VIBRATION DAMPING
WITH LOW-FREQUENCY AIR SPRINGS

FABREEKA®
A STABILUS COMPANY

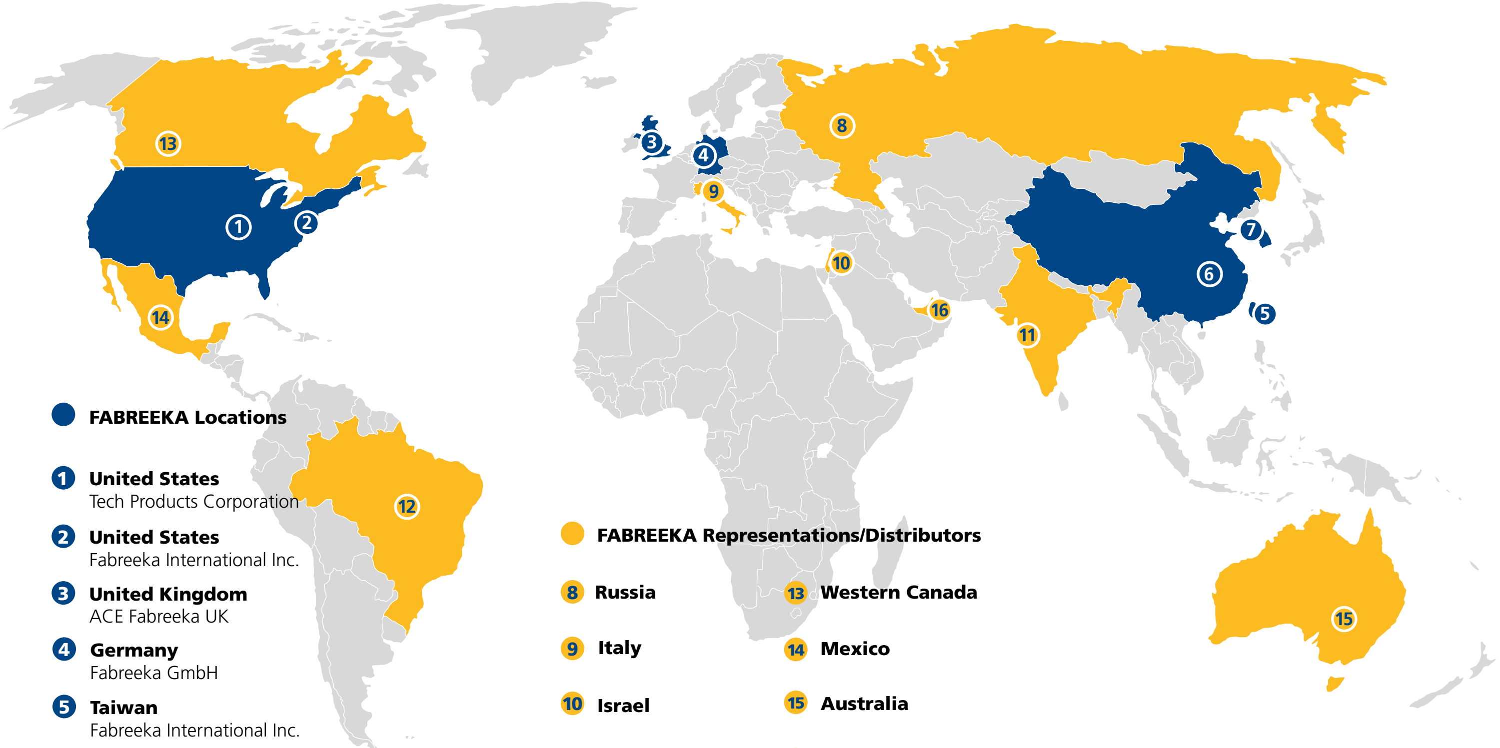
GLOBAL THINKING

Fabreeka® has been leading the world in shock and vibration isolation since 1936. Our facility at Büttelborn near Darmstadt includes our European administration as well as installation, service, quality assurance and warehousing.

Our international presence bears witness to our continued tradition and expertise in the field of vibration and shock isolation. Fabreeka® is more than a manufacturer of isolators – we design bespoke solutions for vibration control challenges for our customers in a variety of fields and industries such as instrumentation and laboratory technology, building services and mechanical engineering. Our in-house and field staff supply on-site vibration measurement and installation services as well as consulting and training.

This brochure details our vibration damping product range. If you have any questions or you are looking for the right solution for your vibration control problem, don't hesitate to contact us for a thorough consultation. Our team at Fabreeka® can be reached by phone, or we can send our capable engineers to your premises or site for a meeting.

Please refer to the last page for our contact details and locations.



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INTRODUCTION

Low-frequency vibration and shock may impact accuracy, repeatability and throughput in precision measuring instruments and positioning and manufacturing equipment. Requirements of accuracy in finished products are constantly increasing, and manufacturing, instrumentation, engineering, and research facilities are placing steadily increasing demands on improved dynamic stability.

Low-frequency and ultra-low vibration isolation aimed at improving manufacturing precision has proved to be an excellent method of achieving a reduction in current vibration exposure. A solution towards setting up an environment that is as vibration-free as possible may be an alternative.

Mechanical vibration and shock are ubiquitous. How much a device is affected by vibration or shock will depend on the strength of the interference combined with the sensitivity of the device.

Vibrations with low seismic intensity may be imperceptible to humans, but they are ubiquitous and will significantly impact sensitive instruments and equipment. Everyday vibration caused by vehicles, pedestrians, forklifts, machinery and HVAC systems further increase the range of devices potentially affected.

Vibration from machines and other sources (including acoustic sources) may carry through supporting structures such as flooring in halls, thus exerting a negative impact on the environment and possibly unwanted vibration exposure.

Equipment and processes affected by mechanical vibration include precision machining tools, coordinate measuring equipment, magnetic resonance imaging (MRI/NMR), laboratory equipment and semiconductor production equipment.

The aim of the vibration isolation is to keep interference vibration under control, and negative effects within tolerable limits. A variety of applications require specifically designed vibration isolators for protection against the effects of vibration and shock.

Vibration carrying from the source into the environment can be reduced by isolators where the equipment requiring isolation is the source of undesirable vibration, as is the case for shock and vibration testing equipment (Fig. 1).

Isolators reduce ambient vibration to recipient equipment such as electron microscopes, coordinate measuring machines and so on that require isolation from interference vibration from the environment (Fig. 2).

Fig. 1

Coordinate measuring systems are sensitive to vibration and shock due to the high measurement accuracy of these instruments. Air springs provide low-frequency vibration isolation to reduce ambient vibration.

Fig. 2

TECHNICAL SPECIFICATIONS
AIR SPRINGS

NATURAL FREQUENCY

Air springs consist of a volume of air (air chamber) sealed by a flexible reinforced diaphragm. The isolator operates by carrying the load using a plunger resting on the diaphragm (Fig. 3).

The effective area of the diaphragm and pressure on the diaphragm determine the load on the isolator. The pressure in the isolator is controlled by a level control valve that controls both the internal pressure and the spring-loaded working height of the isolator.

Fabreeka® Precision Aire air springs always use a two-part air chamber consisting of a spring chamber and a damping chamber. These two chambers are spaced apart from each other and connected by pneumatic tubing (see damping). This dual-chamber structure can be designed in different ways; the isolator's natural frequency depends on the volume V and effective active surface of the diaphragm A_{eff} (Equation 1). Note that the pressure P_{abs} is proportional to load m, resulting in a constant natural frequency even if the load changes.

[Equation 1*]

$$F_n = \frac{1}{2\pi}\left(\frac{n P_{abs} (A_{eff})^2}{Vm}\right)^{\frac{1}{2}}$$

Where: F_n = natural frequency [Hz]

*For operating pressures > 3 bar

n = Ratio of specific heat of gas at constant pressure and constant volume [1.4 for air]
m = Mass of the unsprung weight [kg]
A_{eff} = Effective diaphragm area [m²]
V = Air volume [m³]
P_{abs} = Absolute pressure [bar]

Air spring stiffness mainly depends on the pressure and volume of a given column of air and can be deduced from the relationship between pressure and volume in the gas laws based on the following parameters:

(a) Adiabatic compression
(b) Change in volume low in comparison to the original volume

This yields the following results:

[Equation 2*]

$$C = \frac{n P_{abs} (A_{eff})^2}{V}$$

Where:

C = Stiffness [N/m]
n = Ratio of specific heat of gas = 1,4
P_{abs} = Absolute pressure of the air column [bar]
A_{eff} = Effective diaphragm area [m²]

This expression demonstrates the relationship between the behavior of a mass mounted on an undamped air spring and air volume and effective diaphragm area.

Note that the elastomer in the diaphragm will cause an increase in stiffness at low operating pressures in the air spring, no matter how thin and flexible the diaphragm used. This additional stiffness affects the overall dynamic behavior of the isolator. An air spring's operating pressure should always be higher than 3 bars to reduce this relative increase in stiffness. Valve stiffness can also impact overall stiffness in an air spring element.

