
Brüel & Kjær group

CONTACT DETAILS

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<http://www.bksv.com/LDS>



POWER SYSTEM TESTING

Honeywell Aerospace had been selected to design and develop the state-of-the-art Secondary Electrical Power Distribution System (SEPDS) for the Airbus A380. The A380 is the largest civilian air transport vehicle in production today. It has two full passenger decks and can carry between 555 and 853 passengers.

The SEPDS consists of solid state devices which have the combined capacity of distributing up to 2000 channels of secondary electric power throughout the aircraft. As part of the development, of the art electric power system testing at extreme environmental conditions, is required to verify reliability and flight safety requirements. Honeywell Aerospace continues to be an innovative leader in electric power systems with emphasis on flight safety and reliability.

The Secondary Electric Power System (SEPDS) for the Airbus A380 was

manufactured in Toronto, Canada and was subjected to vibration testing using the LDS V895 LPT1220.

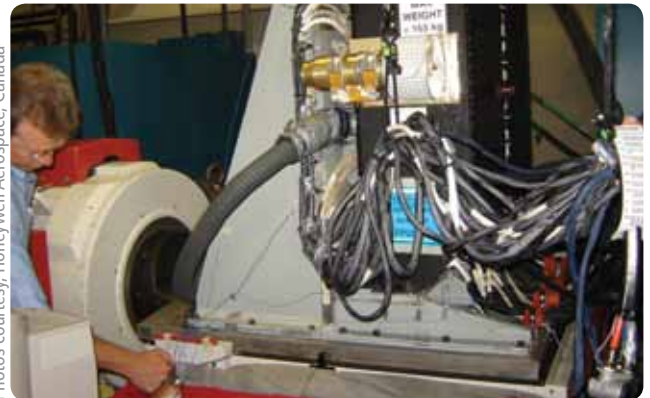
Units are tested at ultra low frequencies with high levels of vibration in order to simulate worst case inputs associated with a fan blade loss condition (windmilling) on the main engine of the A380. Conditions such as these are a challenge for many test facilities.

Honeywell requested on-site assistance from LDS for making tests at levels and frequencies not normally achieved by an Electromagnetic Shaker system. Understanding the structure's mode shapes as well as the shaker's resonant conditions at frequencies as low as 3 Hz are essential in maintaining proper levels.

Test Equipment survival during the test was considered secondary to achieving these tests. Locking out the Shaker's low frequency resonances and adjusting the suspension/

isolation systems for these conditions was done by LDS personnel. Careful monitoring during the test prevented damage to the shaker system for levels that exceeded the Shaker system's designed specifications. Phase 1 involved using a multichannel Dynamic Signal Analyser in parallel with the vibration controller to measure shaker movement, fixture movement and test article movement at reduced levels. Understanding these motions and adjusting the shaker system allowed Phase 2 testing with full levels and durations. Full level testing passed with no damage to the LDS shaker system.

Performing testing in this manner saved Honeywell over \$400,000 in test equipment costs as normally a much larger "engineered" system would be used to perform this type of test.



Photos courtesy, Honeywell Aerospace, Canada

AEROSPACE

The V994 Lin-E-Air is the most powerful vibrator within the LDS range, providing 289kN sine force. Used for satellite testing, the custom design was specially tailored to meet the customers' particular requirements and to suit their existing LDS slip tables and guided head expanders.

The solid trunnion design enables testing from DC to 1700 Hz achieving full displacement at low frequencies for both horizontal and vertical testing.

Through site visits, LDS' project team developed a layout solution incorporating modifications to standard ancillary equipment to meet the customer's needs. Bespoke mounting plates were also provided to simplify installation onto the customer's existing seismic base and to suit their current equipment installation.



V994 Solid
trunnion design
enabling testing
down to DC.

| Accelerometer Family



Sound and vibration expert, Brüel & Kjær has a wide range of accelerometers, suitable for many different applications.

| PULSE Modal



PULSE Reflex Modal Analysis is an easy-to-use post-processing application that enables users to perform single and poly reference Classical Modal Analysis, even in the most demanding situations, by using a targeted set of best-in-class mode indicator functions, curve fitters and validation tools.

