Welcome to the webinar
“How to Select the Right Shaker System for Your Application?”

All attendees‘ microphones are muted for the entire webinar session. Be sure your speaker is active and join the audio conference.

If you have any questions, please send it to the host using the “Q&A” function.
Questions will be answered at the end of the presentation.

Introductions – Brian Zielinski-Smith

- Bachelor of Sciences with Honours in Engineering Design
- Design Engineer at Welding Alloys Ltd, UK
- Operations Manager at Welding Alloys Ltd, UK
- Product Manager at Welding Alloys Global
- Joined Brüel & Kjær in 2016 (based in Royston, UK)
  - Product Manager – Shakers & Amplifiers
  - Product Manager – Shaker Systems

Topics

1. Selecting a Shaker Type
   How do I configure the right shaker size? Which parameters do I need to consider?
2. Choosing a Head Expander
   Do I need a head expander for my application? Which variants are available?
3. Configuring a Slip Table
   Do I need a slip table for my application? Which slip table fits to my requirements?
4. Environmental Testing
   How do I connect a temperature/climate chamber to my shaker system?
5. Installing a Shaker
   What do I need to install a shaker system? Do I need a seismic foundation or is my standard lab floor enough?
6. Producing a Shaker System
   How are shakers produced? Which customer references does HBK have?
7. Questions

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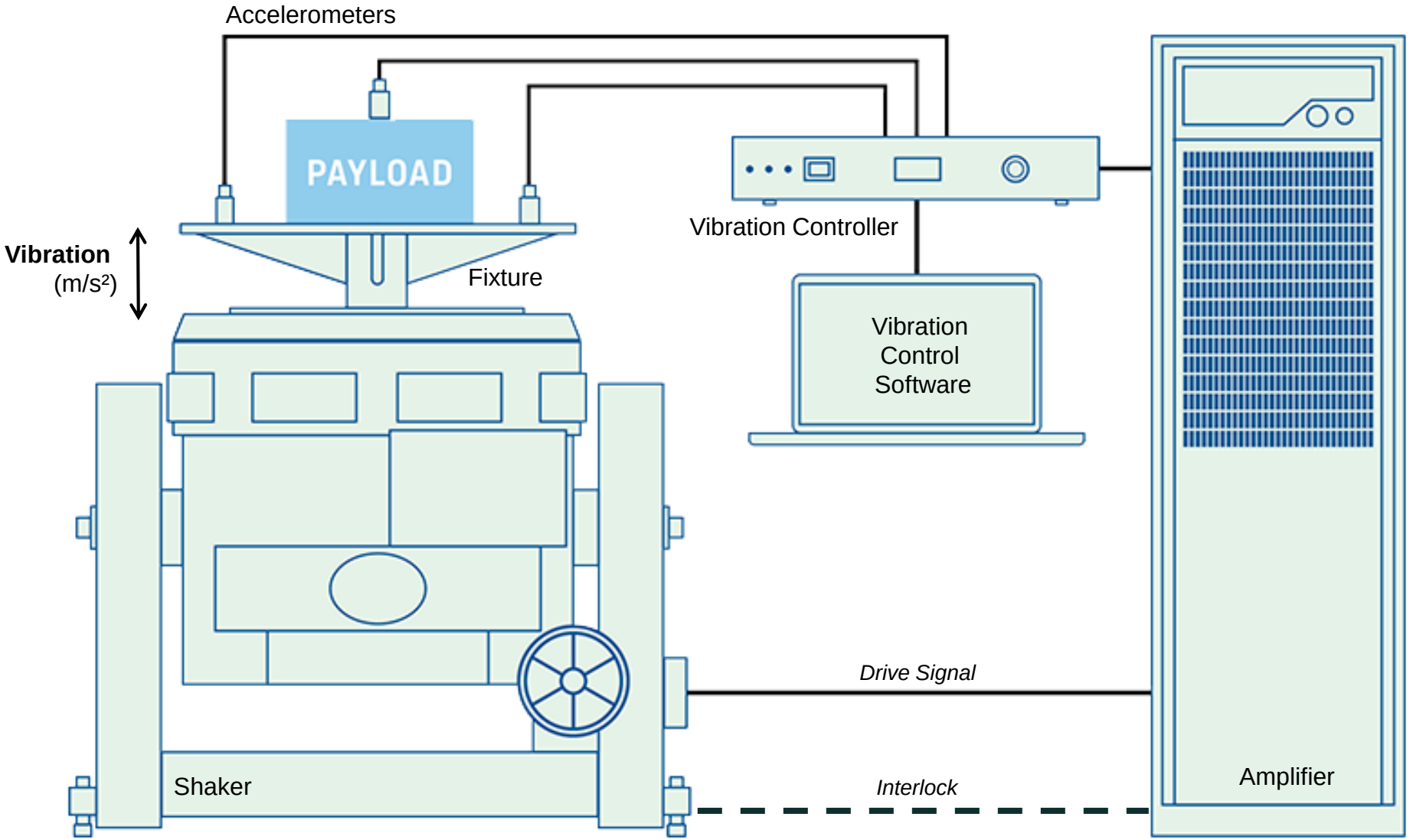
1. Selecting a Shaker Type

HOW DO I CONFIGURE THE RIGHT SHAKER SIZE?

WHICH PARAMETERS DO I NEED TO CONSIDER?

Setup of a Shaker System



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Product Portfolio LDS Vibration Test Systems

- 5 Permanent Magnet Shakers
- 4 Low-Force Shakers
- 5 Medium-Force Shakers
- 5 High-Force Shakers

Which shaker fits your application?

Which Parameters do I need to Consider when Selecting a Shaker?

- Test subject
  - Weight
  - Dimensions: Required clamping surface
- Test profiles
  - Sinus: Max. Acceleration (g peak)
  - Noise: PSD Profile (g rms)
  - Shock: Max. acceleration (g), impulsion period (ms)

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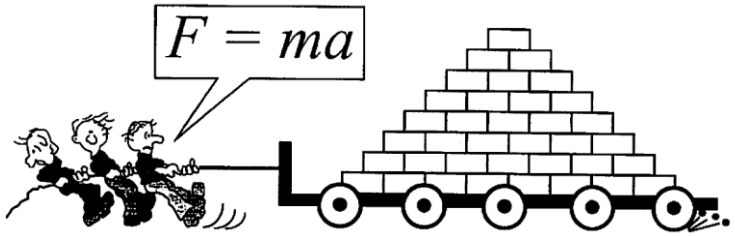
Electrodynamic Shakers – The How

- Most fundamental rule is Newtons 2nd law of motion (F=MA):
  - Force (F) required to move an object is the Mass (M) multiplied by the Acceleration (A)

- However, there are other factors that need to be considered:
  - Displacement (physical distance to move)
  - Velocity (speed at which to move)
  - Frequency Range
  - Overturning moments
  - Voltage & Current



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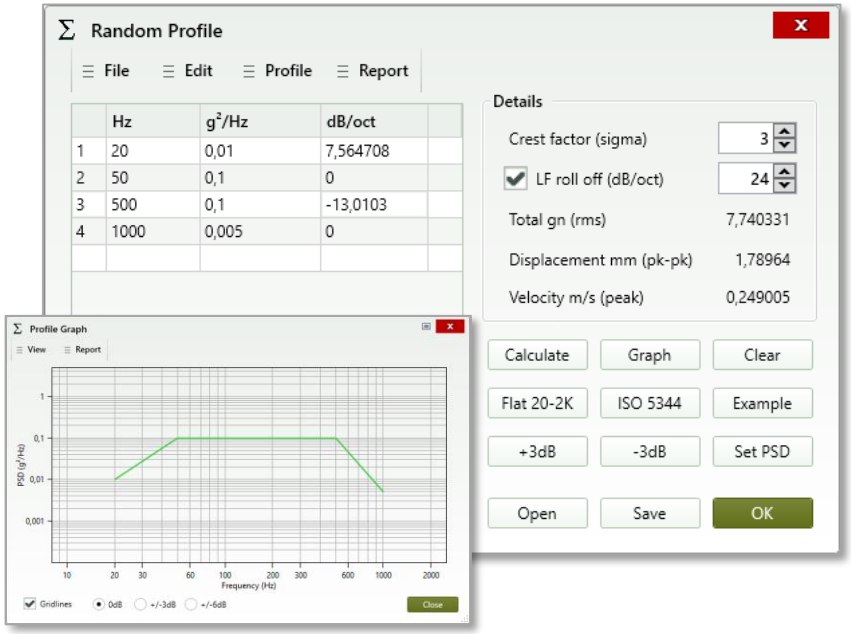
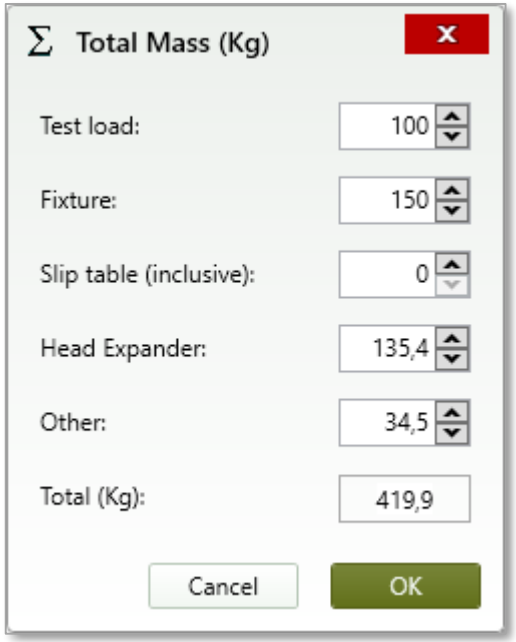
Profile Analysis