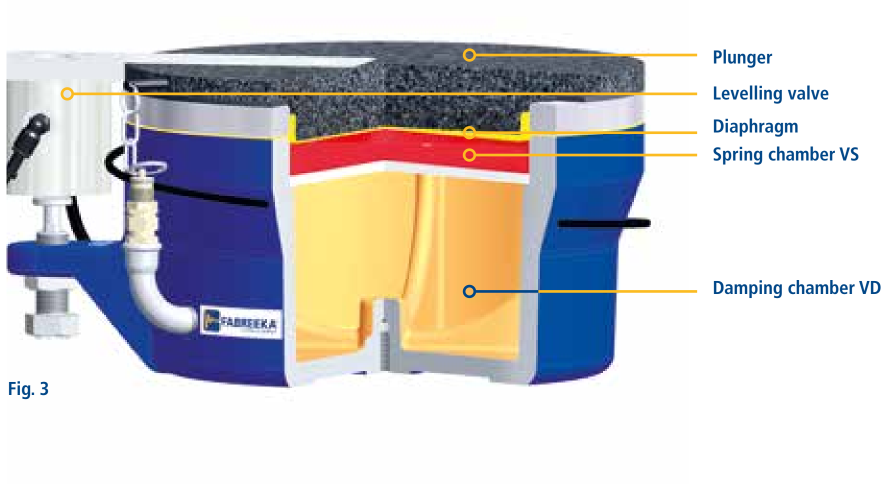


Fig. 3

DAMPING

The aim of damping in an isolator is to reduce or dissipate energy as soon as possible. Another benefit of damping is that it reduces vibration amplitudes at a resonance that would otherwise occur when the excitation frequency matches the isolator's natural frequency.

The ideal isolator has as little damping as possible in its isolation area and as much damping as possible at its natural frequency to hinder resonance. However, damping can also reduce the effect of isolation (Fig. 5).

Vertical damping in a system involves connecting a damping chamber to the spring chamber using pneumatic tubing. Damping behavior can be deduced by examining the energy conversion from air flowing between the chambers and depends on the pneumatic tubing and the volume ratio between the spring and damping chamber.

The damping system must be carefully studied in order to achieve the most effective possible isolation. In spring-mass systems, damping is essential towards limiting vibration caused by movements on a stage or bridge or reducing amplitude of interference vibration at the same frequency as the natural frequency of the isolator. The length and diameter of the damping hose are selected to produce a laminar characteristic in the damper at a given volume ratio, that of the pneumatic tubing, to generate a laminar flow in the damper. This design allows a wide range of damping factors that can be used in various applications.Damping has reached its optimal design where the air flow in the pneumatic tubing is laminar in both heavy and light interference.

Fig. 4

TRANSFER FUNCTION

The natural frequency (dynamic stiffness) and damping properties of an isolator determine the transfer function of the isolator. The relationship between the vibration transferred after isolation to interference vibration is referred to as the transfer function with the basic form shown in Equation 3, where F_d is the interference frequency of the vibration and F_n is the natural frequency of the isolator.

$$T = \frac{1}{\left(\frac{F_d}{F_n}\right)^2 - 1} \qquad \text{[Equation 3]}$$

Taking damping into account changes the equation (Equation 4), where **ξ** represents isolator damping.

$$T = \sqrt{\frac{1 + \left(2 \times \left(\frac{F_d}{F_n}\right) \times \zeta\right)^2}{\left[1 - \frac{(F_d)^2}{(F_n)^2}\right]^2 + \left(2x\,\frac{F_d}{F_n} \times \zeta\right)^2}} \qquad \text{[Equation 4]}$$

The maximum isolator transfer function occurs when resonance interference frequency is at unity to natural frequency ($F_d/F_n = 1$). Equation 5 shows the transfer function at resonance. Note that the magnitude of amplification on the isolator at resonance is a function of the damping of the isolator.

$$T = \frac{1}{2\zeta} \qquad \text{[Equation 5]}$$

Fig. 5 shows a graphical representation of the transfer function of an isolator as a function of frequency ratio. Various percentages of critical damping show the effect of damping in the isolation and amplification range, including maximum amplification at resonance.

Isolation begins at frequencies greater than √2 times the natural frequency of the isolator (reduction of transfer function). The isolating effect improves on increasing frequency ratio. The greatest advantage of an air spring is its low natural frequency and the resulting transfer function at low frequencies.

A reduction of 80 % to 90 % can be achieved below 10 Hz even with heavy damping. Note that the transfer function curve isolation generally flattens out on increasing damping although resonant amplification decreases at around resonance (frequency ratio = 1), the isolation effect decreases in the isolation range (frequency ratio >1). The curves show that natural frequency must be reduced for significant damping in an isolator to achieve the required degree of isolation in the required frequency band.

Theoretical (calculated) transfer function curves do not take into account the influence of vibration amplitude in interference frequencies (Fd). All vibration dampers, including air springs, have different dynamic natural frequencies as a result of interference amplitudes. Very slight vibration amplitudes may cause relatively "stiff" responses in isolators, which therefore have a slightly higher natural frequency. Higher excitation amplitudes cause behavior in isolators that closely follow their theoretical transfer function.

Measured transfer functions should always reflect input amplitude as used in vibration measurement.

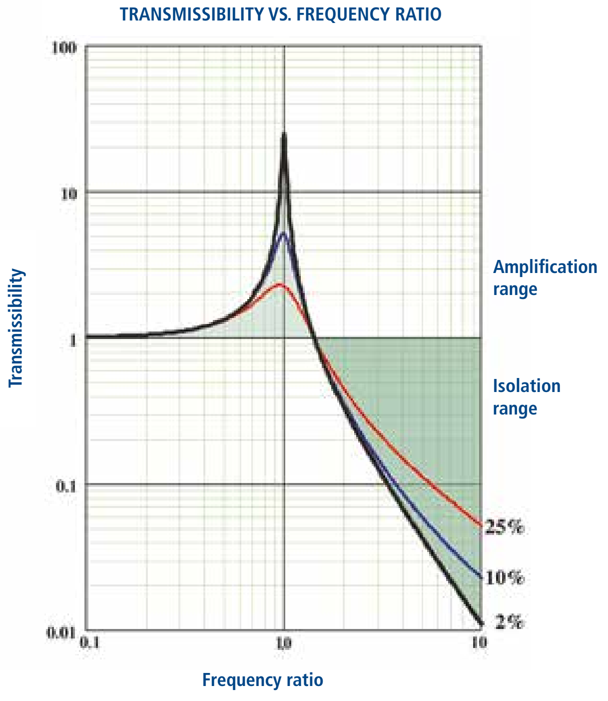


Fig. 5

APPLICATION

The device including bearings, mounting and support structure should be analyzed dynamically for correct arrangement before final selection of an air spring system by analysis or testing. Low structural stiffness may affect the isolation efficiency of a system. The mounting structure of a test device may be considered as a spring as its stiffness may be calculated or determined by testing. A load support structure that is too “soft” causing it to twist or bend at low frequencies near the natural frequency of the isolation system will reduce the system’s isolation efficiency.

A substructure with a dynamic stiffness (depending on application) of at least 10–20 times that of the isolator has proven effective at ensuring the required isolator function. Every support structure (frame, substructure, seismic inertial mass) has its own mass and stiffness. Support structures also have many natural frequencies at which they vibrate or resonate, which are referred to as structural resonances and arise as a function of construction shape, design and material.

As the transfer function curve has shown, air springs make it possible to achieve 80–90 % isolation at frequencies above 10 Hz. This leads to a considerable reduction in vibration transmission at structural resonance as long as the stiffness of the structure is at least ten times the natural frequency of the isolator, which is especially important in steel or aluminum substructures. These metals have very low internal damping when excited to their structural natural frequency, so resonant amplification is high (Fig. 6).

The transfer function curve represents the translational and rotational natural frequencies in the isolator as well as resonances in the foundation and machine base at over 80 Hz.

Damping the support structure to reduce amplification at resonance is a good solution to counteract unacceptable structural resonances. Stiffening the construction may help, as higher structural natural frequencies will not affect overall system performance.

Isolator placement and positioning also play a role in correctly arranging an air spring system. The spring level of the isolators should ideally lie in the same plane as the center of gravity of the test object and its substructure during design; this will ensure that only translational modes (horizontal and vertical) of the isolator take effect. Since all of the isolators move freely in all six axes (translational and rotational), rotational modes are taken into account for isolators placed below the center of gravity (Fig. 6).