See our full range and more information by visiting our website: www.bksv.com

BALLISTICS TESTING

NAMMO AS is a leading developer and manufacturer of ammunition systems and missile & space propulsion products. The company has also become a world leader within environmentally friendly demilitarisation services. The Test Centre at Raufoss in Norway specialises in vibration and climatic (environmental) testing, and is capable of testing munitions for the Defence industry, as well as providing these services for other industries such as automotive and space.

NAMMO has been using LDS shaker systems since the late 1970s when they purchased a V725 (6,667N / 1,500lbf) shaker. They have continuously added to their capabilities and now own a V964 (90kN / 20,000lbf) Combo system, a V994 (289kN / 65,000lbf) shaker, as well as the LDS Vibration controller. These vibration systems are used with the environmental chambers to provide reliability verification tests of various types of equipment. The equipment varies in size from ammunition boxes through to rocket motors for missiles, through to antennae used on frigates that weigh up to 2.5 tons. Tests can run from 2 seconds to as long as 64 hours continuous running, but more normal are durations of 1-4 hours per axis.

A major proportion of NAMMO's business is in the field of munitions testing. They have fifteen firing ranges with the longest being 2,000 metres long. Longer ranges are available using the Governments ranges. Various types of ammunition from 5.56mm to 155mm can be tested on

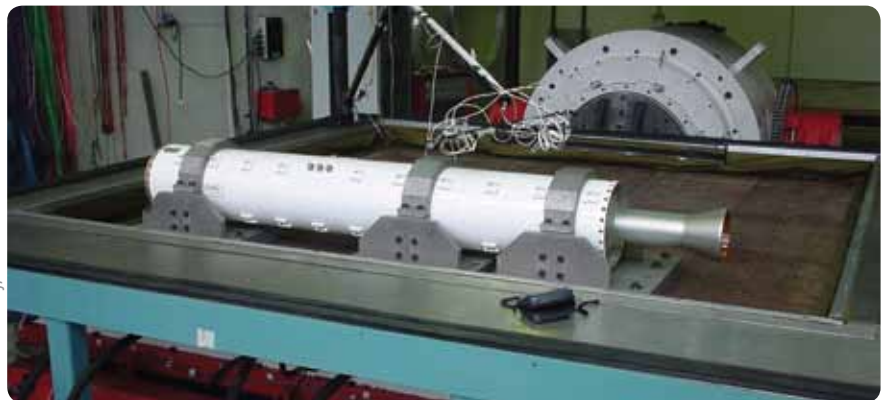
these ranges. Live ammunition is tested to verify its continued reliable operation. This starts with transportation testing with the munitions in their packaging. The tests involve vibrations and shocks to simulate their transportation, as well as environmental testing to simulate their storage. The two tests are also run together to show the combined effects. Increasingly, these tests are conducted using pre-recorded data taken from actual transportation and operation of the systems. Once these tests are completed, the ammunition may be disassembled and inspected or fired on one of the ranges to ensure it is still functional.

Safety is obviously paramount in this application. The tests are conducted in a blast-proof test chamber which is controlled from a separate protected room adjacent to the test room. The LDS Amplifier Remote Control Unit proves invaluable as it allows the operators to control the amplifier from

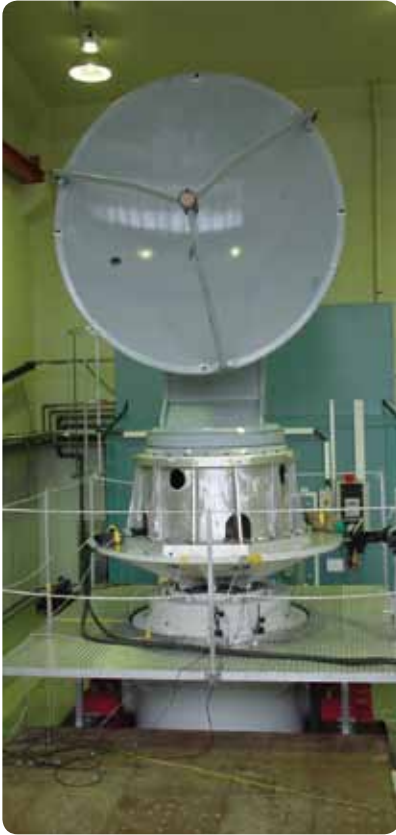
the safety of the control room and the test itself is controlled using the LASER_{USB}[™] controller. This complete remote control capability is unique to LDS, and is widely used in this kind of application around the world. Rocket motors are also tested using the V994 shaker system. The motors can also be tested on the monorail sled for dynamic performance. The V994 shaker was originally purchased to conduct a specific test specification on a physically large test piece, however this has now enabled NAMMO AS to offer their services to a much broader commercial market than they previously thought possible.