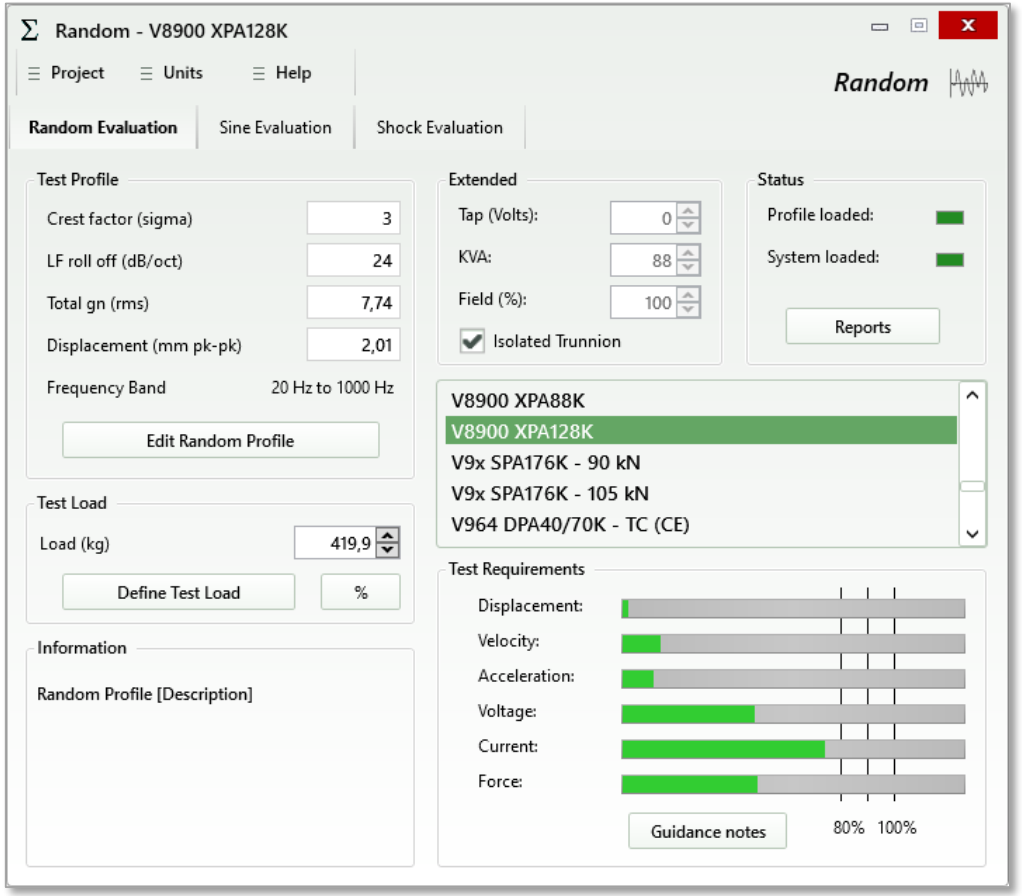
1. Test Profile



2. Total Moving Mass



3. Analysis

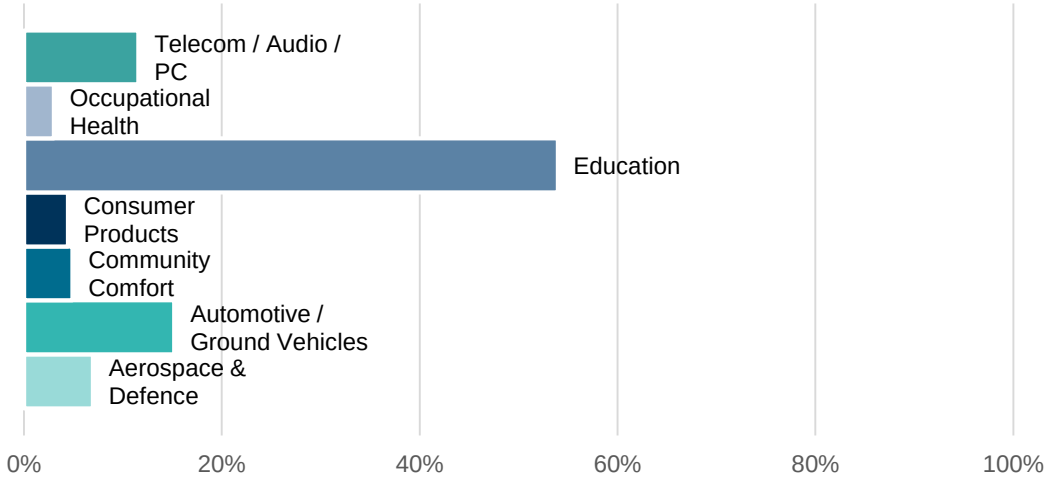


Product Portfolio LDS Vibration Test Systems

SHAKER

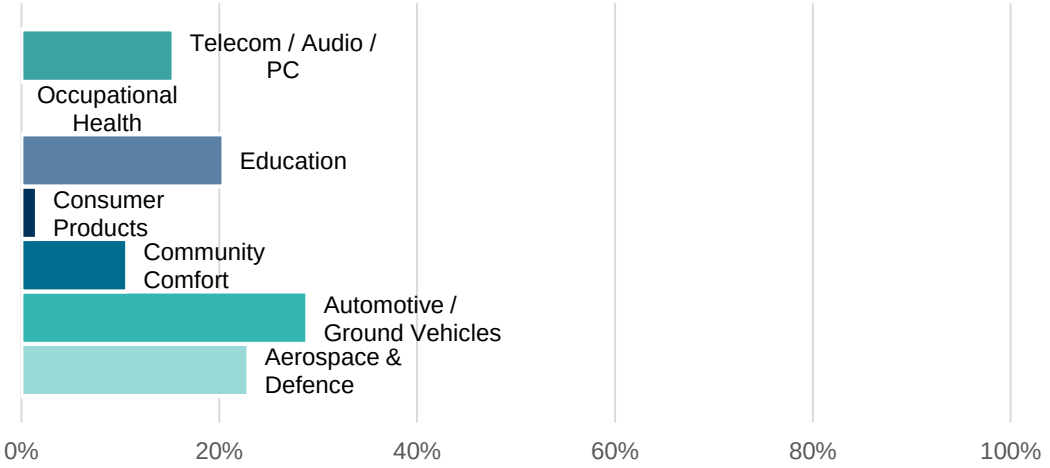
Permanent Magnet Shakers ⑤

V101 – V455



Low Force Shakers ④

V555 – V780



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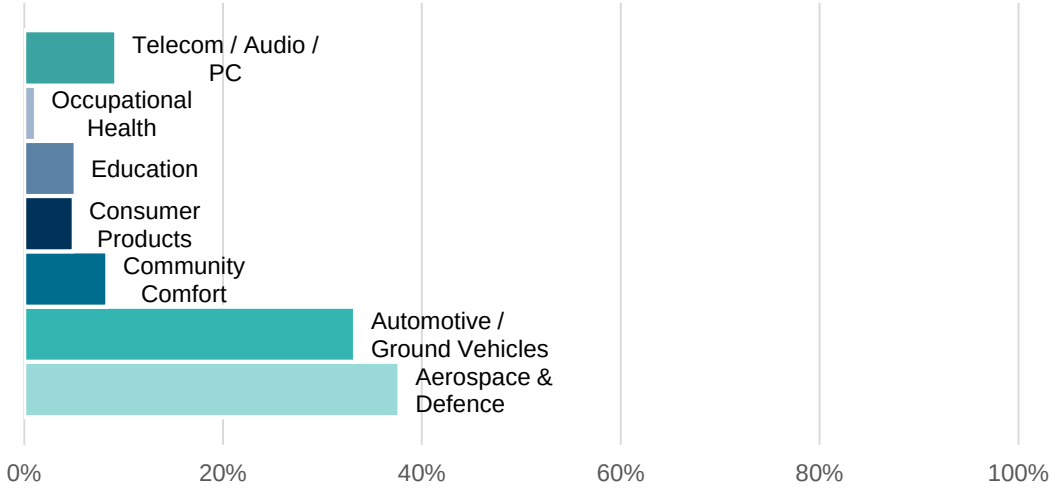
SHAKER

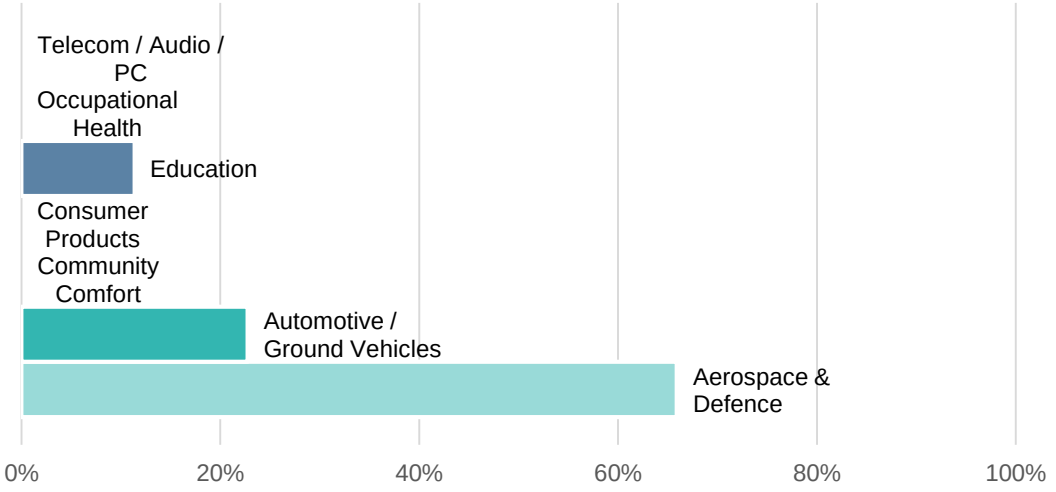
Medium Force Shakers ⑤

V830 – V8



High Force Shakers ⑤

V8900 – V994



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Product Portfolio LDS Vibration Test Systems

AMPLIFIER

LPA Series Amp

HPA-K Series Amp

SPA-K Series Amp

XPA-K Series Amp

DPA-K Series Amp

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Product Portfolio LDS Vibration Test Systems

VIBRATION CONTROLLERS

LDS Laser USB

LDS Comet USB

HBK also provides the corresponding software BK Connect to the Vibration Testing Hardware. BK Connect can be configured to meet your requirements.

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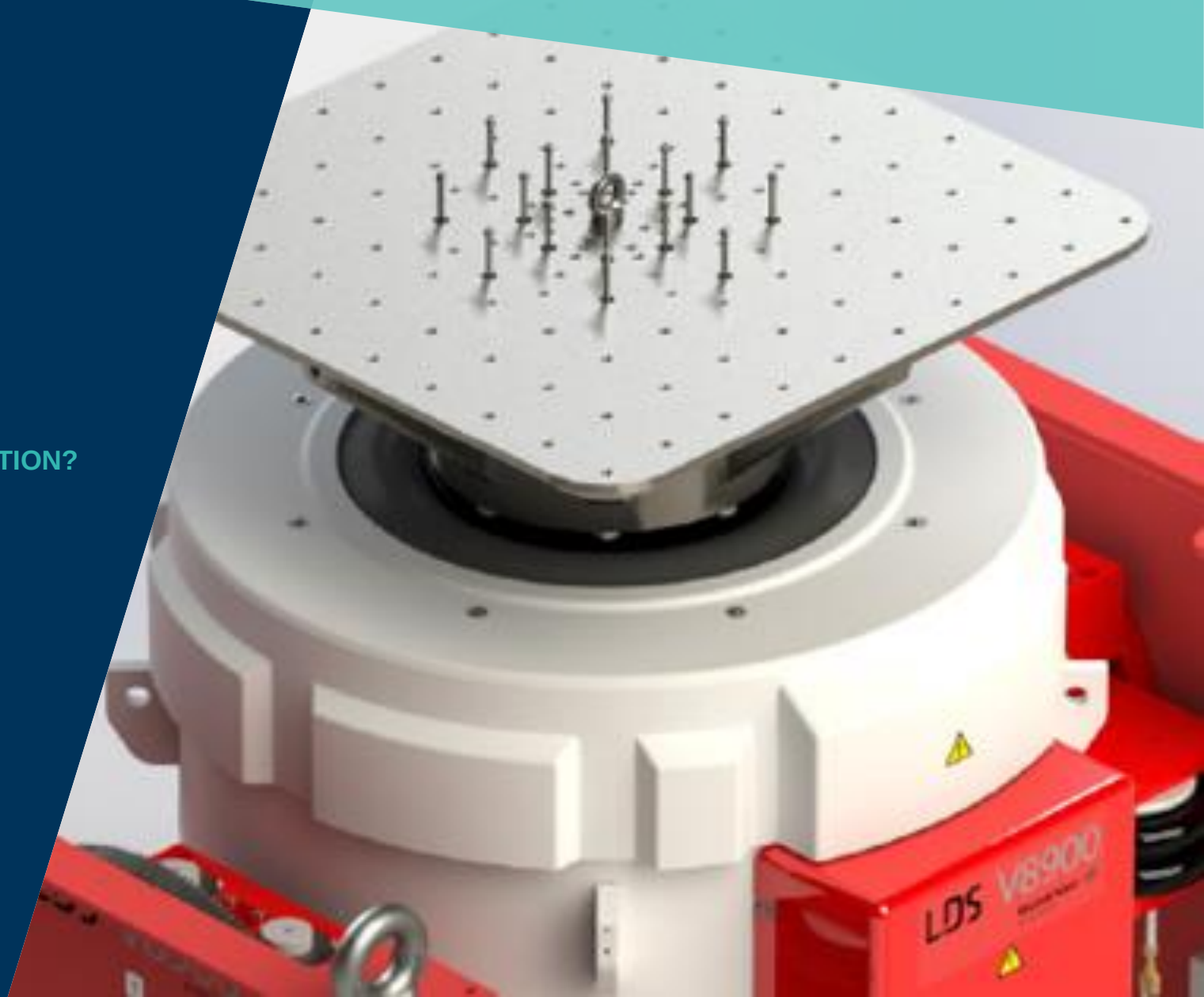
2. Choosing a Head Expander

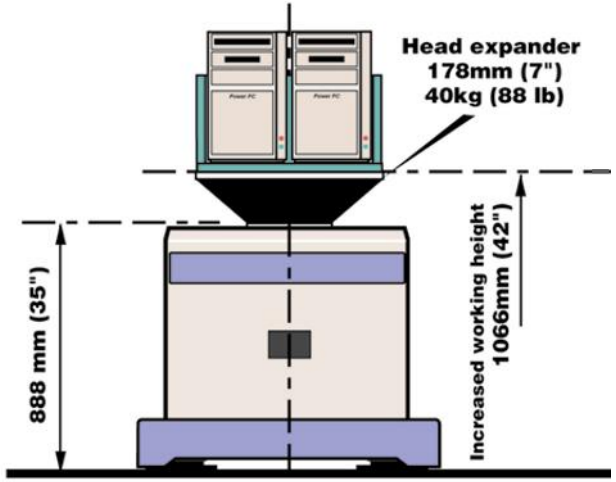
DO I NEED A HEAD EXPANDER FOR MY APPLICATION?

WHICH VARIANTS ARE AVAILABLE?



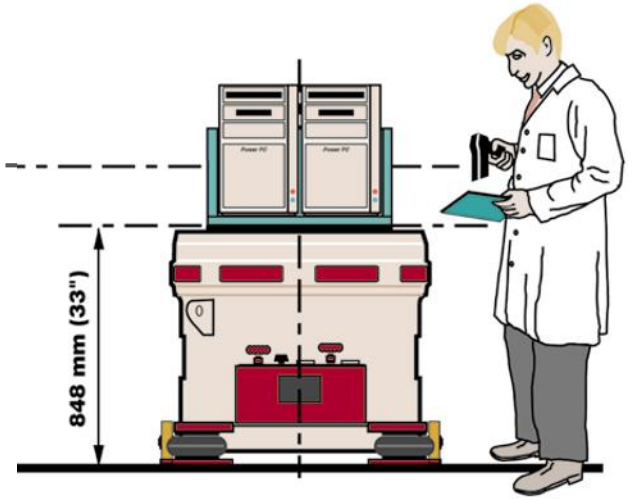
Do I need a Head Expander or a Shaker with a Bigger Armature?

Head Expander:



- Using a Head Expander limits the payload**.** This results in a higher total moving mass
- Higher stall torque due to increase of the center of mass
- Worse dynamic properties

Larger clamping surface armature:



- More clamping surface with lower total mass
- No increase of the centre of mass
- Higher payload due to lower moving mass
- Better dynamic properties
- No <u>additional</u> investment costs

- Armature V830: ϕ185mm / ϕ335mm
- Armature V850: ϕ240mm / ϕ440mm
- Armature V875/V8: ϕ440mm / ϕ640mm

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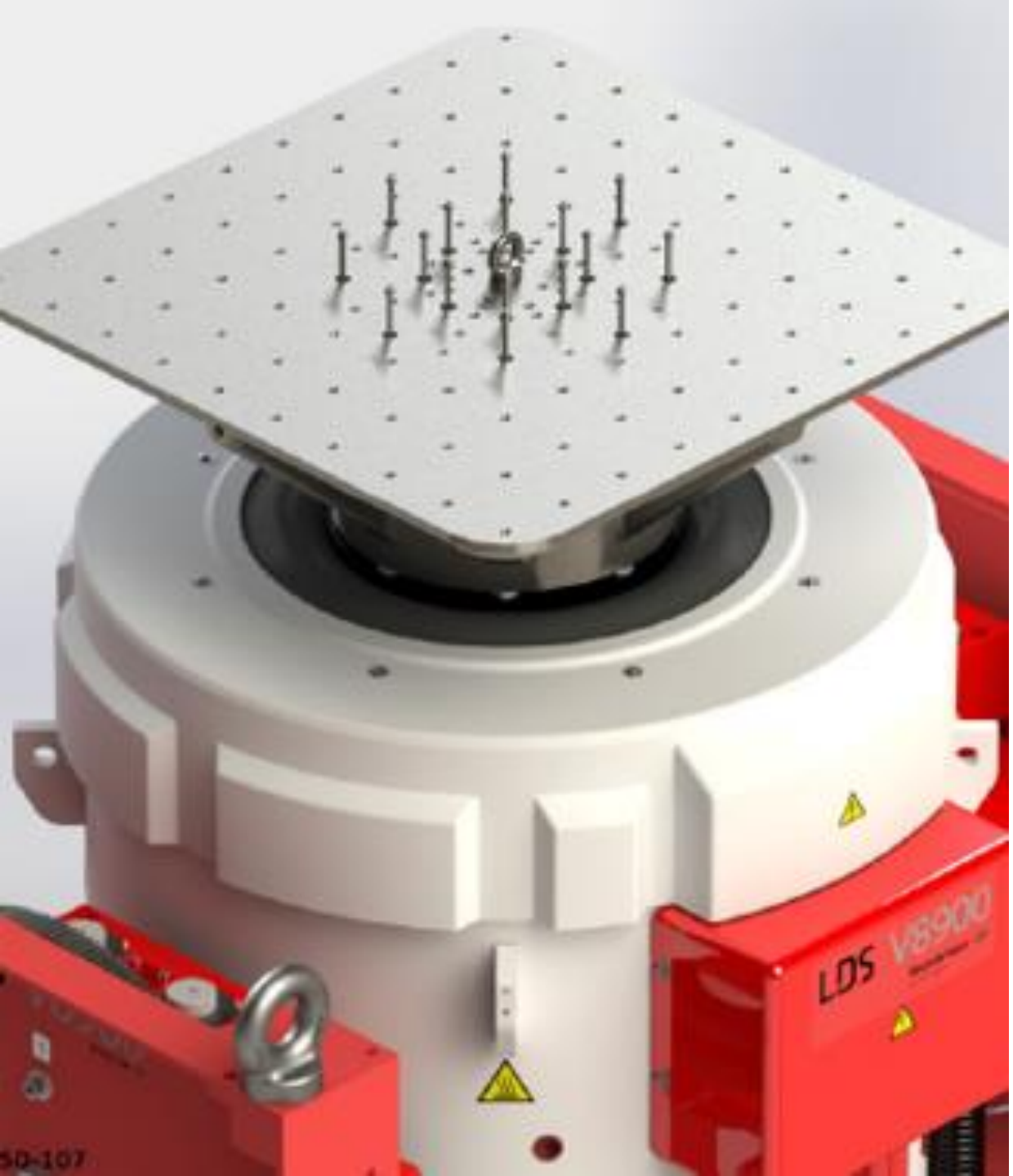