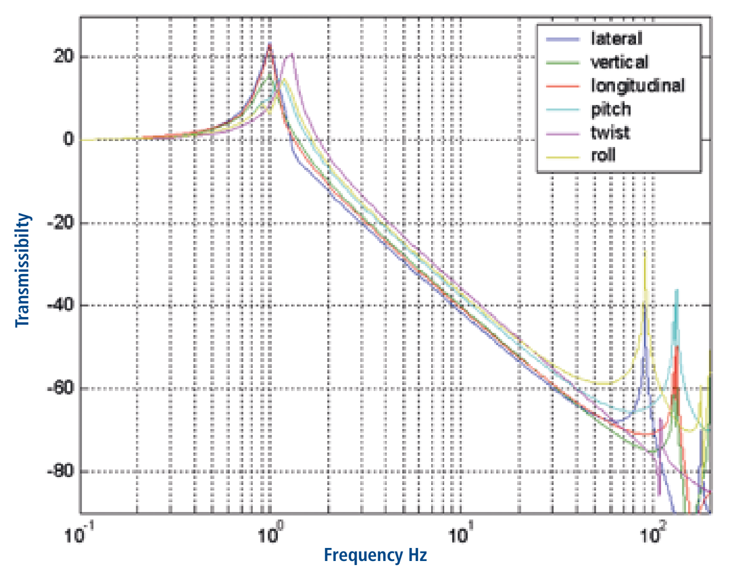


Fig. 6

The transfer function curve closely matches the theoretical curve in Fig. 5 for loads that only vibrate vertically. In addition to linear vibration, rocking and twisting modes are generated when a load swings horizontally and the overall center of gravity lies above the elastic plane. Unacceptable rocking modes may be counteracted by setting the position of the isolator such that the rotational modes are coupled to the translational modes.

A center of gravity too far above the elastic plane of the isolator may lead to instability. The location of the air springs need to be adequate to ensure a stable system. Positioning the isolator within the limits of design rules for a stable system satisfies this requirement (Fig. 7).

Drawing lines to connect the center lines of isolators is industry standard. This creates an area corresponding to the elastic plane of the isolation system. A tetrahedron is designed with the base area at this level; its height corresponds to a third of the shortest side on the base. If the projected center of gravity at this level lies within the triangle, the system should be stable with optimal isolation and damping properties.

Note: The relative position or distance between the isolators in all axes of rotation plays the greatest role in designing a stable system. Isolator design is another key factor in stability. Damping rate, effective volume and valve flow are potential variables. Our Fabreeka® engineers will provide expert recommendations for your application.

The system will be vulnerable to instability if the center of gravity lies outside of the triangle. It may be possible in some cases to change the properties of the isolators on site by using additional damping or level control valves with a lower loop amplification. However, additional damping will increase the stiffness in the system somewhat, and therefore also the vertical natural frequency of the isolators.

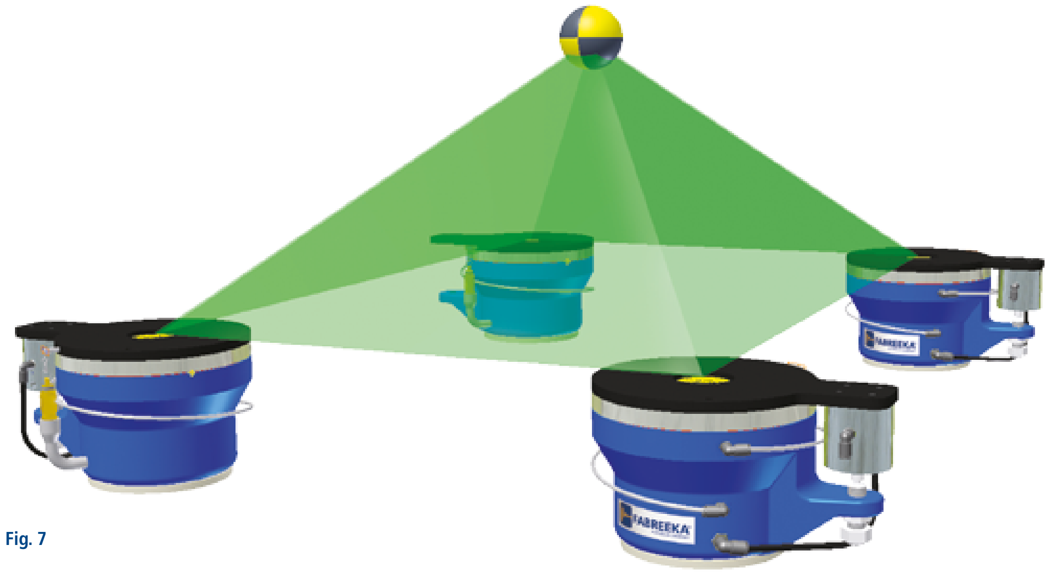


Fig. 7

DESIGN SERVICE

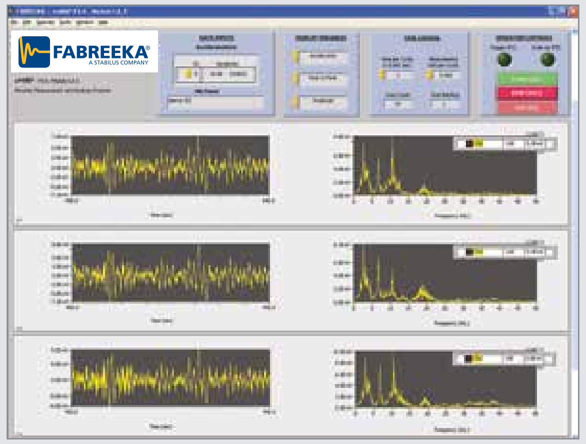


Fig. 8

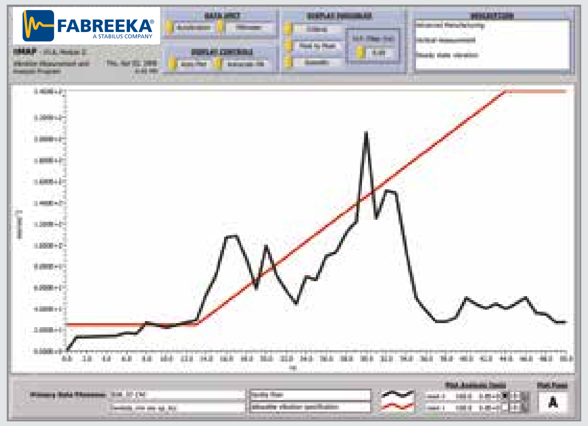


Fig. 9

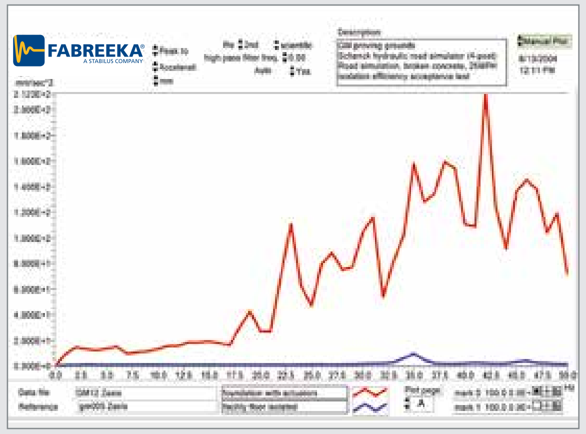


Fig. 10

VIBRATION MEASUREMENT AND ANALYSIS

Low-frequency vibration and heavy shock may impact accuracy, repeatability and throughput in precision machines and equipment. Most precision machine tool and coordinate measuring machine manufacturers have set vibration tolerances in their machines' specifications. We at Fabreeka® use high-precision measuring instruments for measuring vibration amplitude and frequency as a basis for appropriate vibration isolation recommendations.

Our engineers perform vibration analysis on a regular basis the world over, where measurement requirements can vary widely from one case to the next.

Vibration measurement on site

Fig. 8 (top left): Vibration measurement software records amplitude and frequency data for analysis. Every Fabreeka® branch will perform vibration measurements at your premises, wherever you are in the world.

Fig. 9 (center left): Comparing vibration amplitudes with the manufacturer's specifications shows the isolation required at frequencies where the vibration amplitudes measured are higher than the limit for the device in question.

Fig. 10 (bottom left): Our engineers also perform acceptance tests on damping systems following installation. These acceptance tests document vibration amplitudes after isolation system installation.

DYNAMIC ANALYSIS AND FINITE-ELEMENT ANALYSIS

As already mentioned in the technical description, the dynamic behavior of supporting structures is an important point of consideration in isolation solutions for an entire system.

Examining waveforms by varying stiffness, mass and damping in a vibrating system is important in correctly adjusting vibration behavior at key points of the system.

Finite element calculation defines and models mode forms and resonant frequencies in an excited system, as well as describing the effect of an isolation system on mechanically and environmentally induced vibration load.

Waveforms (dynamic stiffness in every direction in space) can be used to identify the physical direction of each frequency component and each deformation such as bending or twisting. Waveforms in a construction basically show the degree of relative stiffness at various points in that construction (Fig. 11 and 13).