Stain Halvorsen, Manager of the Environmental Test Facility, feels they now have a good range of test capabilities, and expects this to accommodate the payloads and frequencies they are expecting from customers in the near future. The efforts are currently for improving the mounting and

Photos courtesy, NAMMO AS



DEFENCE



fixture designs to give more realistic tests. LDS was chosen as the supplier of these systems due to the technical knowledge and aftersales support that was available locally to NAMMO, as well as the reputation of the LDS brand. The total system capability offered by LDS also played a part in the decision. LDS and Nammo now have a long and successful history of working together, stretching back over 25 years.

Designed to test payloads for a defence customer, the Dual LDS V850-440 SPA24/56K special Vibration Test System has been engineered for coupled operation.

Each shaker is fitted with a Guided Head Expander that allows interfacing to the customer's specialised payload. A steel truss rigidly connects the shakers together.

To ensure the dual system is mobile as required by the customer, each shaker base is integrated with Airglides allowing the full shaker assembly to be moved effectively on a cushion of air.

The special LDS Pneumatic Control Stands provide the operator with shaker

body and armature position display and control. Shaker armature and body position are automatically controlled to ensure that the complete system remains balanced.

Both shakers can be used either individually or in the standard dual (push-push) configuration; the LDS Multiple Amplifier Control (MAC) System allows this. Each shaker is driven to a tight amplitude and phase tolerance of the other to ensure consistent application of vibration, minimising cross-coupling and ensuring system and payload safety.



Dual V850-440 mounted in solid trunnions with Load Bearing Platform.

SATELLITE TESTING

The space industry probably has the most demanding requirements of vibration testing anywhere in the world. Given the huge stresses involved in the launch of the payload, and the fact that you cannot easily repair a damaged system (satellite) once it has been deployed, it's best that the system has been thoroughly tested before launch!

ESTEC (European Space Research and Technology Centre) has recently invested in a quad shaker system using LDS' V984LS shakers, delivering forces up to a staggering 640 kN of sine force (each shaker is capable of delivering a maximum sine force of 160 kN/36000 lbf). The four shakers are mounted on a seismic block and connected to a head expander level with the floor. This will be used to test satellite solar arrays, large satellite communications antennae, and complete satellites from 400 kg (882 lb) up to 10 000 kg (22046 lb). These satellites will be launched using a variety of rockets including ARIANE5 and SOYOUZ.

The vibration systems are used for a variety of tests. Alexandre Popovitch, Head of Test Facilities and Test Methods at ESTEC, comments, "For large, light specimens, sine and random tests are usually performed at levels up to 20 g. This will require almost 100% of the quad system shaker capabilities. Complete satellites are only submitted to sine vibration at acceleration level close to 1 g. In certain cases, the whole satellite can be submitted to high acceleration level to simulate the static loads". A test can take anything from one day to two weeks to set up depending on the number of sensors to

be mounted, with the actual test lasting a few minutes at a time.

The new quad system is a vital component in ensuring that ESTEC and ESA maintain their position at the forefront of the space industry. "This new facility will save time in the critical path of the mechanical test campaign and, therefore, will reduce the testing price for our programme," said Mr. Popovitch.

EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTRE – ESTEC

ESTEC is the technical heart of the European Space Agency (ESA), and is located in Noordwijk in The Netherlands. The Agency manages nearly all the programmes on space projects covering missions on science, human spaceflight, telecom, satellite navigation, and earth observation. The only exception is the actual launchers used to deliver the payloads into orbit, which are managed by Arianespace in France. Overall, over 12000 personnel in over 100 European companies are involved in the preparation and launch of each space flight.

ESTEC's test centre is home to about 60 personnel who cover all the fields required for qualification of space hardware for thermal, electrical and mechanical environments. The mechanical facility is operated by six personnel who operate the vibration test systems, acoustic chamber and mass properties measurements systems. This facility is the largest in Europe and one of the biggest in the world.