Unguided Head Expander

- Suitable for test objects whose own weight does not exceed the limit of the pneumatic load compensation
- Low centre of gravity
- Test objects do not cause high lateral forces or have a central centre of gravity
- Usually made of magnesium

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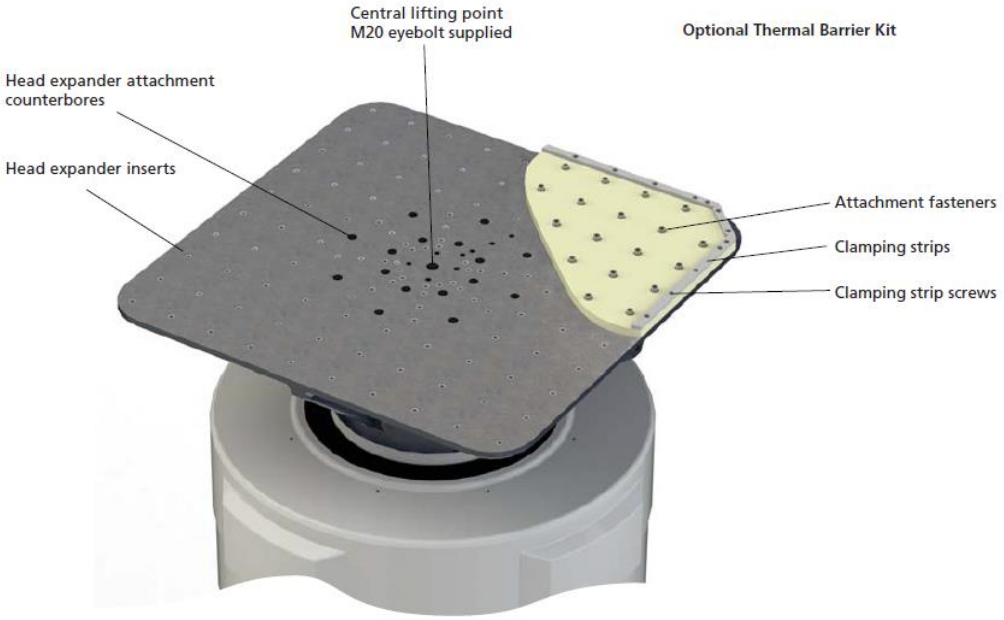
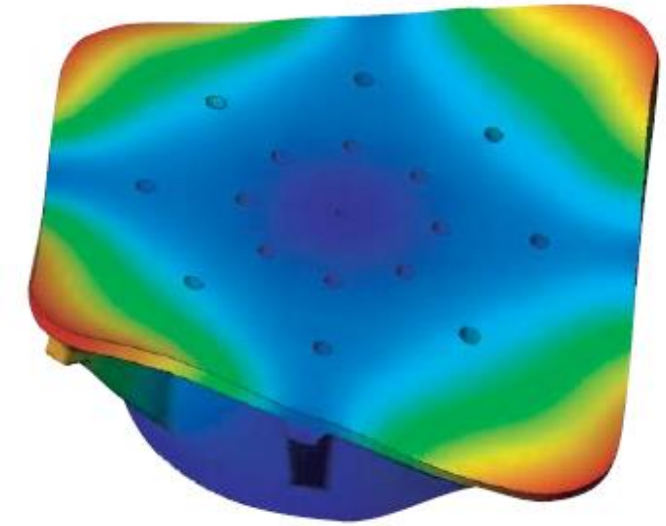
Unguided Head Expander - Square



Standard head expander configuration



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FE analysis of standard head expander (1st vertical resonance)

V850-440*, V875-440, V875-640, V875LS, V8, V9 with M8 Armature Inserts							
Head Expander Kit						Thermal Barrier Kit	
Size mm	Head Expander Inserts	1st Vertical fn† Hz	Height mm	Mass‡ kg (lb)	Kit Number	Mass kg (lb)	Kit Number
610 square	M8	2047	220	57.4 (126.5)	4038260	12.7 (27.9)	4039410
762 square	M8	1161	255	83.9 (184.9)	4038320	20.5 (45.1)	4039420
1000 square	M8	685	325	135.4 (298.5)	4038350	34.5 (76.0)	4039430
1220 square	M8	537	385	239.3 (527.5)	4063520	56.4 (124.3)	4063580

* For the V850-440, the 1220 mm square head expander is not recommended and not offered as a standard option
† Nominal frequency
‡ ±5%

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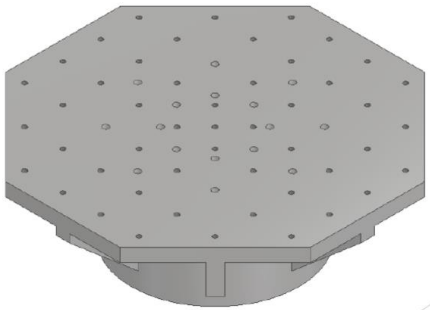
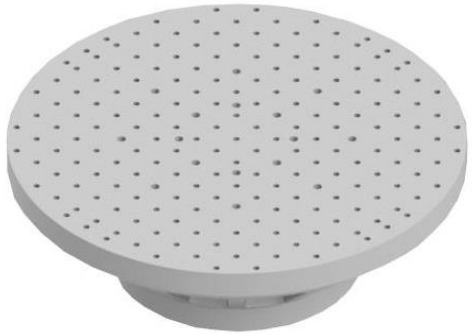
Unguided Head Expander

Version 1



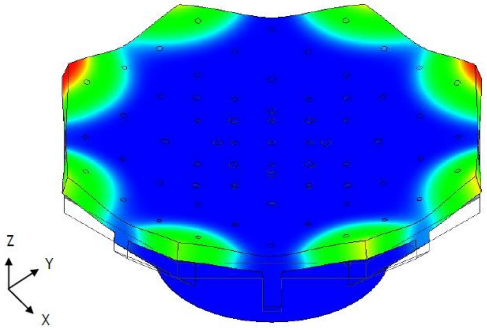
- Dimension of the head expander: 800mm x 800mm, height 255mm
- Usable frequency range 5 to 2,500 Hz
- 1st resonance: 1,500 Hz
- Material: Magnesium alloy
- Mass: 63kg
- M8 Inserts pattern 100mm (square) and armature grid
- Armature: ø440mm

Version 2

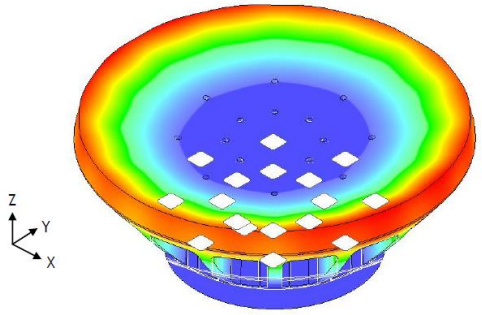


- Clamping surface: ø812mm
- Height: 250mm / Mass: 77kg
- 1st resonance: 1,900 Hz
- Material: Magnesium alloy
- Hole grid: 50mm x 50mm I M8 Inserts +25mm M8
- Armature: 440mm
- Temperature range: -40°C till +180°C

FE Analysis of Version 1



FE Analysis of Version 2



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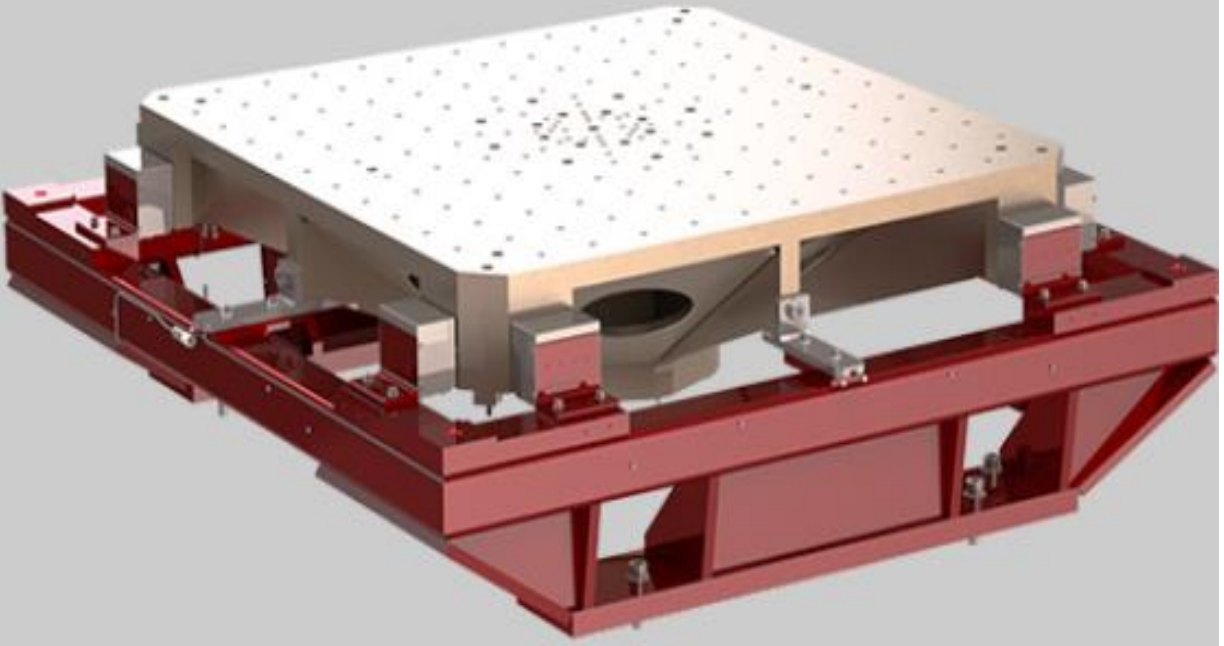

Guided Head Expander

LINEAR GUIDANCE

The guided head expander enables vertical axis tests where the size or mass of the payload is greater than the shaker armature and load supports can accommodate.

Technical Data

Compatible Shakers	V875, V875LS, V8, V9x
Support capability	1200 kg (based on minimum supply pressure of 5.5 bar)
Expander table size	1220 x 1220 mm
Moving mass	264 kg nominal
Controllable frequency range	5 Hz - 2000 Hz (multi-point control accepted)
Dimensions	1614 x 1614 x 517 mm
Weight	521 kg nominal
Materials	Table: magnesium alloy Frame: steel
Table Inserts (configuration option)	M8, M10, 3/8 UNC

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Guided Head Expander

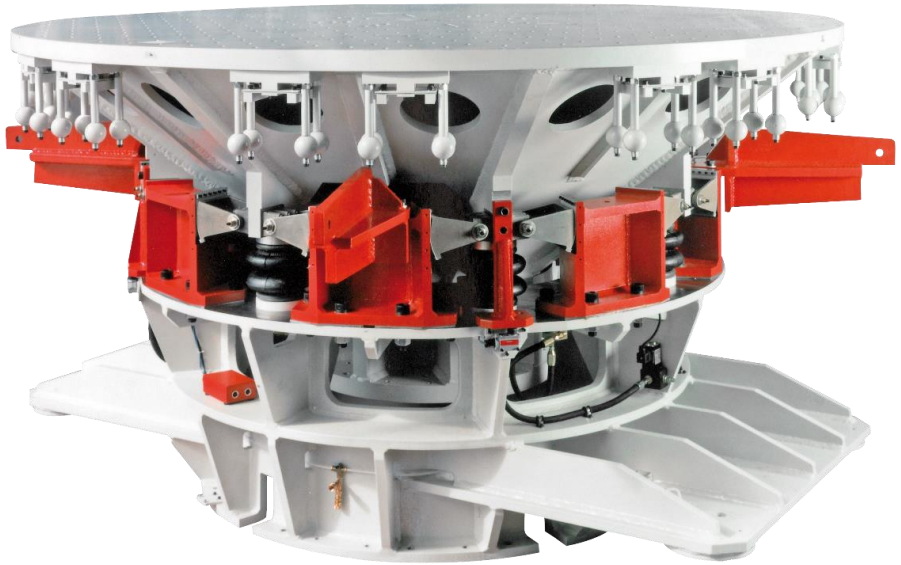
SPECIAL VERSION

Heavy duty platform:

- For large, heavy test pieces (>5kNm)
- Low-frequency tests
- Typical: transport simulations

Hydrostatically guided head expander:

- For very large, heavy test pieces (>40kNm)
- With vibration absorber for resonance damping
- Typical: satellite testing



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3. Configuring a Slip Table System

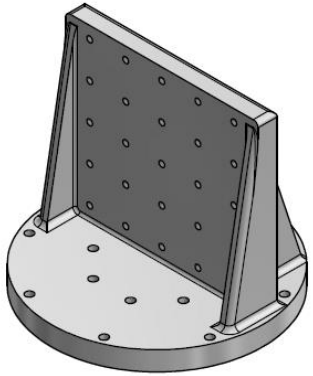
DO I NEED A SLIP TABLE SYSTEM FOR MY APPLICATION?

WHICH SLIP TABLE FITS TO MY REQUIREMENTS?

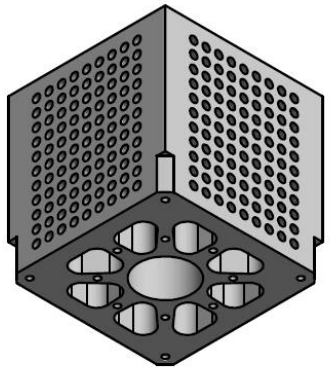
Tests in X/Y: Rotation of the Test Specimen by 90°

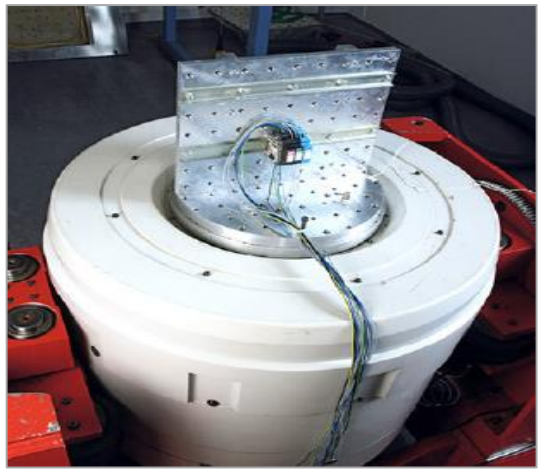
With a special clamping device:

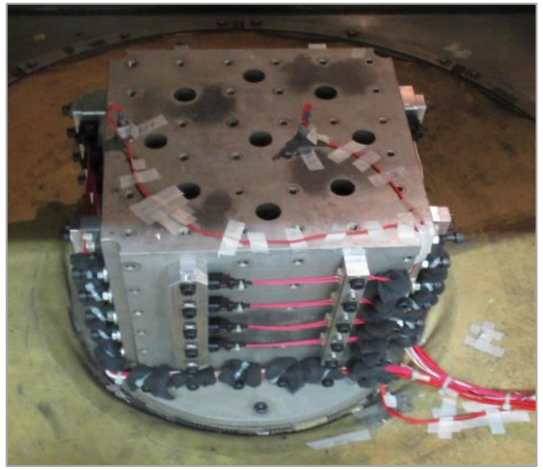
- L/T-shaped fastening



- Clamping cube







Symmetry is key!