The proposed construction of a foundation or supporting structure requires a structural design that meets the static and dynamic requirements of this construction. Deformation under static loads or dynamic forces or actions need to remain within acceptable limits.

This design approach requires modelling to allow predictions as to the subsequent vibration behavior of the support structure, thus largely eliminating any sources of error.

Stiffness calculations in a support structure yield the static and dynamic behavior along with stress concentration points. Stress depends on the geometry of the support structure and the distribution of loads and forces acting on them. Strength analysis shows the magnitude of the stress caused by static and dynamic loads (Fig. 12).

Fig. 11: GG25 measuring plate

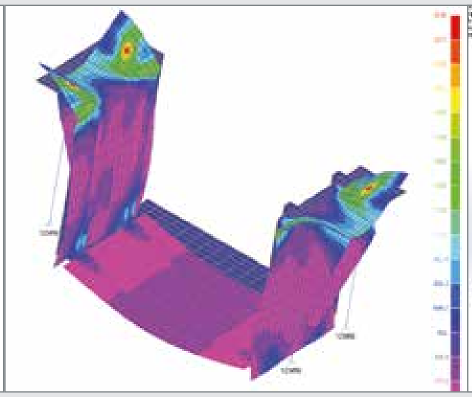


Fig. 12: Von Mises stress diagram

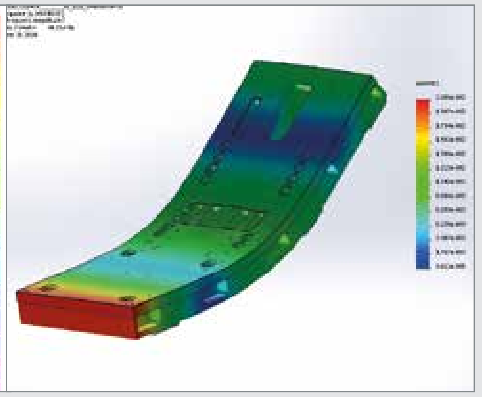


Fig. 13: First bending frequency from the GG25 measuring plate

PRECISION AIRE™ AIR SPRING ELEMENTS
WITH AUTOMATIC LEVELLING (PAL)

Air spring elements in the PAL series provide superior low-frequency vibration isolation for measurement equipment, electron microscopes, MRI scanners, coordinate measuring machines and precision manufacturing equipment.

Precision Aire™ levelling PAL air spring systems from Fabreeka® use automatic levelling air springs. These isolators are ideally suited for conditions requiring both height control and vibration isolation. Fabreeka® PAL isolators meet all of the essential requirements for instrumentation, electron microscopes, measuring stations and precision manufacturing machines.

PAL AIR SPRING DESCRIPTION

Standard Fabreeka® PAL isolators have natural frequencies from 1.5 to 2.7 Hz, depending on isolator height. Bespoke isolators optionally have even lower natural frequencies (down to 0.5 Hz).

A complete Fabreeka® PAL system consists of at least three main master isolators for three-point level control. Each isolator has an integrated level-control valve that functions as a load sensor and height control. Any number of additional slave isolators may be added to support the total device weight.

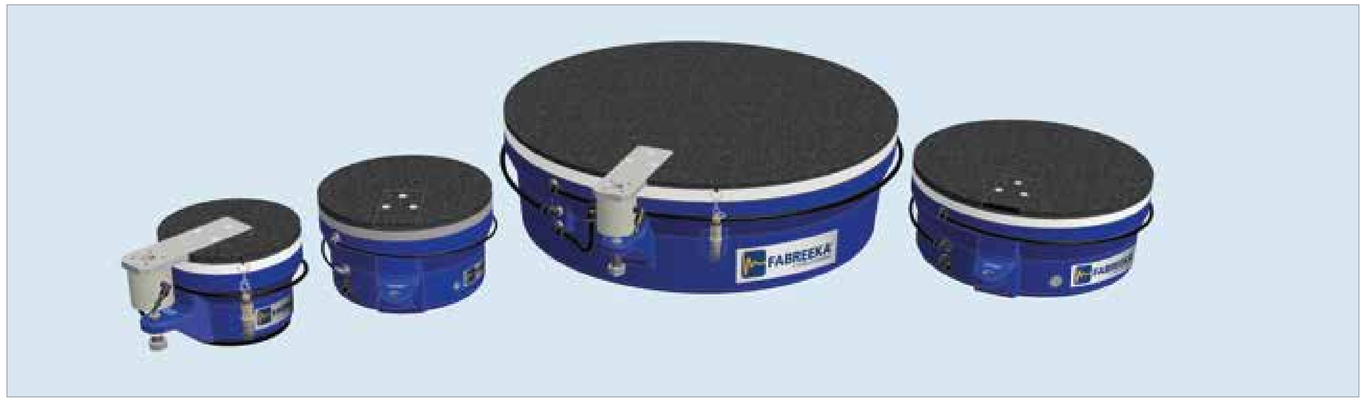
Each system comes with a control unit, automatic level control valves, pneumatic tubing and all of the other pneumatic accessories necessary for complete system installation.

PAL AIR SPRING FUNCTION

PAL air springs respond quickly to changes in load and center of gravity. Deviations from positions once preset are automatically readjusted.

Air spring system performance is always a compromise between natural frequency (isolation), level control valve restoring accuracy and settling time.

Settling time is the time it takes for the isolation system to achieve a preset reference value after a predefined instance of interference. The interference may be caused by the environment or forces from the machine itself, such as moving the measuring bridge on a measuring machine.



PAL air spring elements

Settling time is minimal at optimum damping and corresponding valve flow. Long settling times are unacceptable in air springs, as they may lead to repeatability errors and part throughput losses in precision measuring instruments and positioning machines.

We at Fabreeka® supply a variety of levelling valves depending on application. Key variables in designing an acceptable solution include valve flow, stiffness and accuracy characteristics. Restoring values at an accuracy of +/– 0.15 mm or +/– 0.025 mm are available. Valve flow and stiffness are selected as based on air spring and damper design.

LEVEL CONTROL VALVES

Level control valves are available in various types. Our Fabreeka® levelling valves meet all application requirements at accuracy levels of +/– 0.15 mm to +/– 0.025 mm and varying flow rates. Valve stiffness, flow rate and accuracy play a key role in optimizing settling time and isolation efficiency.

A lever arm affects the accuracy of valves, but also increases the setting range.

Overview of valves

PAL36 with valve

PALV20-1

PALV5-5

PALV1-2

STANDARD AIR SPRINGS

ISOLATION FEATURES AND SPECIFICATIONS

Bertrandt vibration foundation

Wenzel coordinate measuring machine

Air spring for test bench

Measuring machine in detail

AOI measuring machine

TECHNICAL SPECIFICATIONS

Natural frequency	(–6)	(–12)
Vertical	2.5 – 2.7 Hz	1.5 – 1.7 Hz
Horizontal	2.0 – 4.5 Hz	2.0 – 4.5 Hz

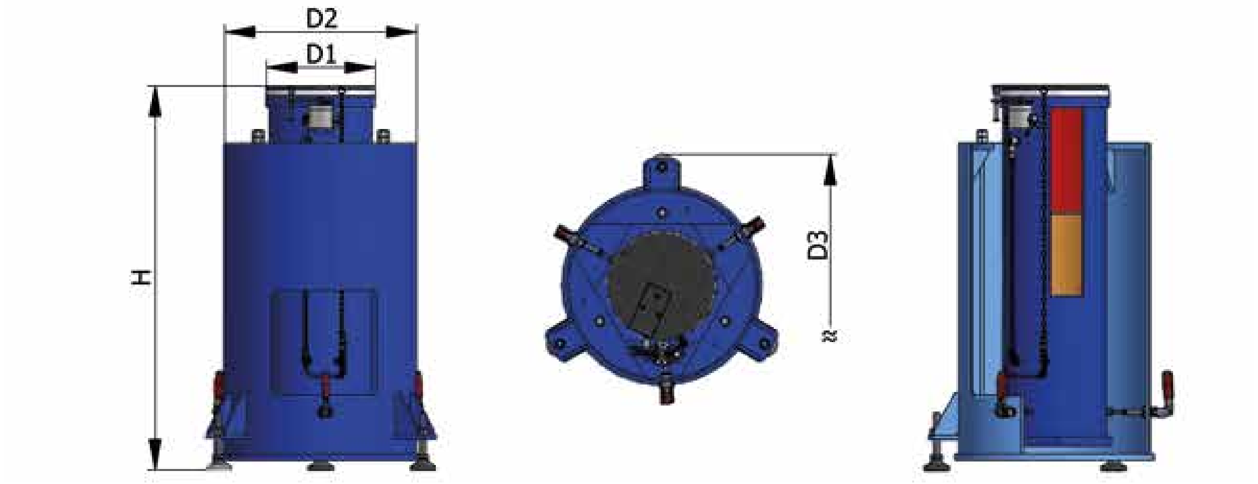
Damping		
Vertical (adjustable)	6 % – 20 %	6 % – 20 %
Horizontal	3 % – 6 %	3 % – 6 %