LDS' V984LS SHAKER SYSTEM

Paul Steel, LDS Project Manager for the vibration system, is justifiably proud of LDS' contribution to the overall installation, and the work he and his team have achieved. He describes this new system as "a showpiece for the industry". "This has been a big project in partnership with other suppliers and we have all pulled together to see the project through to a successful conclusion," he says.

This new quad-shaker system is in addition to an existing dual-V984LS system, which can either be used in single-shaker mode (vertical or horizontal with a slip table) or in dual-mode with a custom made dual head expander. The slip plate for horizontal excitation measures 3.5 m (11.48 ft) long by 3.0 m (9.84 ft) wide. The dual system is fixed to a springmounted 550 tonne seismic mass to protect the building from forces generated.

ESTEC also has a V964LS (90 kN/20 000 lbf) shaker used for testing smaller payloads in sine, random and shock modes up to 2000 Hz, and with a 1200 (3.94 ft) × 1200 (3.94 ft) mm slip table for horizontal testing.

THE ADVANTAGE OF WATER-COOLED SHAKERS

The V900 series of water-cooled shakers has a long-established reputation in the aerospace and space industries. Water-cooled shakers are able to deliver higher forces than equivalently powered air-cooled shakers. The water-cooling is applied to the field coils and results in quieter operation