Important specifications are always:

- Required clamping surface
- Max. Frequency range FEM analysis
- Fitting diameter and fitting hole grid for mounting
- Hole grid threaded inserts (e.g. M8 50x50mm)
- Material: aluminium or magnesium alloy

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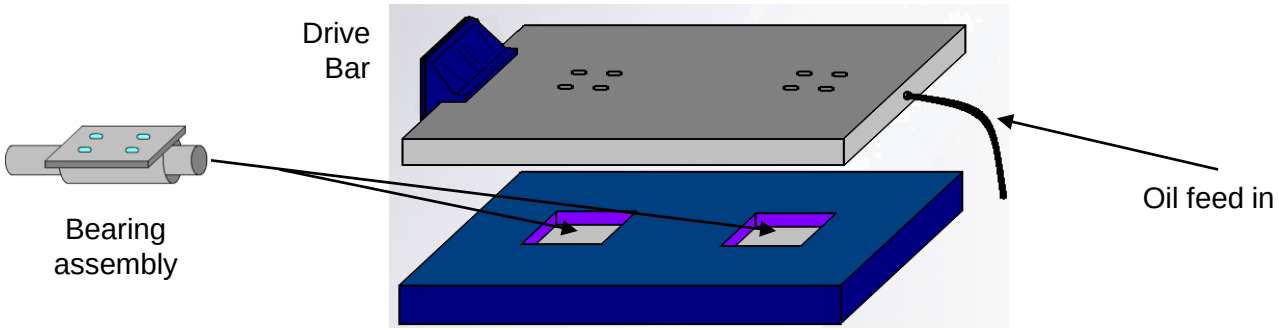
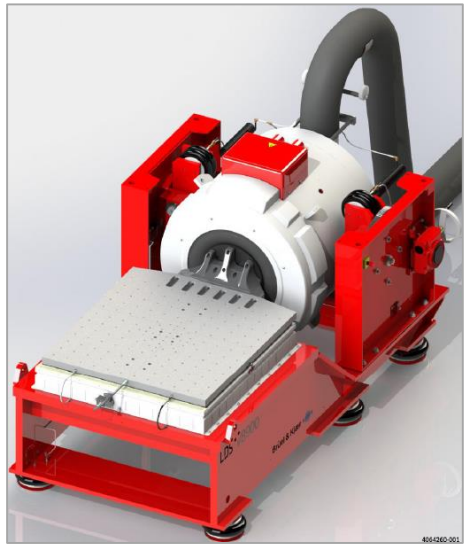
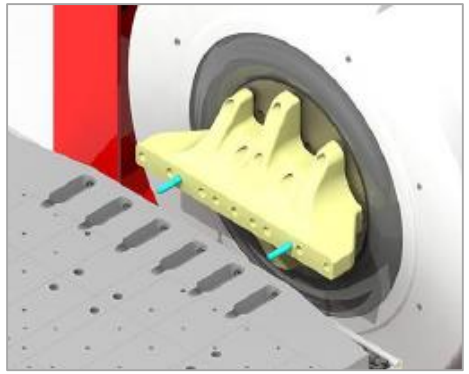
Slip Table Systems

- Magnesium slip plate slides on an oil film supported on a granite block.
- The Granite block is mounted on a precision machined steel plate.
- Hydrostatic bearings in the openings of the granite block limit pitch, roll and yaw of the slip plate.

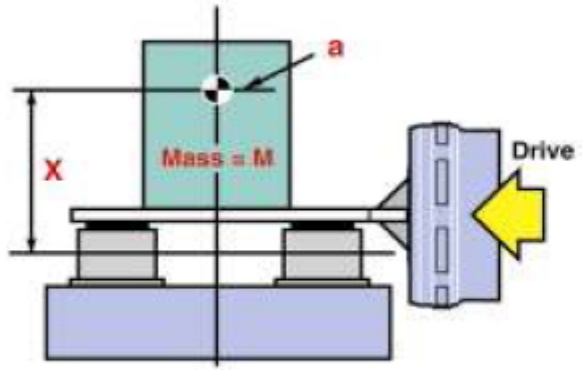




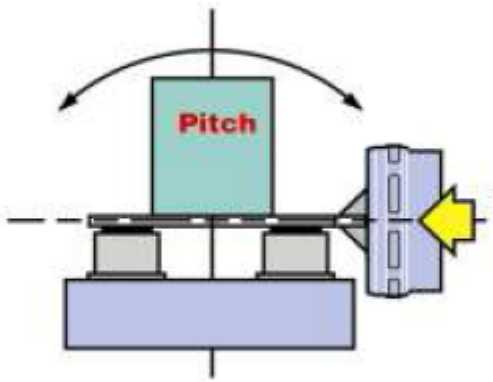


Slip Table Systems: Overturning Moments

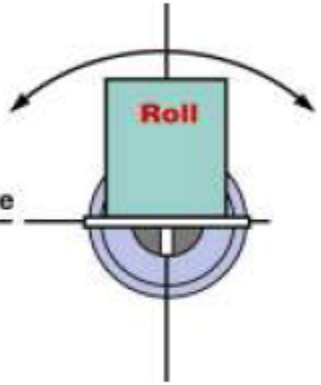
The dynamic properties of the test mass influence the calculated values. Calculations are based on test samples without significant natural frequencies.



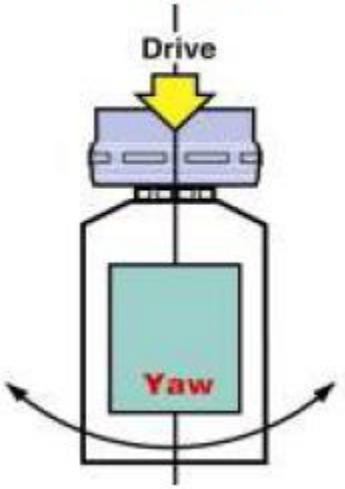
Distance X



Distance Y



Distance Z



$$M\ [Nm] = x\ [m] \cdot m\ [kg] \cdot a\ [m/s^2]$$

x Distance of the centre of mass of the test sample from the bearing
m Effective dynamic mass of the test sample
a Maximum particle size under resonance conditions

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Slip Table Systems

HBT

- HBT bearings are used on slip plates
  - Fixed bearings - used on the centreline of the plate
  - Free bearings - used on edges of slip plates
- Use high pressure oil (172 bar) through the bearing

Cross section of a fixed HBT bearing

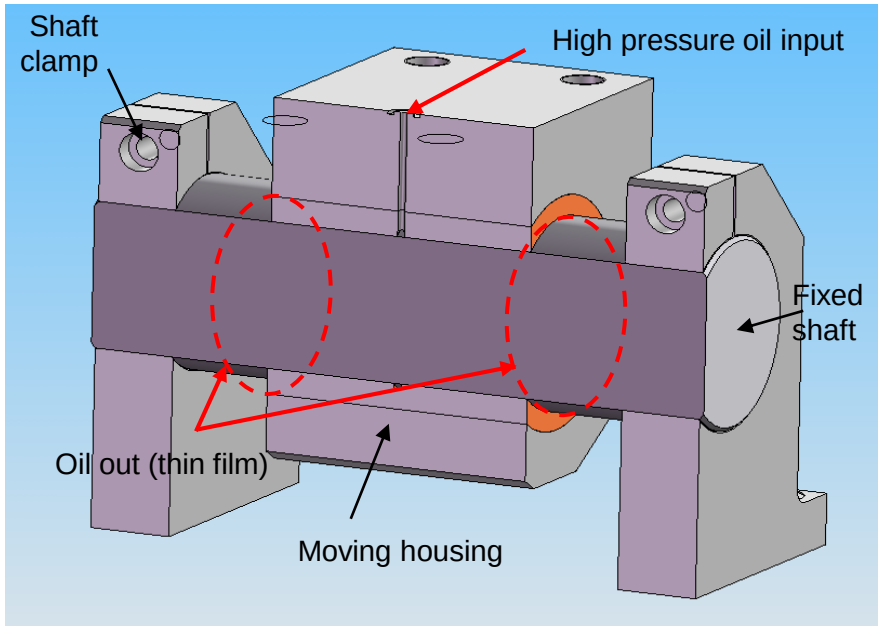
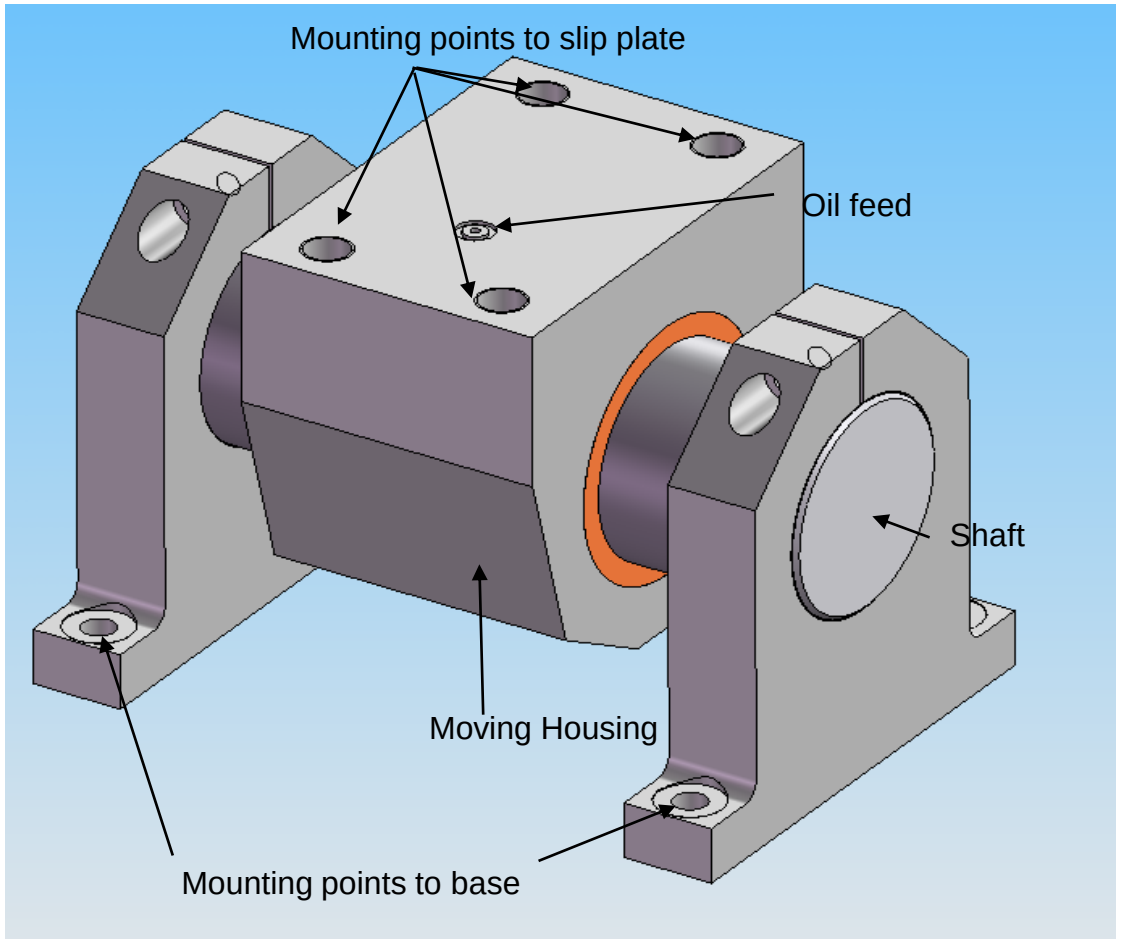


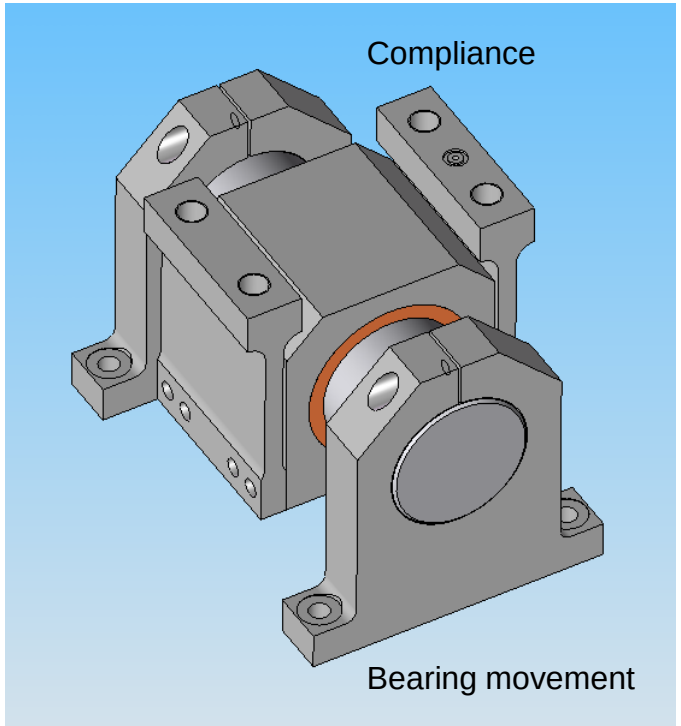
Illustration of a fixed HBT bearing platform

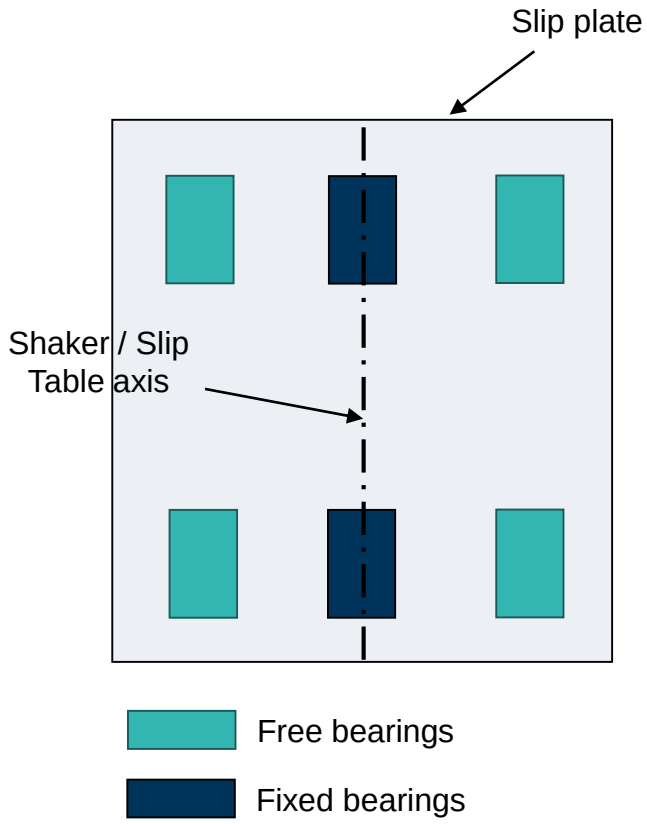


Slip Table Systems

MULTI BEARING HBT

Free bearings: Similar principle with built-in conformity for thermal expansion (at the edges of the slip table top)