Type	D1	D2	H unpressurized	H max. rebounded	L	Design load at 4.5 bar	Max. load at 10 bar
	mm	mm	mm	mm	mm	kg	kg
PAL9-6	130	130	153	163	200	248	550
PAL15-6	165	165	153	163	235	428	950
PAL 21-6	200	160	153	163	270	608	1350
PAL21-12	200	200	305	315	270	608	1360
PAL36-6	220	190	153	163	290	1035	2300
PAL36-12	220	220	305	315	290	1035	2300
PAL55-6	260	230	153	163	330	1606	3570
PAL55-12	260	260	305	315	330	1606	3570
PAL75-6	300	265	153	163	370	2180	4850
PAL75-12	300	285	305	315	370	2180	4850
PAL133-6	380	350	153	163	450	3900	8670
PAL133-12	380	380	305	315	450	3900	8670
PAL255-6	530	470	153	165	600	7425	16500
PAL255-12	530	460	305	317	600	7425	16500
PAL416-8	640	585	203	215	710	11700	26000
PAL750-6	850	817	153	165	920	21950	48750

SPECIAL AIR SPRINGS
PENDULUM AIR SPRINGS

TECHNICAL SPECIFICATIONS

Natural frequency	(–15/-18/–19)	(–36)	(–52/–60)	Damping			
Vertical	1.3 – 1.5 Hz	0.9 – 1.0 Hz	0.7 – 0.9 Hz	Vertical	6 % – 20 %	6 % – 20 %	6 % – 20 %
Horizontal	1.3 – 1.5 Hz	0.6 – 0.7 Hz	0.4 – 0.5 Hz	Horizontal	3 % – 6 %	3 % – 6 %	3 % – 6 %



Type	D1	D2	H unpressurized	H max. rebounded	D3	Design load at 4.5 bar	Max. load at 10 bar
	mm	mm	mm	mm	mm	kg	kg
PAL21-15P	200	279	381	391	N/A	608	1350
PAL36-18P	220	220	457	467	N/A	1035	2300
PAL55-15P	260	470	381	391	603	1606	3570
PAL55-52P	260	470	1321	1331	603	1606	3570
PAL75-19P	295	378	483	493	N/A	2180	4850
PAL133-36P	380	622	914	924	800	3900	8670
PAL133-60P	380	622	1524	1534	800	3900	8670
PAL255-36P	530	775	914	926	953	7425	16500
PAL255-60P	530	775	1524	1536	953	7425	16500
PAL416-36P	640	927	914	926	1143	11700	26000
PAL416-60P	640	927	1524	1536	1143	11700	26000
PAL750-36P	850	1140	914	926	1356	21950	48750

Measuring machine foundation

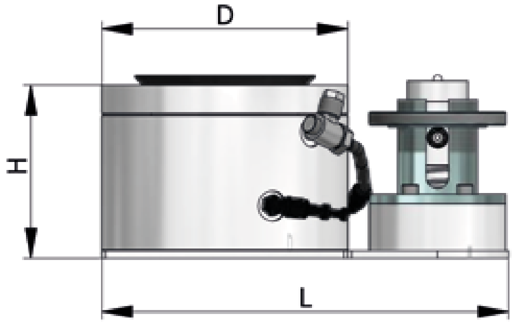
Nano 2000, Ilmenau Technical University

Francis Crick, London

Space telescope bearing

BESPOKE PRODUCTS AND ISOLATORS

Air springs for OEM and special applications are available, and integrate easily into existing machine designs. Exhaust air from level control valves is drained off and isolators are made of cleanroom-compatible materials, then cleaned and packaged for cleanroom applications. The air springs can also be manufactured using non-magnetic materials.



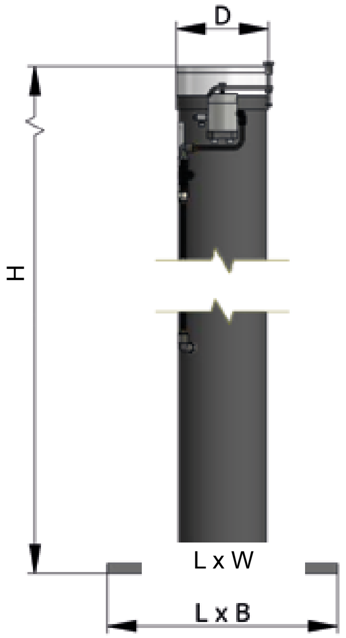
Type	D	H unpressurized	H max. rebounded	L	Design load at 4.5 bar	Max. load at 10 bar
	mm	mm	mm	mm	kg	kg
PAL3-2.5	80	64	70	157	85	190
PAL5.5-2.5	100	64	70	177	158	350
PAL9-4	130	94	98	207	248	550

GIMBAL AIR SPRINGS

Gimbal air springs offer low natural frequencies in vertical and horizontal direction, and are used in particular for vibration isolation in very sensitive equipment such as NMR spectroscopes and high-resolution scanning electron microscopes.

Gimbal air springs are made of non-magnetic materials due to the application areas they are used in and natural frequencies in the bearings between 0.8 Hz and 1.7 Hz (vertical and horizontal) can be achieved depending on size.

Bespoke solutions from standard materials are also available.



Type	D	H unpressurized	H max. rebounded	L x W	Design load at 4.5 bar	Max. load at 10 bar
	mm	mm	mm	mm	kg	kg
PAL9-18G	140	457	467	300 x 350	248	550
PAL9-42G	140	1049	1059	300 x 350	248	550
PAL18-18G	180	457	467	300 x 350	520	1155
PAL18-50G	180	1270	1280	300 x 350	520	1155
PAL22-18G	190	457	467	300 x 350	640	1420
PAL28-18G	205	457	467	300 x 350	810	1800
PAL36-18G	220	457	467	300 x 350	1035	2300

Deviating heights and base plates as well as non-magnetic design to customer specification

SUSPENDED PLATFORMS AND MACHINE FRAMES


Shaker bearing


Isolated lithograph machine


Foundation for Nano 2000

Suspended platforms and bespoke machine frames improve stability in vibration-isolated, level-controlled air spring systems while also decreasing the relative height of the isolated device's center of gravity.

Location and placement play a key role in designing air spring systems under the devices or equipment to be isolated. The elastic plane of the isolator should be placed close to the center of gravity of the device and its support structure in system design.

Rotating and rocking vibration arises when loads swing horizontally and the center of gravity is above the elastic plane of the isolators. Stability may be negatively affected if the center of gravity is too far above the elastic plane of the isolator. The air spring location must meet the requirements of a stable system.

A suspended isolation system is used to bring the elastic plane of the isolators closer to the overall center of gravity and reduce rocking vibration (illustrated below).

Apart from that, a suspended platform is used if the substructure of a machine cannot be modified to accommodate the air springs, requiring a rigid support frame.

The static and dynamic design of the suspension frame plays a major role. Stress and deformation (bending) under the influence of the weight of a machine or device as well as dynamic stiffness (structural resonances) are part of a successful solution using PAL or PLM air springs.


Suspended platform

BELLOWS CYLINDER AIR SPRINGS

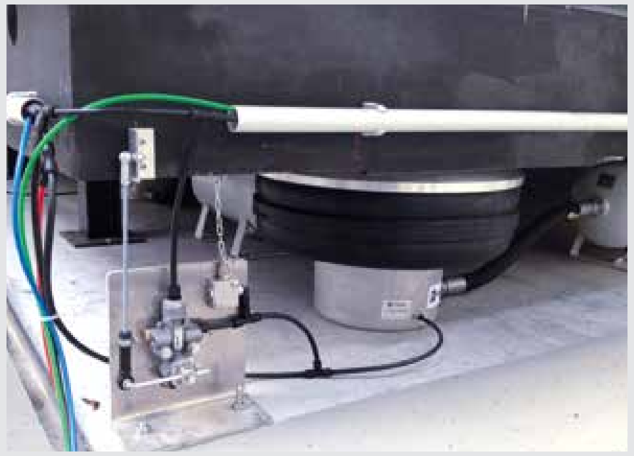
Bellows cylinder air springs provide low frequency vibration isolation for engine test benches, large reaction masses and applications requiring high dynamic vibration amplitudes and lifting heights.

Bellows cylinder air springs may have vertical and horizontal natural frequencies from 0.7 Hz, depending on operating height, and bellows cylinder design (single, double or bellows). Horizontal spring rate (stiffness) and stability also depend on operating height, so each air cushion type has an ideal operating height. Lower vertical natural frequencies are achievable by increasing air volume, for example by using an auxiliary tank.