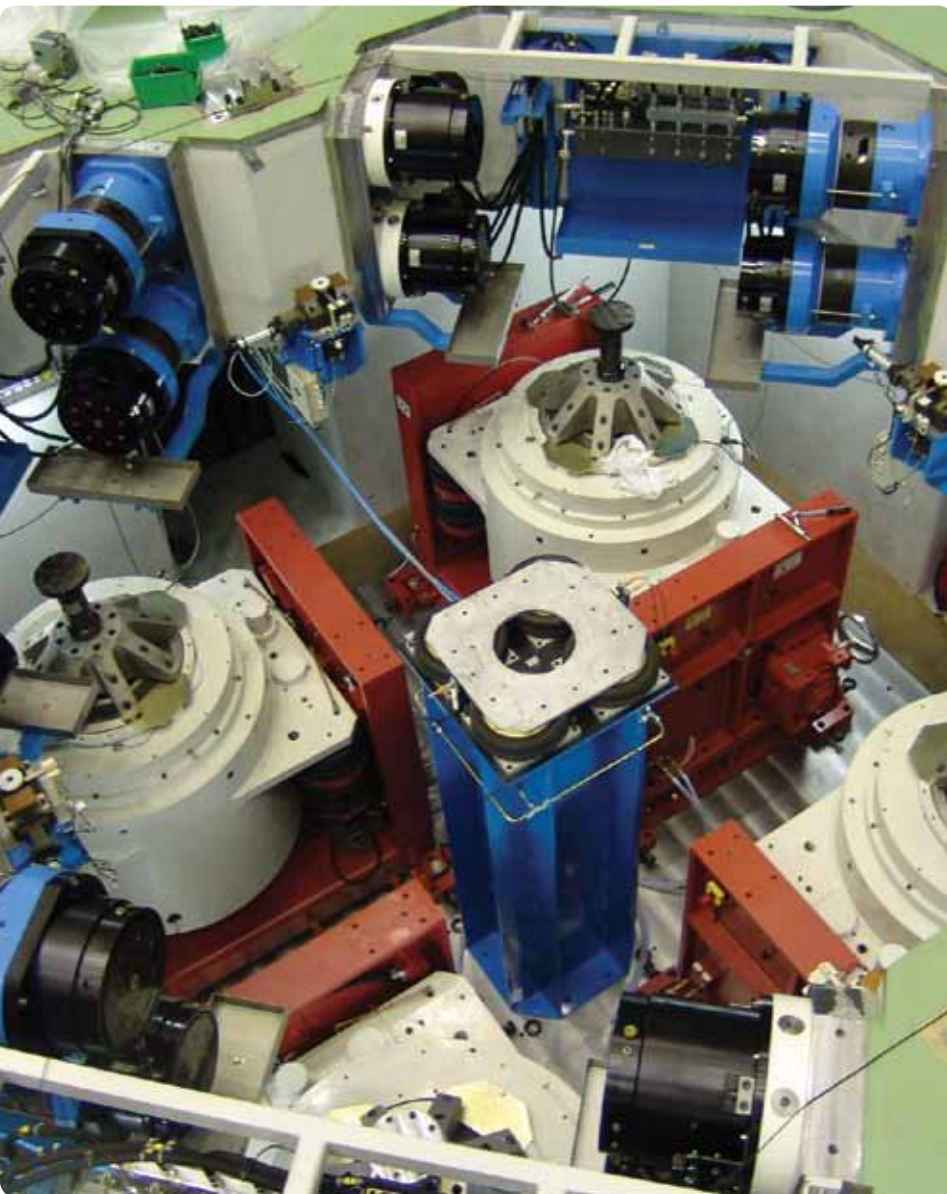


Photo courtesy, ESA/ESTEC

and a cooler body temperature, minimising the temperature effects on the equipment under test. This makes water-cooled shakers ideal for applications requiring high forces or large payloads tested for short durations. The absence of the air blowing around the shaker and test equipment makes water-cooled shakers particularly appealing in clean room environments or when testing hazardous materials.

Acknowledgements: LDS would like to thank Alexandre Popovitch, Head of Test Facilities and Test Methods, ESA/ESTEC Test Centre Division, and Gaetan Piret, Technical Officer in charge of the quad shakers procurement, for their contributions and permissions for this article.

Highly Attuned Accelerometers



Type 4524 series consists of lightweight triaxial piezoelectric OrthoShear® accelerometers, each with three independent outputs for simultaneous measurements in three mutually perpendicular directions. Type 4524 series utilise a 4-pin connector.

For more information about Brüel & Kjær's accelerometer products, please visit www.bksv.com

HOT SHAKE

VIBRATION TEST AT TEMPERATURES UP TO 1000 °C

Cars are a hot topic around the world – and not only when it comes to racing. Even our cars can get pretty “hot” – especially components like the exhaust or the brakes. Such extreme conditions are simulated during design to ensure that these components do not fail when it counts.

Vibration Testing experts simply call it “Hot Shake” – but it is not that simple! At Peus Testing in Germany they are pushing the envelope of high temperature environmental testing. The combination of a “hot gas generator” and a shaker system creates a very hot test environment. Hot gas at temperatures of up to 1000 °C streams through car components such as catalysts or diesel particle filters, causing them to glow bright red.

In order to improve the thermal stability of components, it is necessary to push the limits during the test. An air volume of up to 700 kg mass per hour streams through the device under test and generates a pressure of up to three Bar inside. Under these conditions, the stainless steel becomes more homogeneous and the component

approaches a point at which it expands like a balloon.

As tough as this might already be, the design engineers want to know the full truth, so when the thermal limits are reached the test engineer switches to the next level. From his cool position in the control room, he starts his 60 kN shaker system by means of a mouse click. This shaker system consists of an V8 Shaker, a LASER_UGB™ Vibration Controller and an SPA-K Power Amplifier. The Vibration Controller ensures that the component is vibrated constantly at 175 Hz and during this test, which runs for more than 100 hours non-stop, the device experiences an acceleration of 75 gn peak. Given the fact that this happens at its thermal limits, one would think this should be enough to

prove the product. But the test has not yet reached its climax. 15 minutes after the test run begins, the controller opens a valve for a new experience: thermal shock! 20 litres of cold water at 13 °C rain onto the red hot device. The conditions for the material test are changed in a split second to that of a worst case scenario. Shocked by the flood of cold water the material rapidly contracts, changing the stresses on the component.

The cold water shock treatment ends after 30 seconds and terminates the first test cycle. But this is not the end – it is only the beginning. 499 more cycles follow before the test is complete. Only after more than 100 intense hours of testing on the hot shake test bench can the design engineers be certain that their component is ready to face the real world.



Photos courtesy, PEUS, Germany



ELECTRIC & HYBRID TESTING

BATTERY PRE-PRODUCTION QUALIFICATION AND FUNCTIONAL TEST FOR ELECTRIC AND HYBRID VEHICLES

As the automotive industry embraces hybrid powertrains, there is an increased demand to invest in research and development of battery power.

Competition in the automotive industry and the speed of development in hybrid power technology is driving manufacturers to deliver high quality products in shorter time scales. Time to market is key and has put an emphasis on product testing; vehicle re-call is expensive. Manufacturers are therefore under increased pressure to do accelerated lifetime vibration testing, even on large and fully operational component assemblies, whilst also meeting all health and safety guidelines.