Typical multi-bearing configuration for an HBT slip table top

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Slip Table Systems: Multi Bearing HBT

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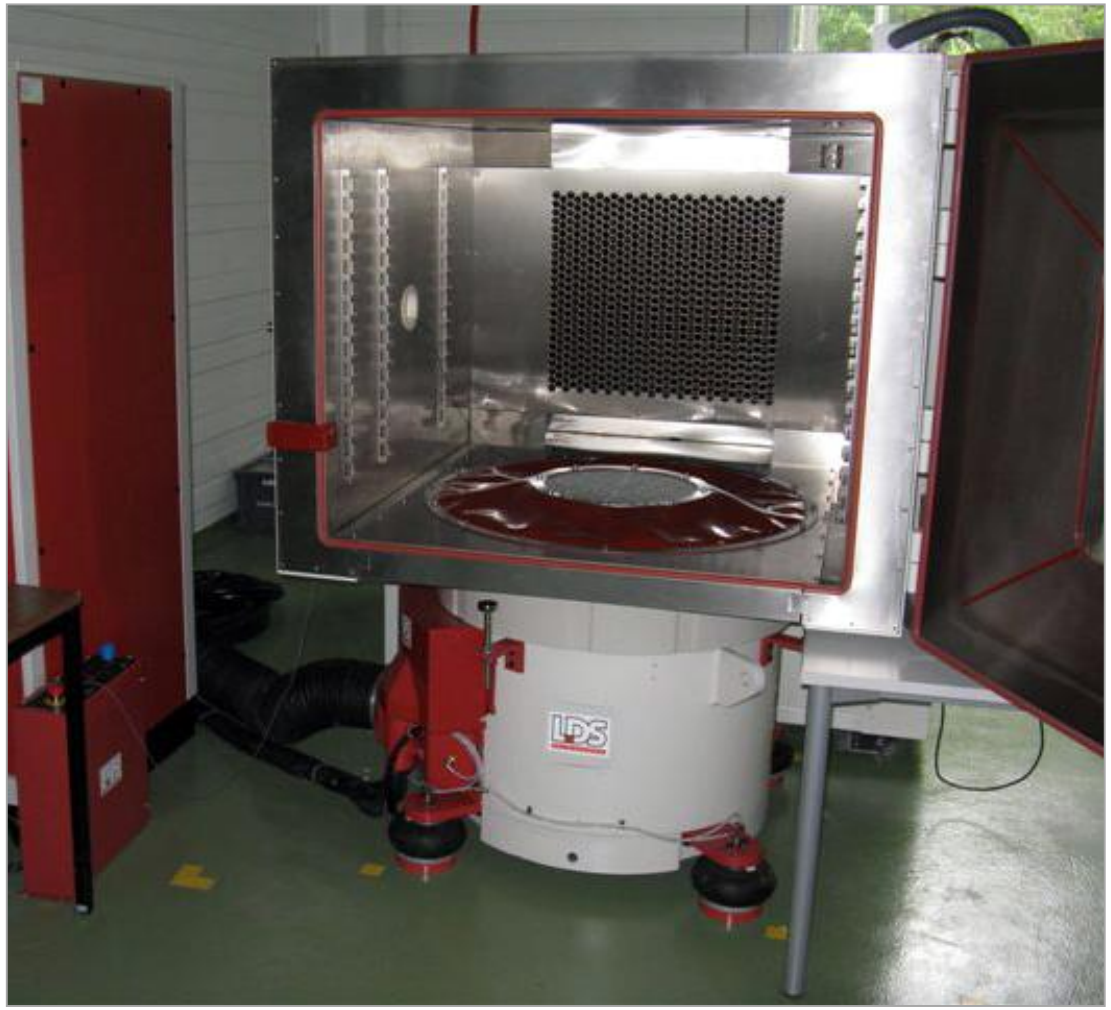
4. Testing Vibration and Climate

HOW DO I CONNECT A TEMPERATURE/CLIMATE CHAMBER TO MY SHAKER SYSTEM?

Testing Vibration and Climate

- Vibration tests are often carried out on electrodynamic shakers
- Combined tests under the influence of vibration, temperature or even humidity
- Combining temperature and climate test chambers with shaker systems.
- Interface between shaker and climatic chamber



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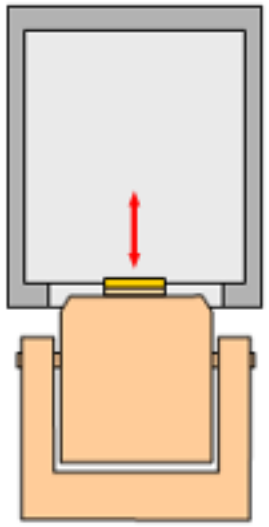
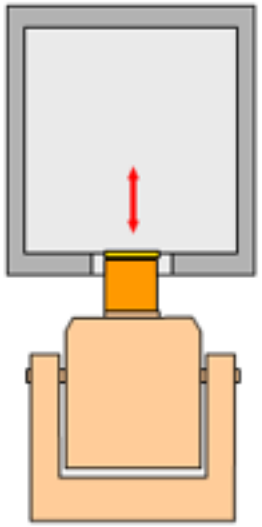
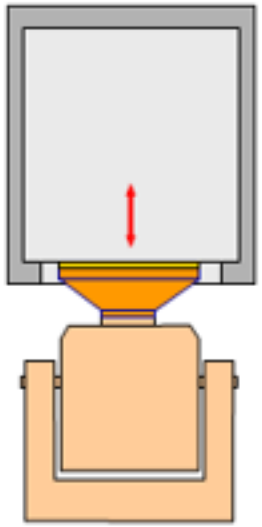
Vertical Connection Possibilities



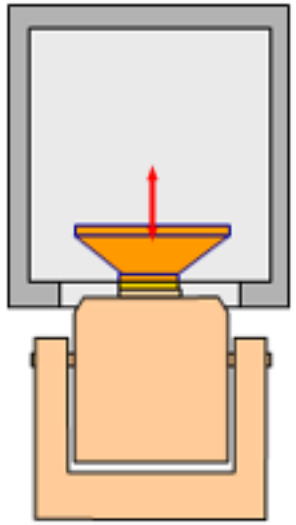
#1
Direct Installation



#2
Cylindrical plunger extension Head Extender



#3
Plunger extension Head Expander (floor level)



#3B
Plunger extension Head Expander (in the test room)

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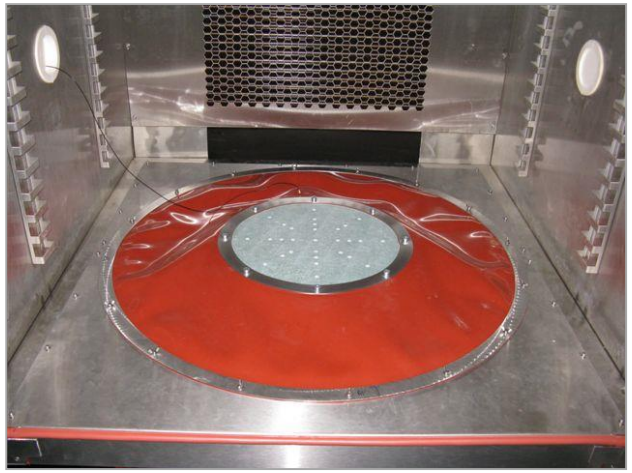
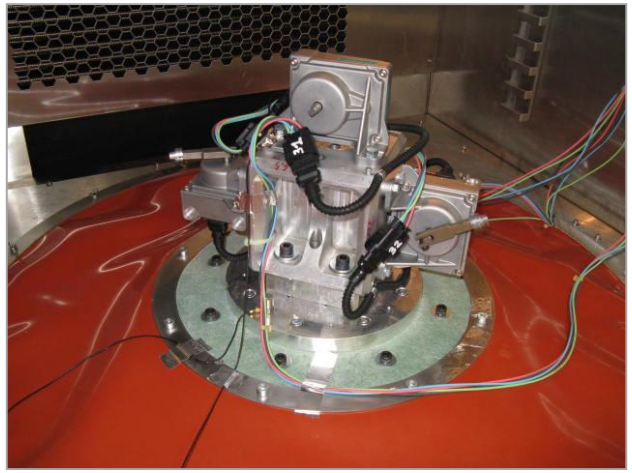
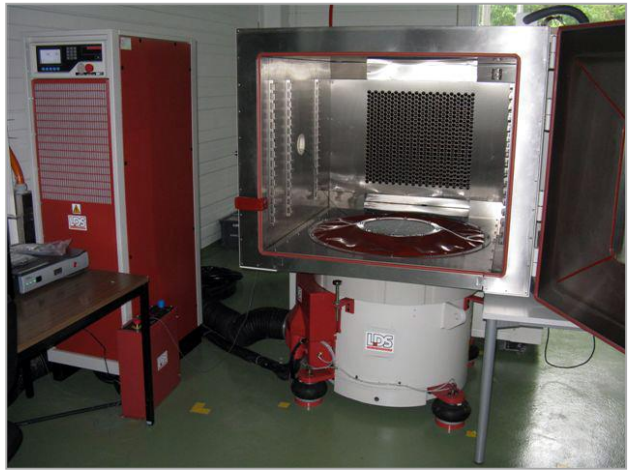
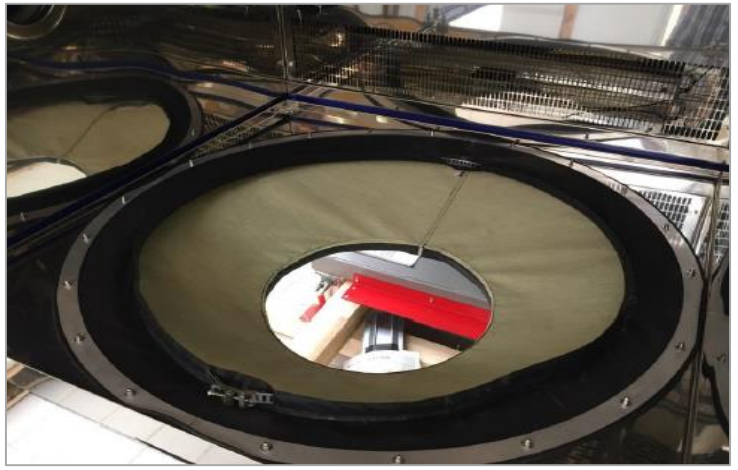
#1: Direct Installation





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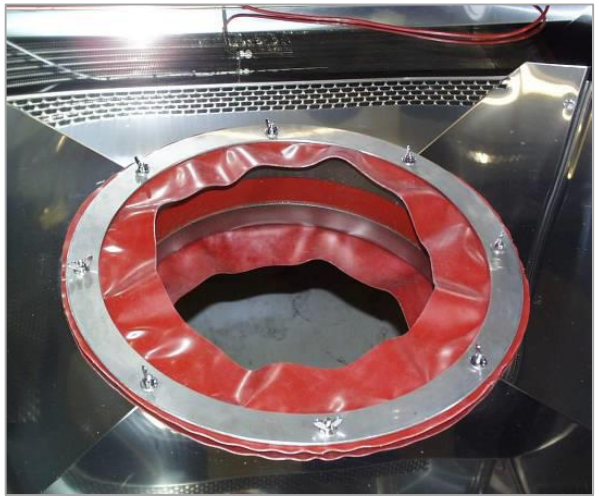
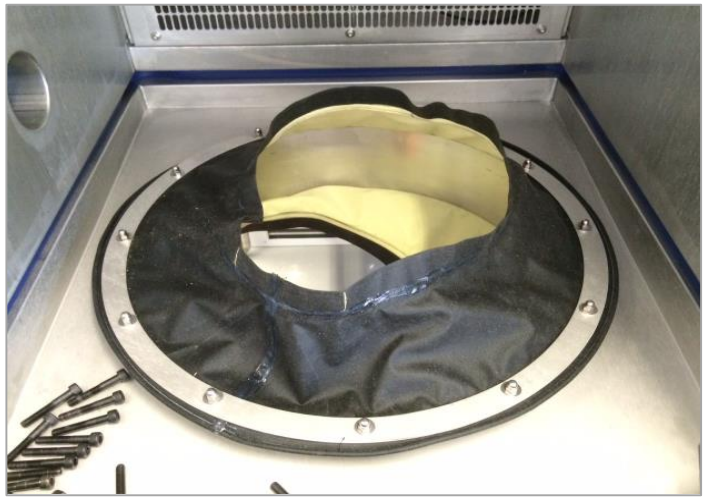
#2: Cylindrical Plunger Extension Head Extender