Large usable stroke range is a key feature in bellows cylinders, with stroke ranges from 50 to 75 mm possible depending on bellow design – ideal for applications prone to large dynamic deflections.

Both bellows cylinders and diaphragm air springs have very low damping (3 % to 4 %), unless damping volume is coupled to air spring volume. Most designs require damping at 10 % to 15 % depending on application as well as isolation and settling time specifications.

A complete isolation system will consist of at least three controlled air springs for three-point level control. Each isolator has an integrated level control valve that functions as a load and position sensor. Any number of additional air springs can be added to carry larger loads. Each system comes with a control panel, automatic height control valves, pneumatic tubing and all of the pneumatic accessories necessary for complete system installation.


SAF Holland test bench


SAF Holland test bench plate


BMW test bench bearing

FABREEKA PRECISION AIRE BELTED BELLOWS

RLA TYPE RANGE

For effective vibration and shock isolation in:

All kinds of dynamic testing equipment such as:

- Automotive test benches (such as road simulation, MAST, Hexapod, hydropulse units)
- Earthquake simulation equipment
- Wind power test benches
- Railway test benches
- Aircraft component testing systems
- Material testing stations
  - Emergency generators, with or without foundations
  - Shredders
  - All other kinds of large foundation

Additional volume

RLA AIR SPRING DESCRIPTION

- Load range of 3,500 kg to 31,500 kg depending on design size
- Virtually constant load-independent vertical natural frequency over a wide load range
- Low vertical natural frequency to below 0.7 Hz (optionally with additional volume)
- Switchable vertical natural frequency (optionally with additional volume)
- Progressive vertical stiffness curve
- Horizontal natural frequency adaptable by design in a wide range to match a particular application
- Low-noise version (sound hardness at E2 4.45 kg/m²/s) for best possible solid-bound soundproofing
- niveautone® design using mechanical-pneumatic Triflow® proportional control valves
- Optional pneumatic double chamber principle for effective visco-pneumatic system damping
- Effective damping behavior by optional adjustable laminar flow damping
- Optional internal viscous safety damping for Lehr's damping ratios up to 0.25

TECHNICAL DESCRIPTION

RLA air springs are calculated and prepared following pressure vessel regulations DGRL 2014/68/EU.

Production and assembly processes in regards to safety, testing and quality control are in accordance with Machinery Directive 2006/42/EC.

RLA air springs are equipped with safety valves for overpressure and over travel limitation functions as standard.

Levelling

PALV20 mechanical-pneumatic closed loop Triflow® proportional level control series with a restoring accuracy of +/- 0.25 mm, flow behavior adapted to air spring size and application, combined switching proportional flow function, blocking function with purely static load, optional electro-pneumatic PA DEL levelling with contact-free sensors.

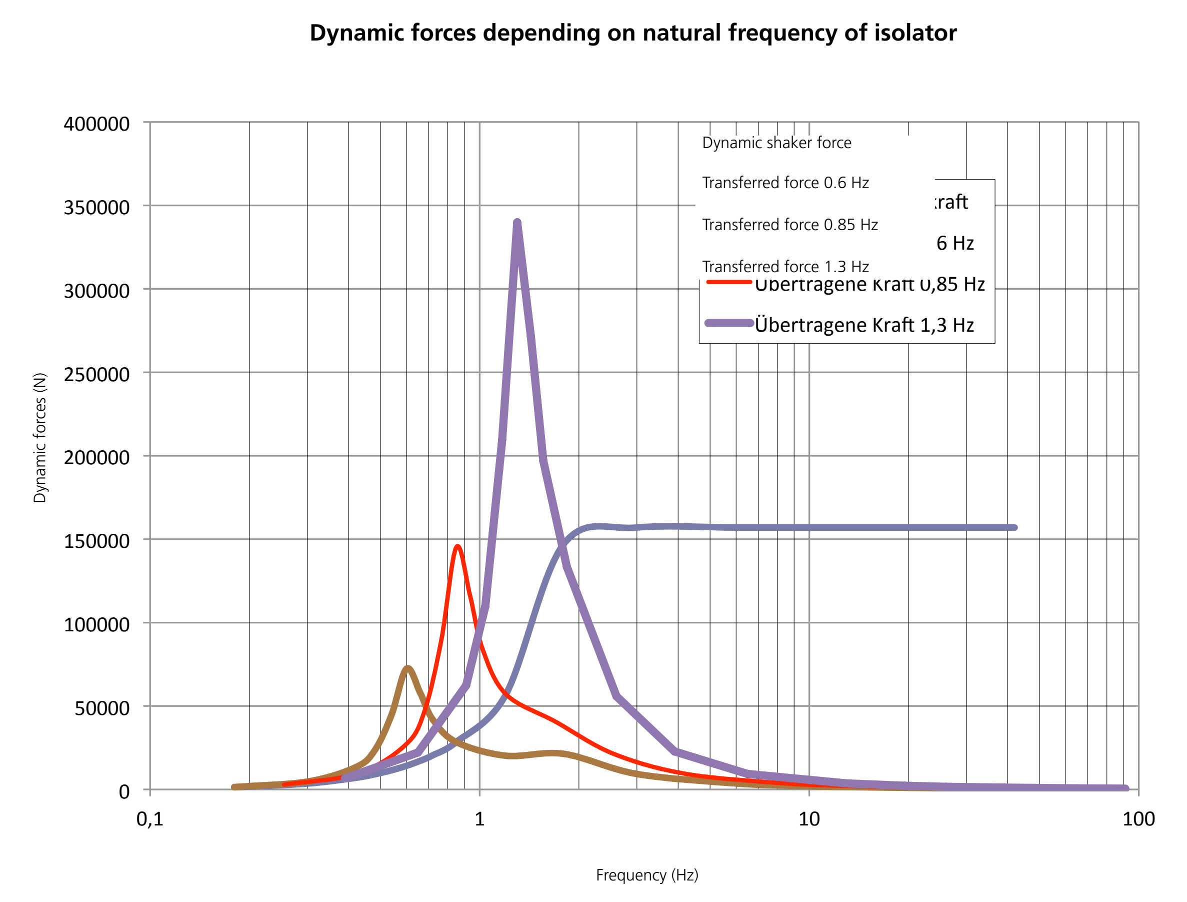
Air spring with belted bellow design

- Fabric-reinforced oil-resistant elastomer diaphragm
- Resistant to most oils, alkaline or acidic cleaning agents, dust, dirt, ozone, UV radiation, general weathering
- Temperature range from -30 to +50°C, optionally up to +70°C
- Air chamber pressure vessel in approved cast aluminum alloy in accordance with Machine Directive 2006/42/EC
- Documented compressive strength of container using finite-element analysis
- Piston plate in plastic oil-resistant material to prevent galvanic corrosion, or cast aluminum alloy
- Optional powder coating in RAL 5002 for corrosion protection on air chamber casing

RLA650 TU Graz

DYNAMIC FORCE TRANSFER USING AN AIR SPRING WITH BELTED BELLOWS

The graph below shows how the natural frequency of a vibration damping system affects dynamic forces transferred to the environment. A reduction in natural frequency of 1.3 Hz (the lowest achievable using an ordinary bellows cylinder) to 0.6 Hz lowers peak values of forces transmitted by a factor of 5 (350 kN ⟶ 70 kN).



FABREEKA PRECISION AIRE BELTED BELLOWS
REFERENCE OBJECT: BMW AG, MUNICH

Foundation isolation using RLA 390-14 type belted bellows

Formwork on the support foundation

Support foundation rebar

Fixing plate

RLA isolation with RLA air springs on supports (with levelling)

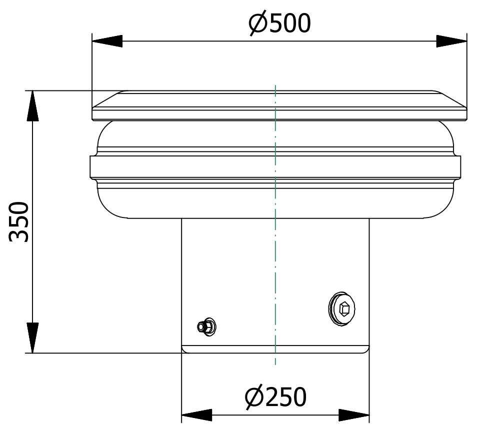
Foundation

FABREEKA PRECISION AIRE BELTED BELLOWS
TYPE RLA180-14

Options:

Standard without additional volume or additional damping

- ED with an adjustable pneumatic damping, D_{max} = 0.15
- VD with viscous safety damping, D = 0.15 to 0.25
- LF with additional volume and very low natural frequency (up to 0.6 Hz vertical)