HYBRID BATTERY DURABILITY TESTING

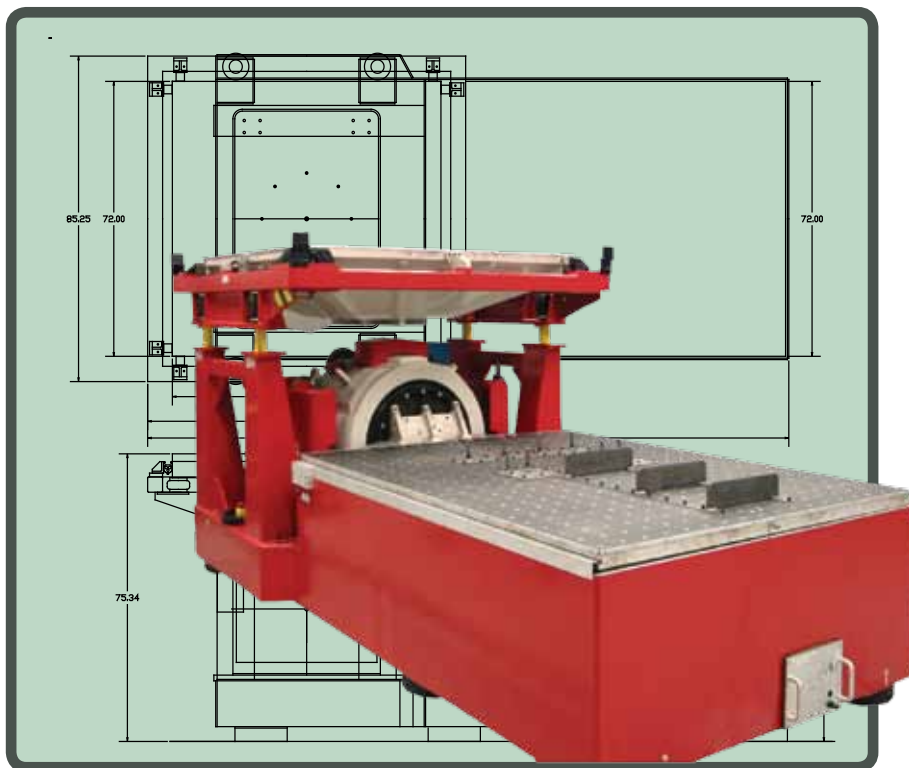
Working with a leading automotive research department, LDS has delivered a custom vibration test system for hybrid battery durability testing and for Highly Accelerated Life (HAL) testing of multi-cell computer managed batteries. The system will be used for hybrid vehicle pre-production qualification, and for functional testing of a complete battery assembly designed to be mounted underneath a car.

The delivered LDS Vibration Test System is an excellent example of a customer requesting a high performing and versatile system that can easily be adapted to several

test demands on large heavy payloads in multiple axes. The requirements demanded a heavy-duty system that could perform accelerated durability tests simulating the whole lifetime of the car.

The V8 force shaker required the combination of a large 6 by 6 ft. slip-table and guided head expander of equal size. The design incorporated special plugs for quick release of the head expander, thus removing the need to undo hundreds of thermal barrier bolts. A great time saver,

compared to reconfiguring a standard system from vertical to horizontal which may take up to several hours. The head expander guidance frame allows fast rotation of the shaker without removing the head expander and allows a 'quick-switch' to a smaller head expander. For testing heavy assemblies the design was optimised for manpower savings, minimising heavy component movement during the axis change process.



PACKAGE TESTING

Most consumer products undergo vibration testing, the most common form being package testing. Package testing is designed to simulate a product's journey once boxed at the factory for transport through to the customer's home.

One such LDS package system was designed to enable the customer to simultaneously test two plasma screen television sets, weighing 85 kg each, in their transport boxes. The tests were designed to reproduce the effects of transport experienced by the televisions. These tests allowed for the optimisation of the packaging

design and savings on materials such as polystyrene packaging. The customer used a combination of Sine tests, typically <5mm peak-to-peak in the 5 - 20 Hz range and Random tests <1.5g up to 200 Hz.