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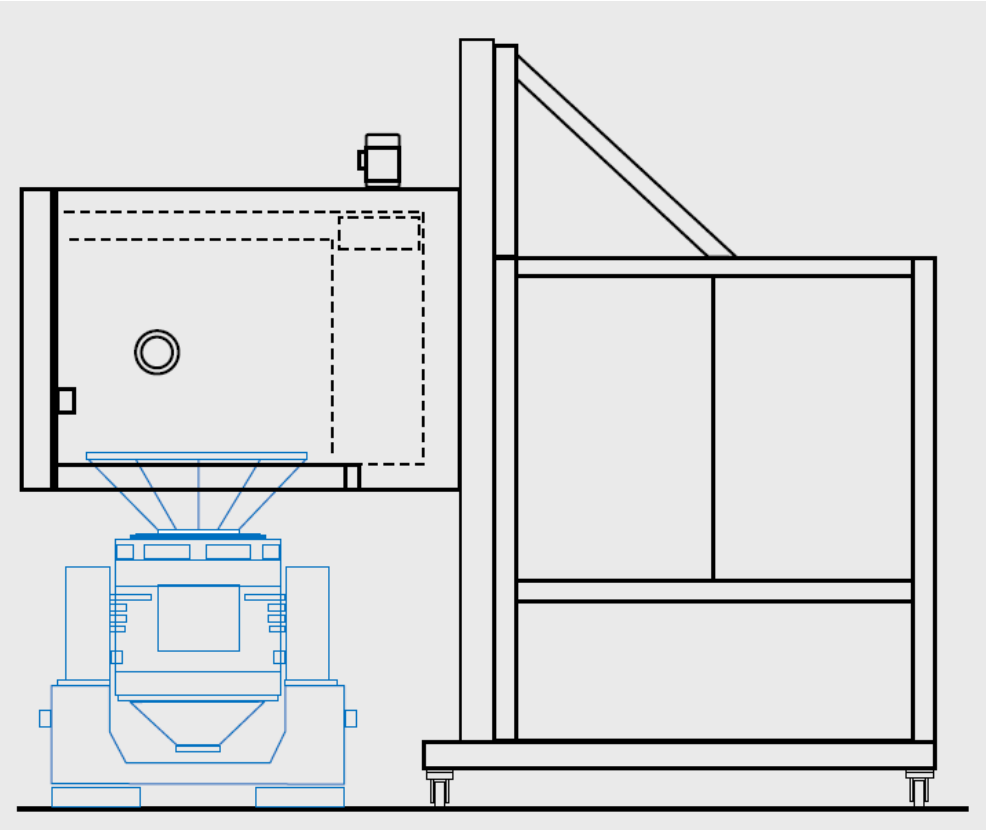
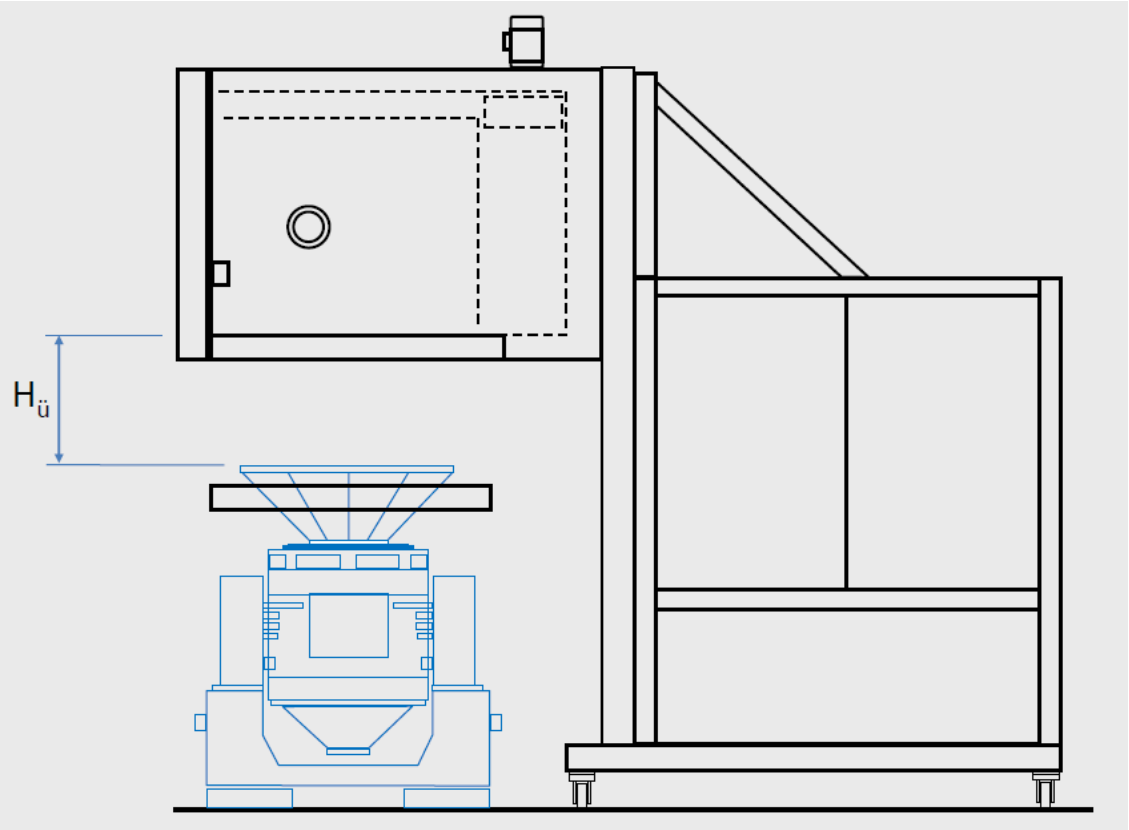
#3A / #3B: Plunger Extension Head Expander



Vertical position with connection to head expander



Vertical position with uppermost position of test chamber

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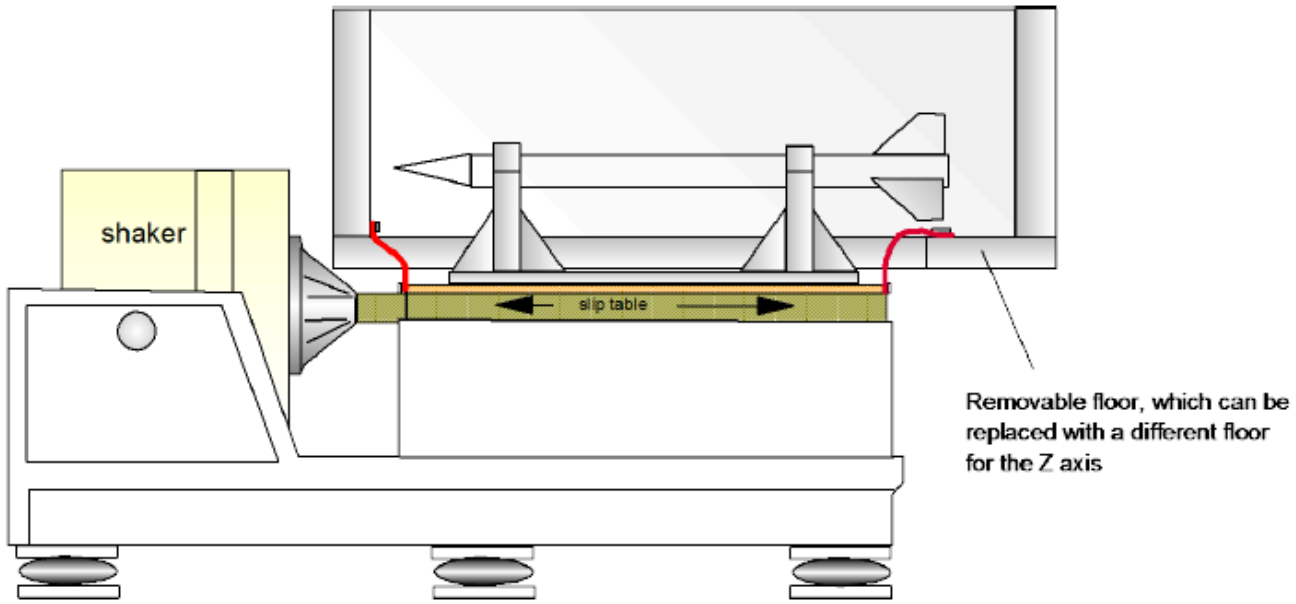
#3A / #3B: Plunger Extension Head Expander

Horizontal Connection to Slip Tables

STANDARD

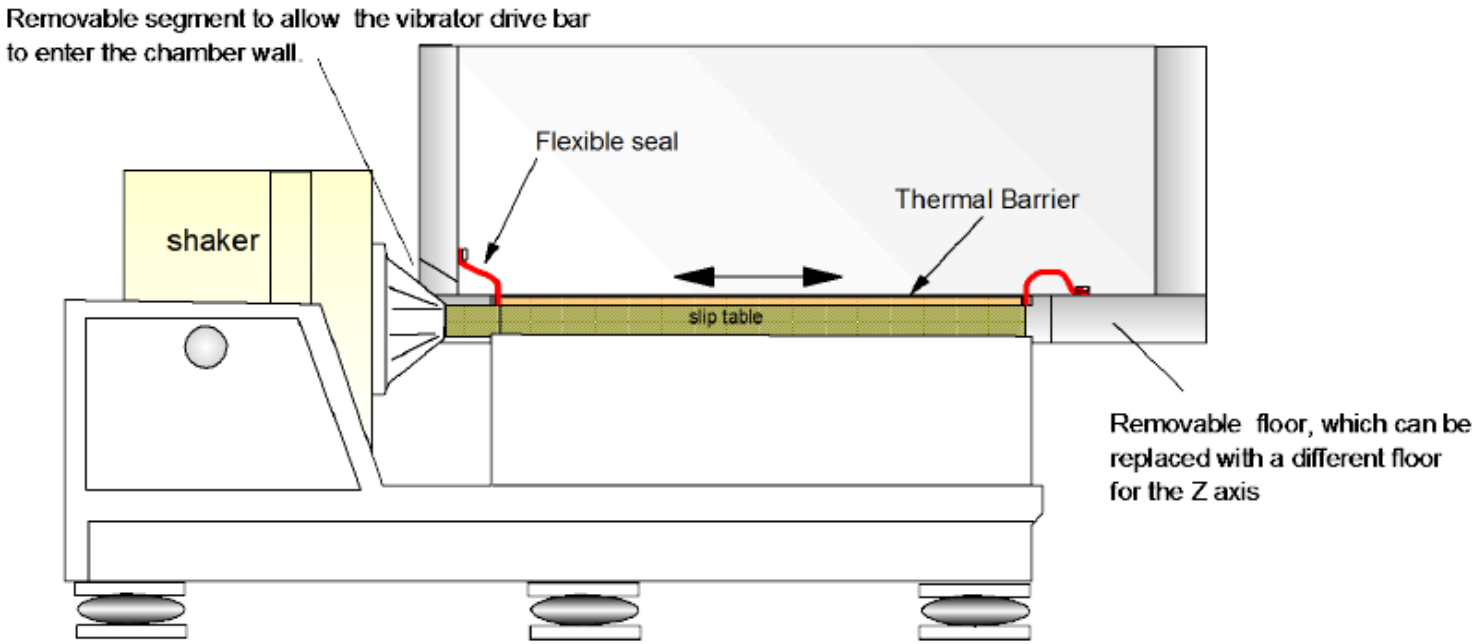
- Large test loads must be raised above the chamber floor level
- Chamber floor located above the slip table
- Space between the Driver Bar and the climate chamber allows the movement of the valve
- DUT remains outside the climatic chamber test area
- Water can collect around the seal if running at high humidity levels



Horizontal Connection to Slip Tables

INTEGRATED

Chamber floor should be as close as possible to the slip table surface.



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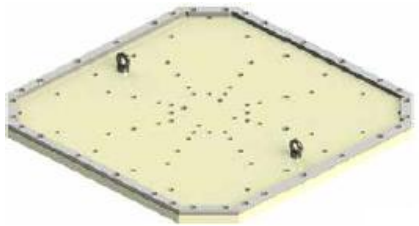
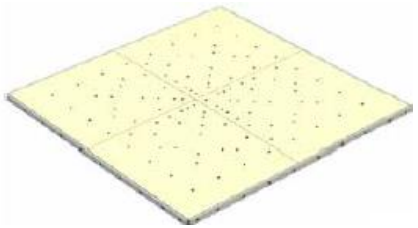
Thermal Barriers

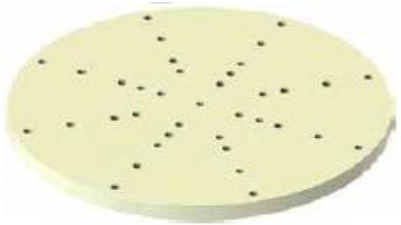
Attaching a thermal barrier to the sliding plate reduces the heat conduction between the payload and the armature/slip plate.



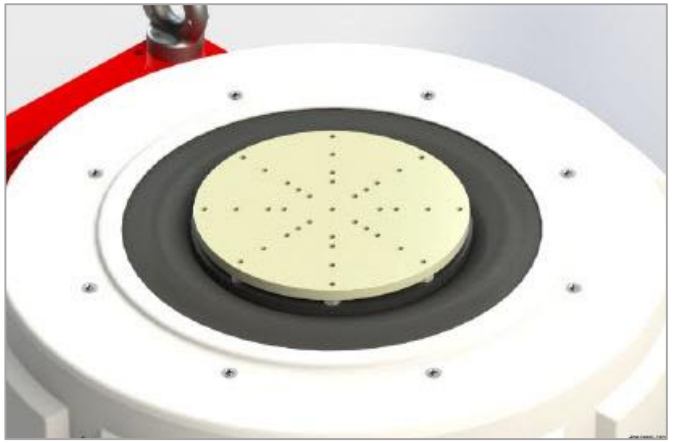
Typical LDS Thermal Barrier for LDS Head Expander



Typical LDS Thermal Barrier for LDS Slip Tables

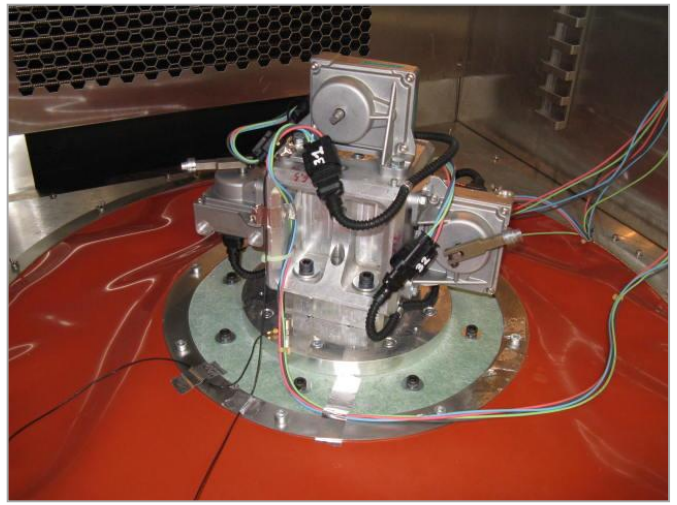


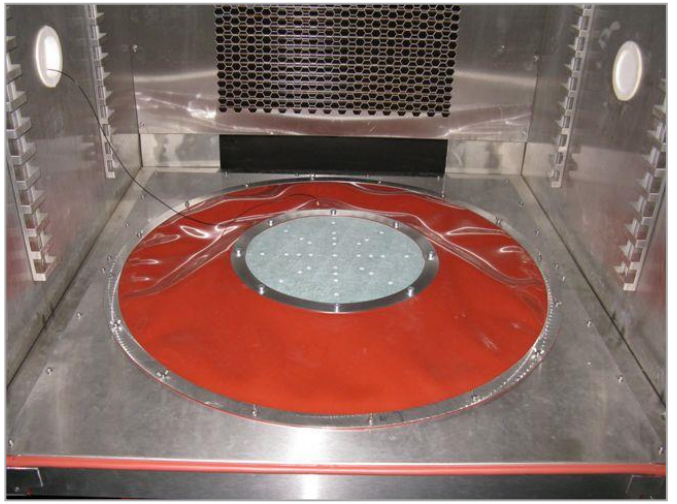
Typical LDS Thermal Barrier for LDS Vibrator Armature



General Indications

- Thickness: 20mm
- Conductivity: 0,28W/m/°K
- Temperature limits: -70 bis +230°C