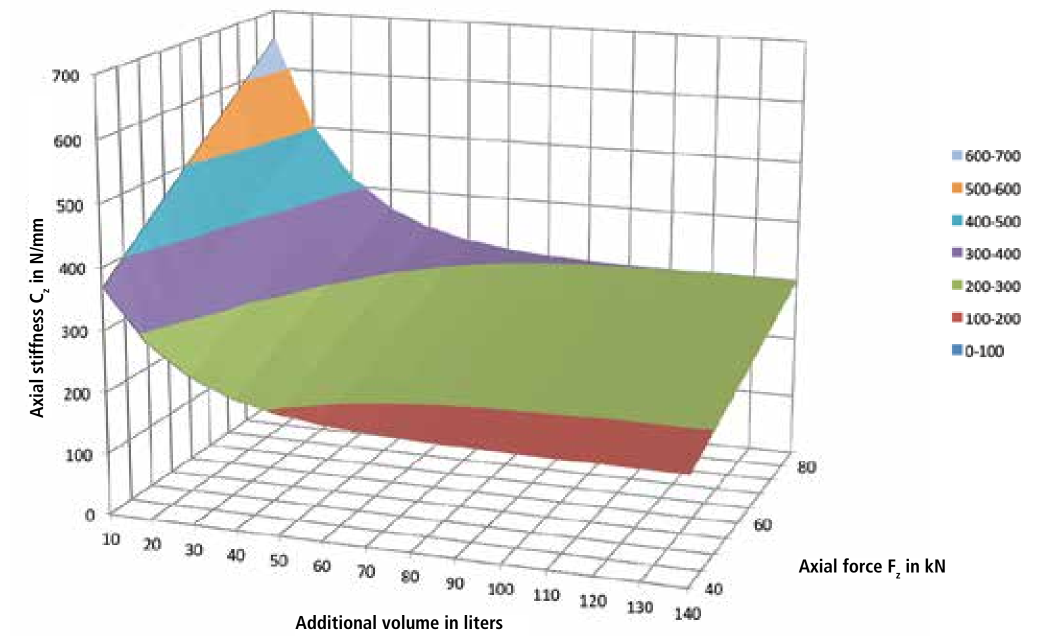


1. Load-bearing capacity to pressure curve					
Pressure [bar]	2	3	4	5	6
Fz [kN]	22.8	34.7	46.6	58.6	70.1
Diameter [mm]	496.3	496.6	496.7	496.7	496.7

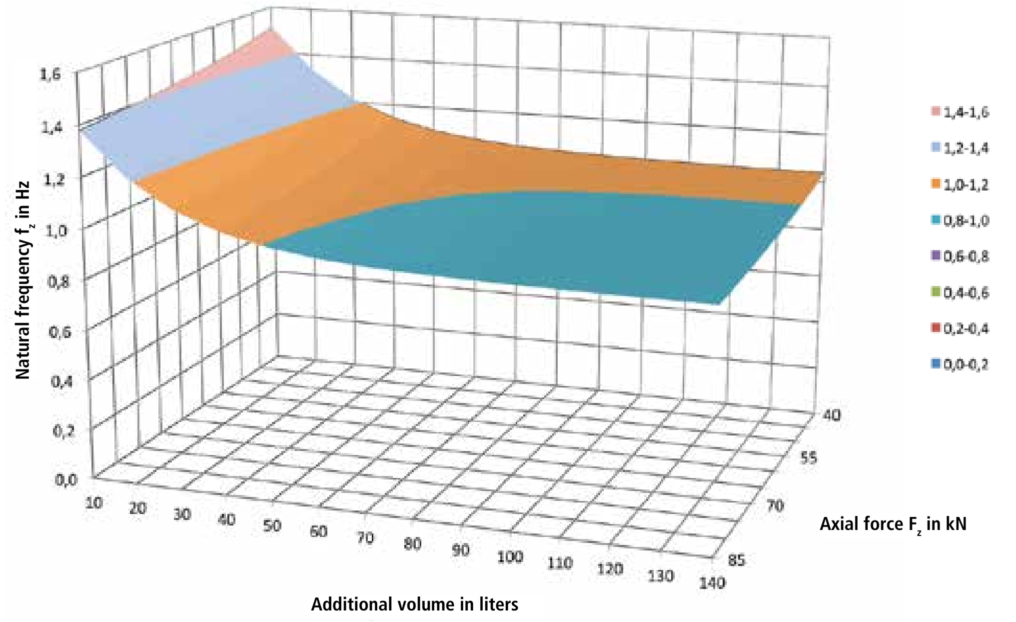
2. Quasi-static axial (15 mm prestressing at 70 kN / 0 L. 10 min waiting time)					
		Axial stiffness [N/mm]		Natural frequency [Hz]	
Axial force Fz [kN]	additional volume	70	46.5	70	46.5
Axial Cz ± 10	Vzu = 40	315	234	1.06	1.12
Axial Cz ± 10	Vzu = 20	431	318	1.24	1.3
Axial Cz ± 10	Vzu = 0	541	413	1.40	1.50

3. Quasi-static radial (10 x 60 mm prestressing, 15 min waiting time)					
		Lateral stiffness [N/mm]		Natural frequency [Hz]	
Fz [kN]		70	46.5	70	46.5
Radial Cz ± 10		218	183	0.88	0.99

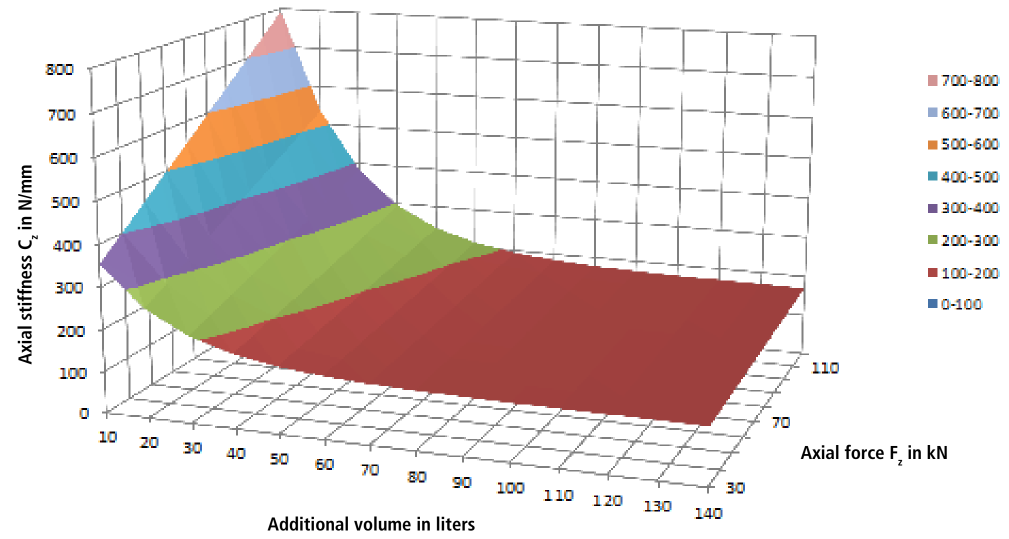
RLA180: Axial stiffness C_z over additional volume and axial force



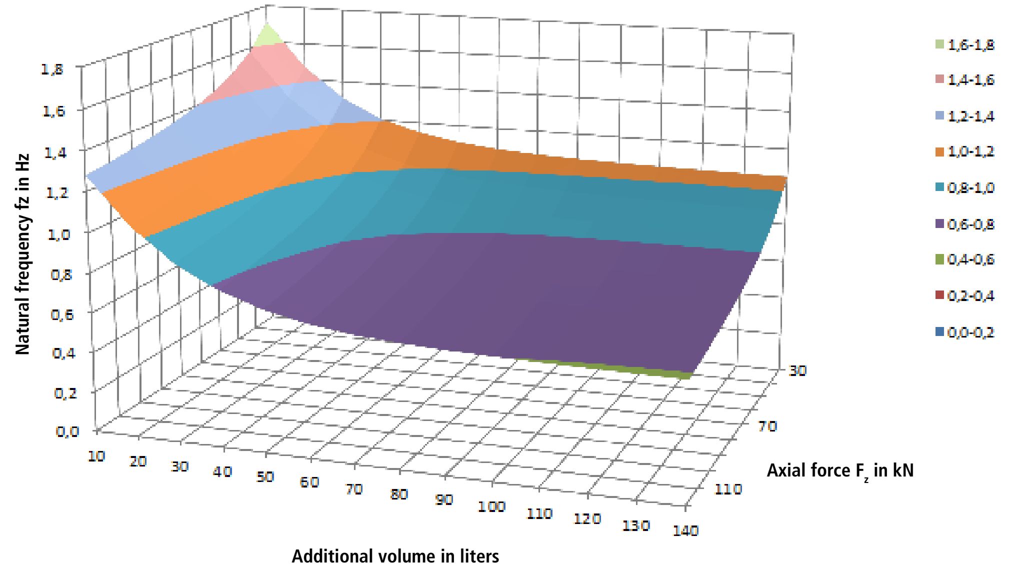
RLA180: Natural frequency f_z over additional volume and axial force