The system combines a rigidly mounted standard LDS V875-640 shaker with specially designed steel trunnions and a magnesium head expander, 1.8 m x 2.2 m, is supported by a Load Bearing Platform (LBP). The basic over-turning capability of the LBP is 5 kNm, and it is restrained by guide shafts which are part of the steel work. Air-bags located underneath the trunnions isolate

the vibration. Pneumatic isolation is incorporated to prevent unwanted vibration being transmitted into the building.

Once on site the head expander is positioned at floor level, allowing the loading and unloading of the payloads by pallet truck for the quick turn around of large test articles. A remotely operated safety mechanism to lock and unlock the LBP had to be designed to allow access to the shaker.



V875-640 mounted in trunnions with Load Bearing Platform and 1.8 m x 2.2 m head expander.

Data recording without ranges or limits



Brüel & Kjær's LAN-XI Notar™ allows PC-less recordings directly to a small and rugged solid state memory card - for applications where the use of a PC is not an option - such as in-flight or in-vehicle measurements or other harsh environments.

For more information about Brüel & Kjær's data analysis products and software, please visit www.bksv.com

LOW FREQUENCY TESTING

FIGHTING VIBRATION EMISSIONS

The need for higher machine performance in recent years has generally been accompanied by higher speeds and cutting rates as well as an increase in impact power in the field of forming. This resulted in increased vibrations transmitted to the surroundings, which must be efficiently controlled. During the development process of suitable isolation mechanisms an LDS Shaker System plays an important role.

The constant increase in productivity requires extreme efforts to keep vibration emissions within stringent targets for working conditions and comfort. Most critical are the emissions which are dissipated directly to the structure of the building. In order to minimise pulsating or sinusoidal vibrations, various isolating mechanisms are being designed for machine mounting. The most challenging task is to keep the motion of the flexibly mounted machine within permissible limits of operation.

The efficiency of vibration isolation depends to a large extent on the relationship between the machine speed/stroke rate and the natural vibration frequency of the isolator. In general, the lower the natural vibration frequency of the isolator, the greater its efficiency.

Bilz Vibration Technology AG designs and manufactures isolation mechanisms for machine mounting where it is very important to stimulate structures at very low frequencies of less than 1 Hz. To accomplish this, they must use the latest "state of the art" test equipment. This was one of the

Photo courtesy, Bilz Vibration Technology AG



reasons why Bilz chose a LDS V650 Shaker for their brand new 1600 Newton three axis Test Bench. With all the critical components – electro dynamic shaker, power amplifier and vibration controller – coming from a single source the entire system could be fine tuned to meet their extreme low frequency requirements.

The V650 shaker can be operated both vertically and horizontally, and the

multi-channel LDS LASER_{USB}[™] vibration controller is operated in a velocity controlled mode enabling Bilz to test isolation mechanisms across the frequency range of 0.5 Hz to 150 Hz or more. Thanks to a very precise stimulation of the test platform a variety of floor constructions can be tested enabling Bilz to significantly speed up the design process.



The quad V9 (4 x 105 kN) Vibration Test System has been specially designed for a transport simulation application testing structures at frequencies from DC and payloads exceeding 6 tonnes. With a cross section over 6 m x 3 m it is much larger in size than the vibration system interface plates. The capability to independently control the vibration accelerations at multiple positions on a single payload of this size is revolutionary.



TRANSPORT SIMULATION

The payload interfaces for each of the 4 V9s are not connected to each other. Therefore to control their relative positioning, a new Position Indicator Control Stand has been developed.

A special version of the LDS combo has been designed to incorporate a solid trunnion vibrator body mounting, with the slip table combo frame being attached

directly to steel plates on top of a seismic mass. The base fabrication is designed to accept a Load Bearing Platform (LBP) used for vertical vibration.

An air isolated seismic block has been designed so that all forces are transmitted to this block. Testing is controlled using an LDS Multiple Amplifier Control (MAC) System together with a Multi Input Multi

Output vibration controller (MIMO) to simultaneously control each V9 system independently in order to achieve the required combined effect. Using Airlides, the four combos can be readily repositioned into multiple orientations to enable both vertical and horizontal testing of various sized payloads.



Solid Trunnion quad
V9 HBT 1220 and
LBP 1430 with
independent control.



BRÜEL & KJÆR | LISTEN... FEEL.. SOLVE.

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