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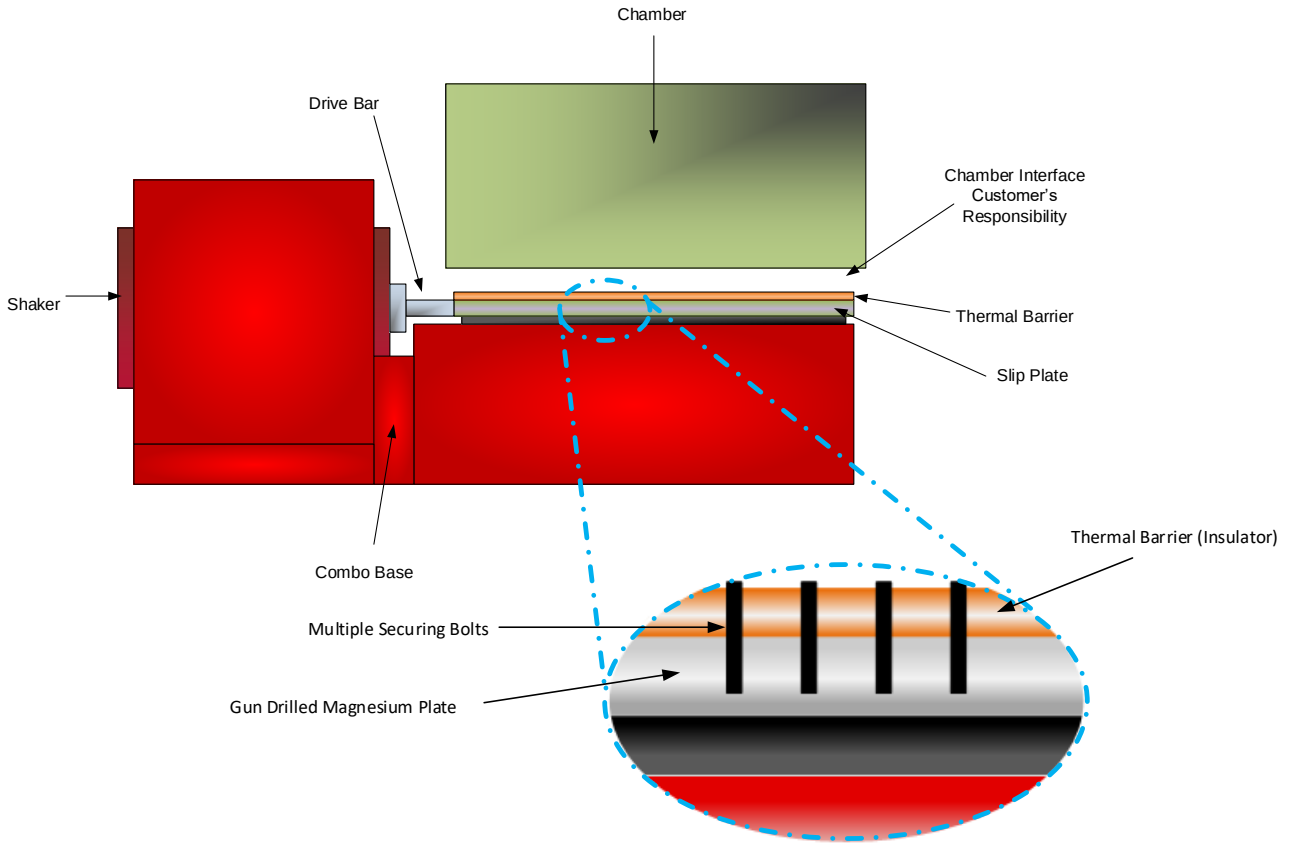
Further Measures in Horizontal Operation

- Heat and condensation can cause problems
- Heat can be transferred to the slip table plate
- Condensation can contaminate the oil
- The granite resin can soften if the temperature is at 70°C or above for a sustained time unless counter measures taken:
  1. Using an alternative hydraulic oil
  2. Operation with Hot & Cold Unit



1. Alternative Hydraulic Oil

- The permissible working temperature range of a slip table is limited by the hydraulic oil used to lubricate the magnesium/granite interface and the guide bearings.
- Working temperature of the slip table must be between +20°C and +55°C.
- Alternative oils with a wider temperature range are available

Table 4 Oil temperature limits

Oil type	Minimum temperature	Maximum temperature
Shell Tellus 68	+20° C	+55° C
Century 779	-10° C	+65° C
Mobil Delvac 1	-20° C	+80° C

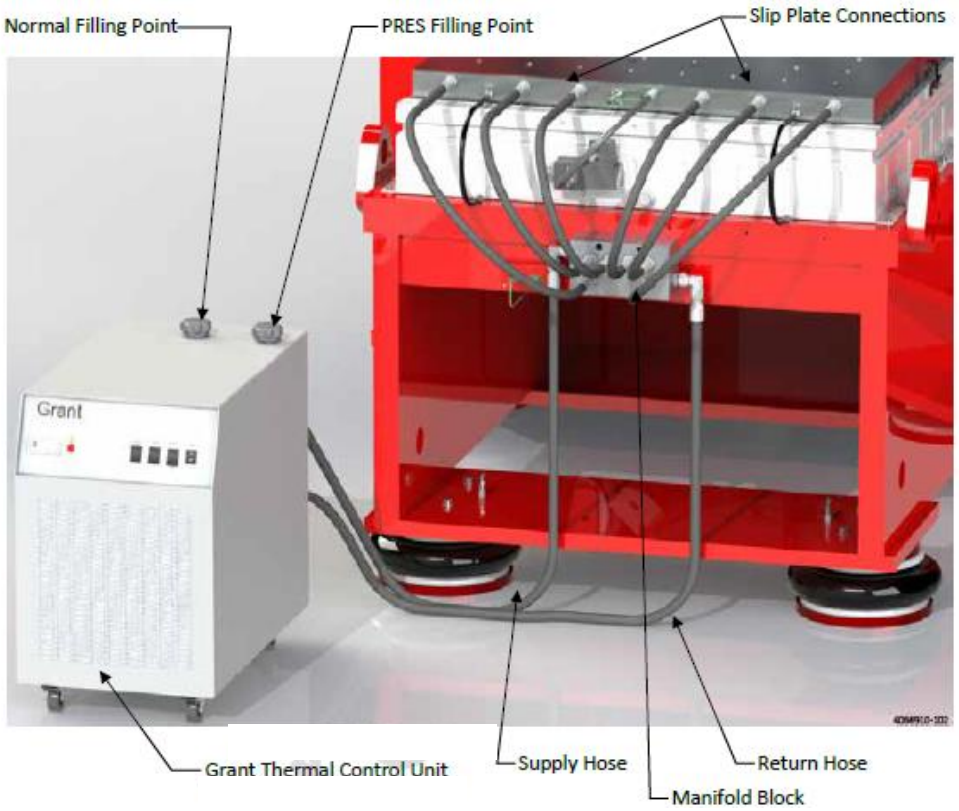
2. Operation with Hot & Cold Unit

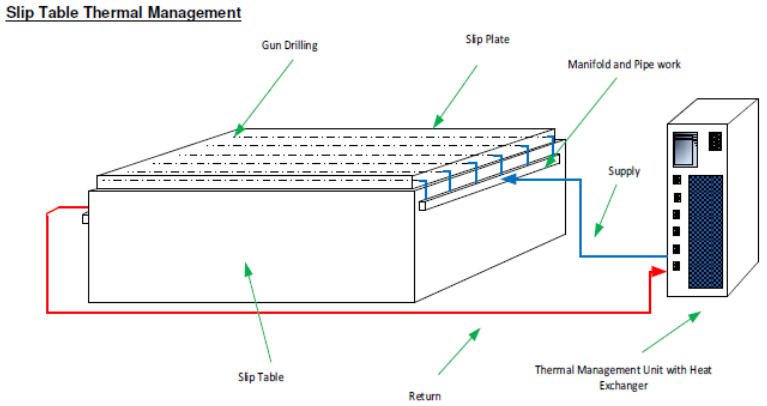
To maintain a steady operation temperature on the slip plate a thermal control unit needs to be used to avoid damage:

- Slip plate being subjected to higher of lower temperatures for a continuous period of time.
- Temperature transferring from the slip plate to the oil in the slip table.
- The bearings seizing and the oil failing to provide the required lubrication

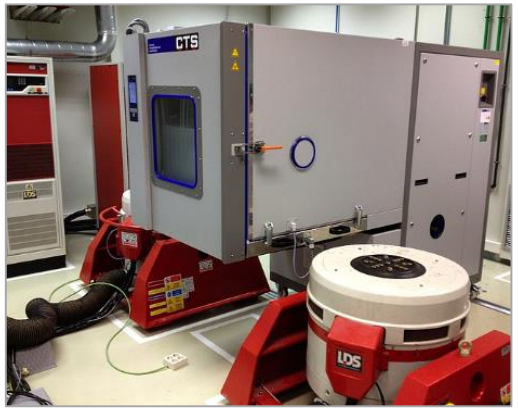
Advantages of using the Thermal Control Unit (TCU):

- Extends the performance of the system
- Maintains the slip plate at a pre-set temperature
- Slip plate can be preconditioned to a set temperature
- Will add heat to the slip plate during cold running and draw heat away during hot testing
- Reduces the heat transferred to the bearings and oil film





Examples



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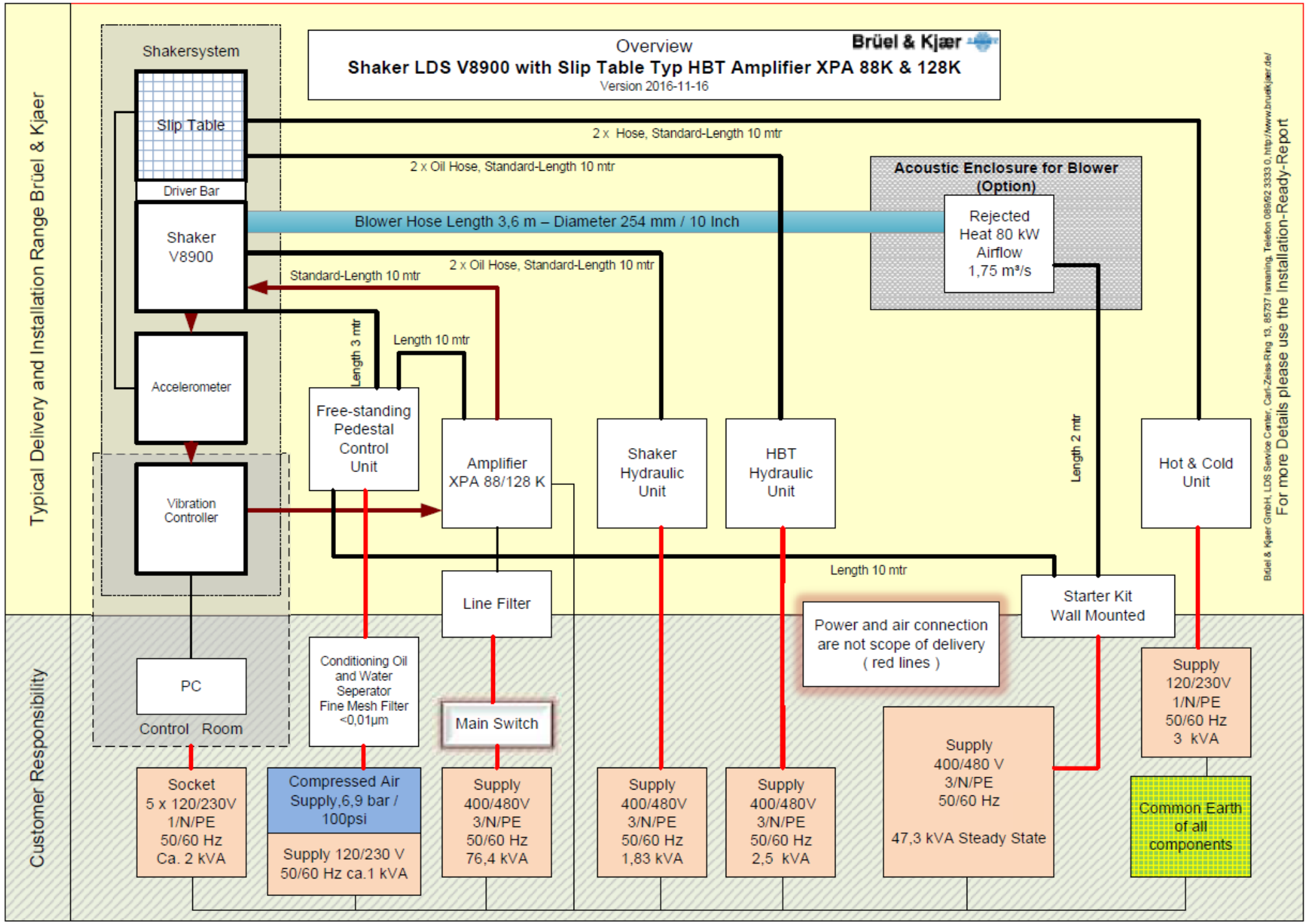
5. Installing a Shaker System

WHAT DO I NEED TO INSTALL A SHAKER SYSTEM?

DO I NEED A SEISMIC FOUNDATION OR IS MY HALL FLOOR ENOUGH?

Connection overview of a shaker: Example V8900 (80kN)



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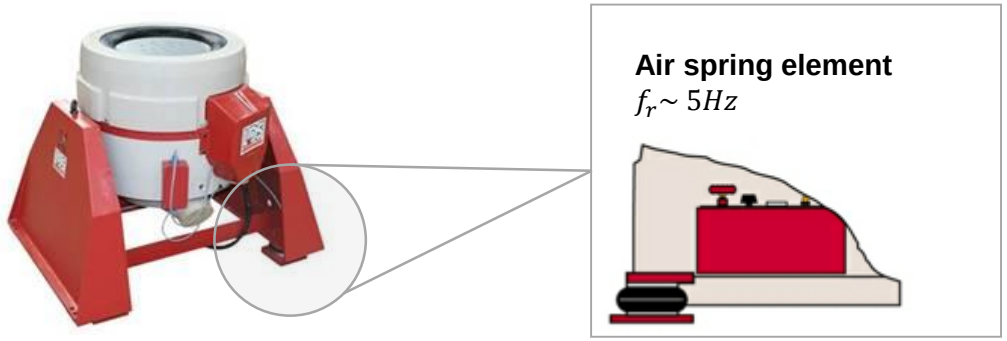
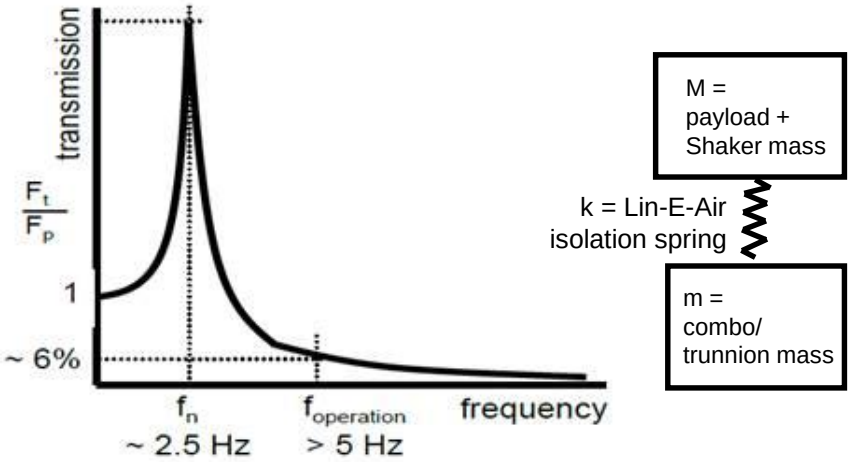
Shaker Isolation

Isolation through air springs:

- Designed for installation on industrial floors from ~10Hz

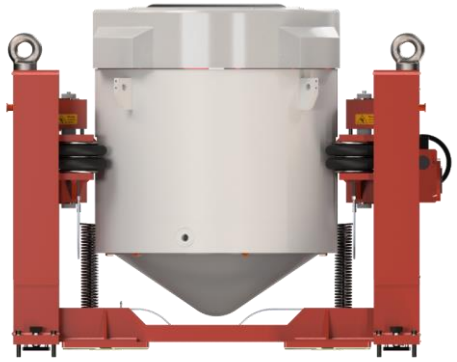




Lin-E-Air suspension system:

- Designed for installation on an industrial floor from 5Hz
- Enables better insulation in the low frequency range (5-20 Hz)
- The shaker body is isolated from the swing-arm mountings

Lin-E-Air system
$f_r \sim 2{,}5Hz$



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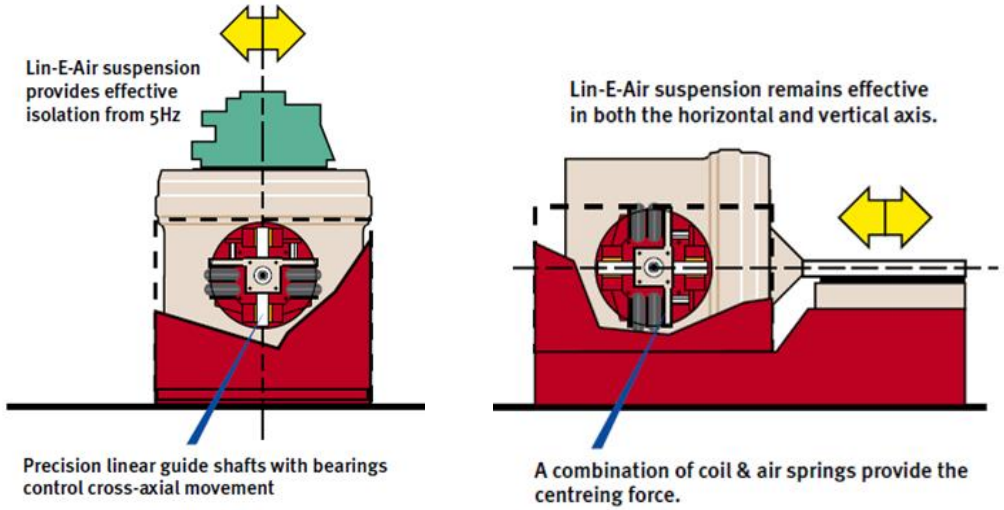
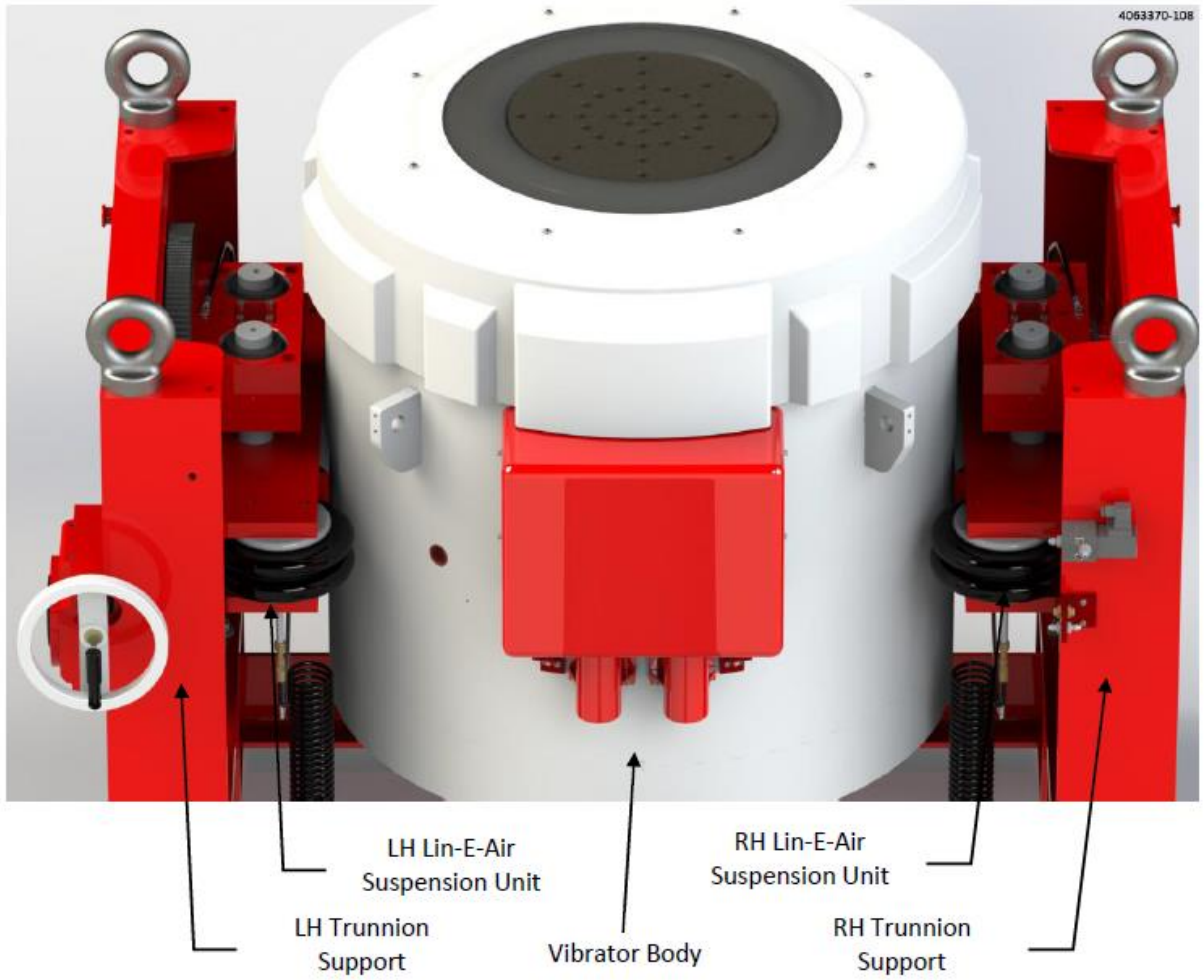
Lin-E-Air Shaker Isolation System

- Can be operated both horizontally and vertically
- The airbags are supplied with compressed air
- The Lin-E-Air control unit takes over the centring of the shaker body in vertical position





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Installation of the Shaker with/without Seismic Mass

- Lin-E-Air combo systems offer multiple levels of isolation and do not require seismic mass
- A seismic mass always offers the best isolation
- Isolating the vibrator transmits less force into the block – smaller seismic mass required

Pros-Cons
Decision Maker

V994 HBT combo with GHX

Lin-E-Air body-suspension

Combo-support air-bags

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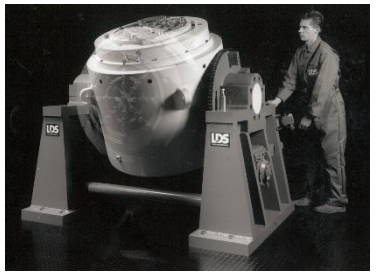
6. Producing a Shaker System

HOW ARE SHAKERS PRODUCED?

WHICH CUSTOMER REFERENCES DOES HBK HAVE?

A Brief History

1950	Original joint venture Pye-Ling moved to Royston, UK (LTV Ling Altec)
1970	Ling Dynamic Systems (LDS) founded from US and UK S&V businesses
1976	LDS began selling vibration test systems in the US market
1988	World's highest force 289kN water-cooled shaker (V994)
1988	Prince Charles opens the new building extension at the Heath Road works
2001	LDS acquires Dactron (vibration controller & analysis specialist)
2002	V9 shaker system launched
2003	V8 shaker system launched
2004	LDS changes its name to LDS Test and Measurement
2008	LDS Test and Measurement is acquired by Brüel & Kjær
2008	V875LS shaker system launched
2009	Supplied the V994 to NASA JPL for the testing of the Mars Rover (launched 2011)
2016	World's first 80 kN air-cooled shaker (V8900)
2019	B&K and HBM merge to form HBK



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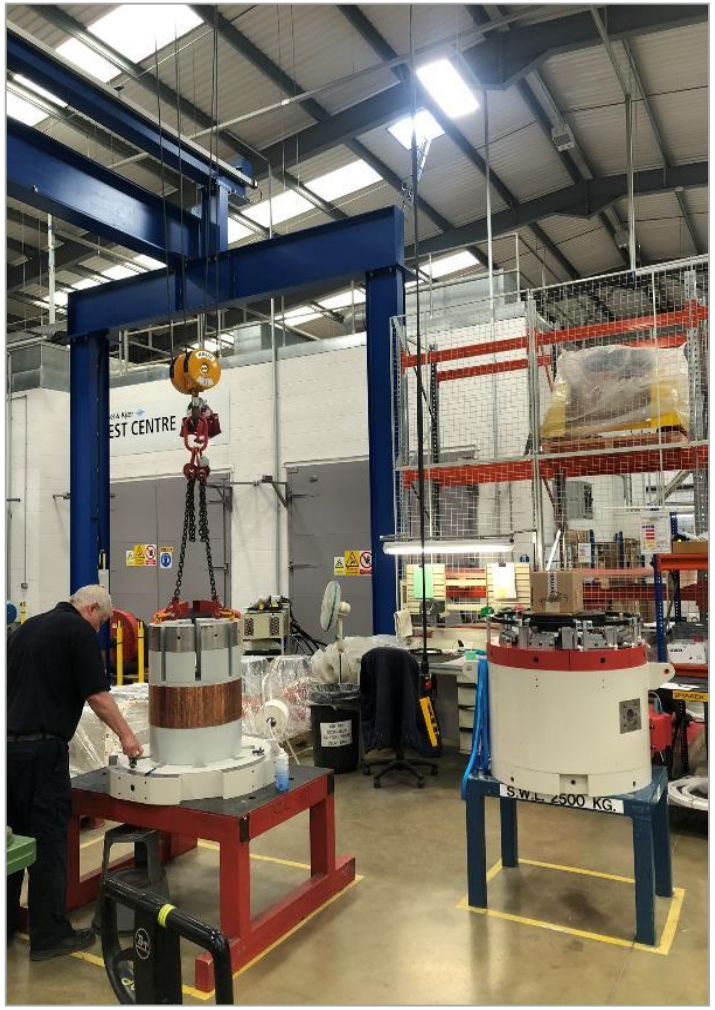
LDS Vibration Test Systems Production in Royston



Assembly Area for Armatures

LDS Vibration Test Systems Production means:

A lot of manual work with highly qualified personnel

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LDS Vibration Test Systems Production in Royston

Assembly Area for Shakers

LDS Vibration Test Systems Production means:

A lot of manual work with highly qualified personnel

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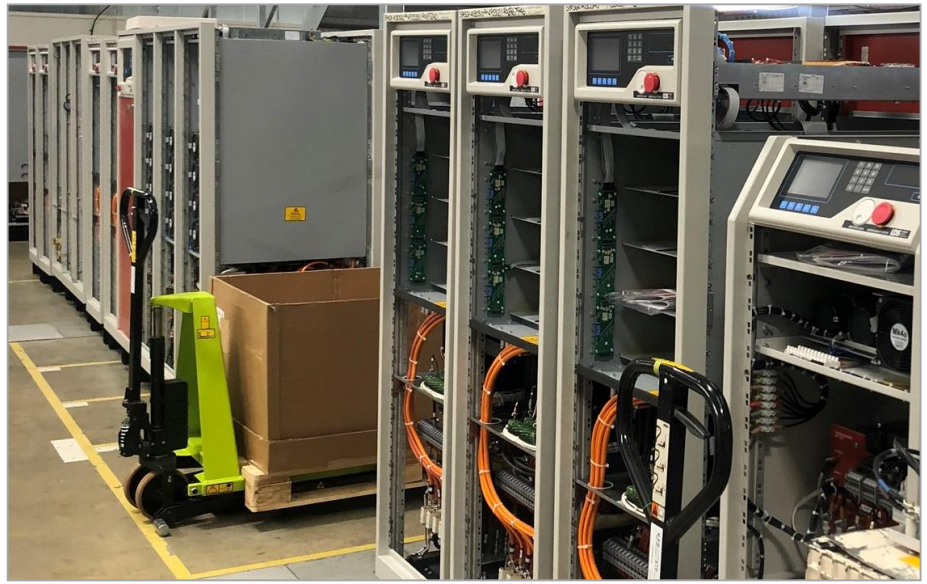
LDS Vibration Test Systems Production in Royston



Assembly Area for Amplifiers

LDS Vibration Test Systems Production means:

A lot of manual work with highly qualified personnel

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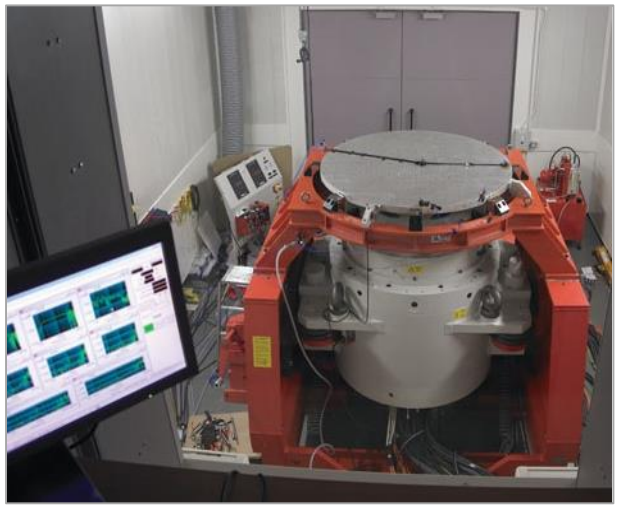
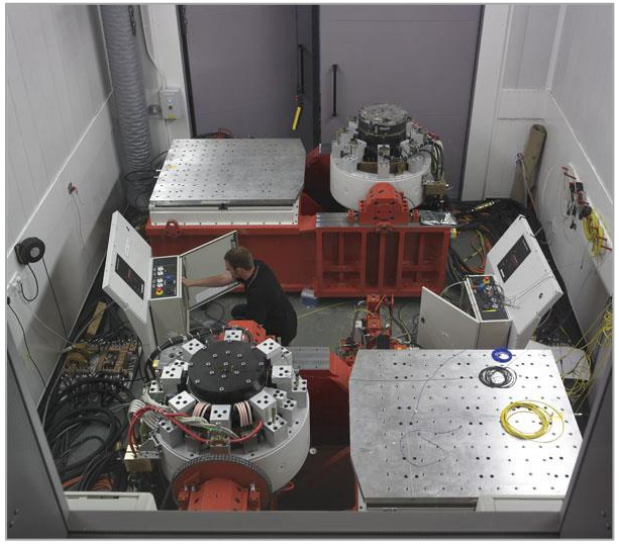
LDS Vibration Test Systems Production in Royston





Vibration Test Systems Test Area

- Manufacturing in UK, Europe with a high-quality level
- ISO 9001 certified

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Customer References

- Automotive Industry
- Electronics industry
- Aerospace
- Defence Technology
- Engineering partner
- Test Labs
- Universities

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LDS Vibration Test Systems Global Field Service

EFFICIENT MAINTENANCE IS IMPORTANT TO PROTECT YOUR INVESTMENT AND MAXIMIZE UPTIME.

- ✓ Installation
- ✓ Approval and Additional Tests
- ✓ Training
- ✓ Preventive Maintenance
- ✓ Maintenance and Troubleshooting
- ✓ (DAkkS certified) Calibrations

Questions?

Thank You

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