FABREEKA PRECISION AIRE
BELTED BELLOWS
TYPE RLA260-14



RLA260:
Axial stiffness C_z over additional volume and axial force

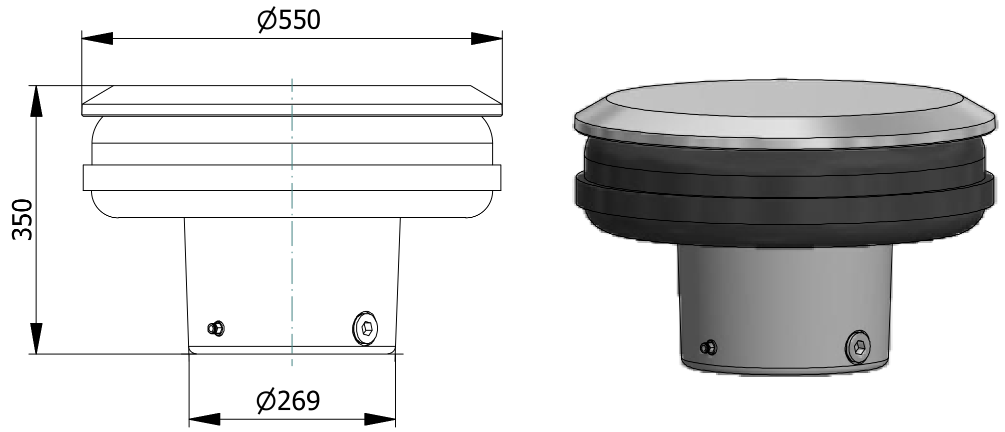


RLA260:
Natural frequency f_z over additional volume and axial force

Options:

Standard without additional volume or additional damping

- ED with an adjustable pneumatic damping, $D_{max} = 0.15$
- VD with viscous safety damping, D = 0.15 to 0.25
- LF with additional volume and very low natural frequency (up to 0.6 Hz vertical)



1. Load-bearing capacity to pressure curve					
Pressure [bar]	2	3	4	5	6
Fz [kN]	33.5	50.3	66.9	83.8	100.8
Diameter [mm]	549.4	549.5	549.6	549.7	549.8

2. Quasi-static axial (15 mm prestressing at 101 kN / 0 L., 10 min waiting time)					
		Axial stiffness [N/mm]		Natural frequency [Hz]	
Axial force Fz [kN]	additional volume	100.8	66.9	100.8	66.9
Axial Cz ± 10	Vzu = 40	224	192	0.74	0.84
Axial Cz ± 10	Vzu = 20	475	371	1.08	1.17
Axial Cz ± 10	Vzu = 0	719	595	1.35	1.50

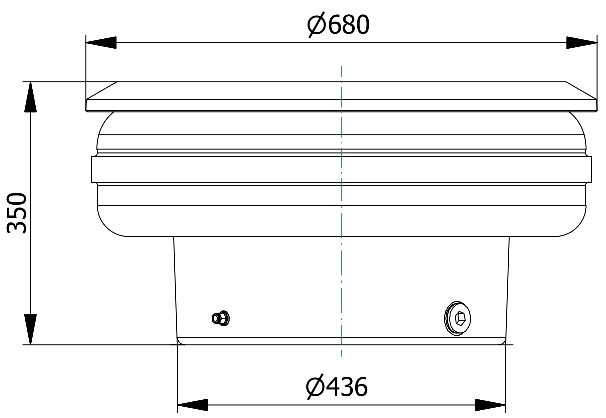
3. Quasi-static radial (10 x 60 mm prestressing, 15 min waiting time)					
		Axial stiffness [N/mm]		Natural frequency [Hz]	
Fz [kN]		100.8	66.9	100.8	66.9
Radial Cz ± 10		402	347	1	1.14

FABREEKA PRECISION AIRE
BELTED BELLOWS
TYPE RLA390-14

Options:

Standard without additional volume or additional damping

- ED with an adjustable pneumatic damping, $D_{max} = 0.15$
- VD with viscous safety damping, D = 0.15 to 0.25
- LF with additional volume and very low natural frequency (up to 0.6 Hz vertical)

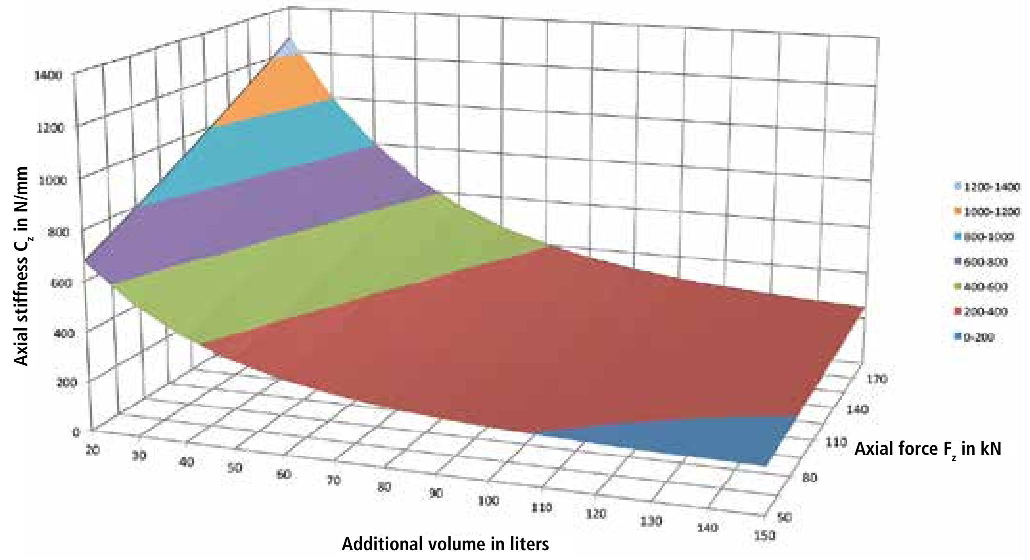


1. Load-bearing capacity to pressure curve					
Pressure [bar]	3	4	5	6	7
Fz [kN]	75.1	99.9	124.6	149.7	174.6
Diameter [mm]	674.2	674.2	674.3	674.4	674.5

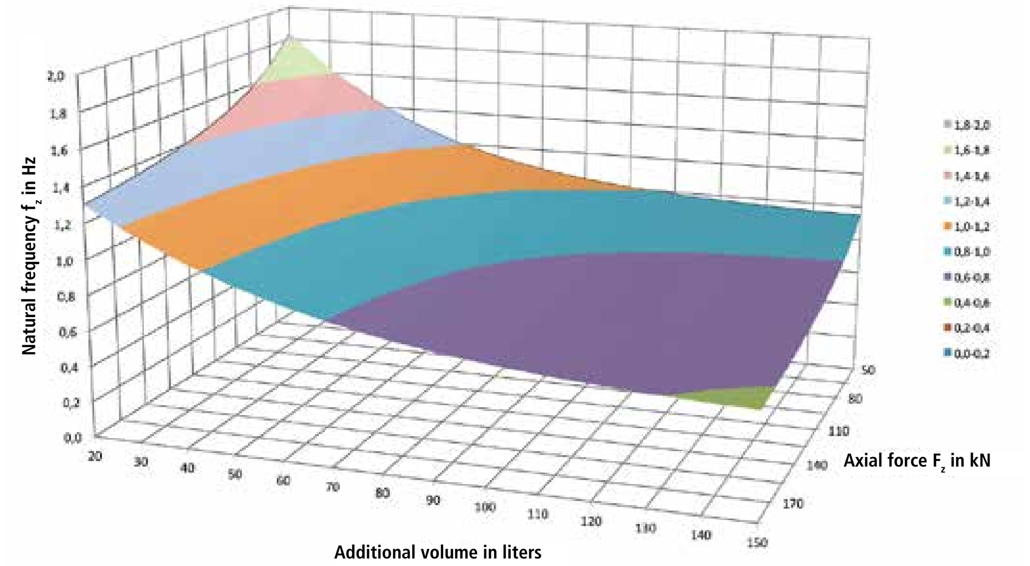
2. Quasi-static axial (15 mm prestressing at 160 kN / 0 L., 10 min waiting time)					
		Axial stiffness [N/mm]		Natural frequency [Hz]	
Axial force Fz [kN]	additional volume	160	114	160	114
Axial Cz ± 10	Vzu = 40	299.7	256.2	0.68	0.75
Axial Cz ± 10	Vzu = 20	722.2	585.8	1.06	1.13
Axial Cz ± 10	Vzu = 0	908	760	1.20	1.30

3. Quasi-static radial (10 x 60 mm prestressing, 15 min waiting time)					
		Axial stiffness [N/mm]		Natural frequency [Hz]	
Fz [kN]		160	114	160	114
Radial Cz ± 10		569.2	545.8	0.94	1.09

RLA 390:
Axial stiffness C_z over additional volume and axial force

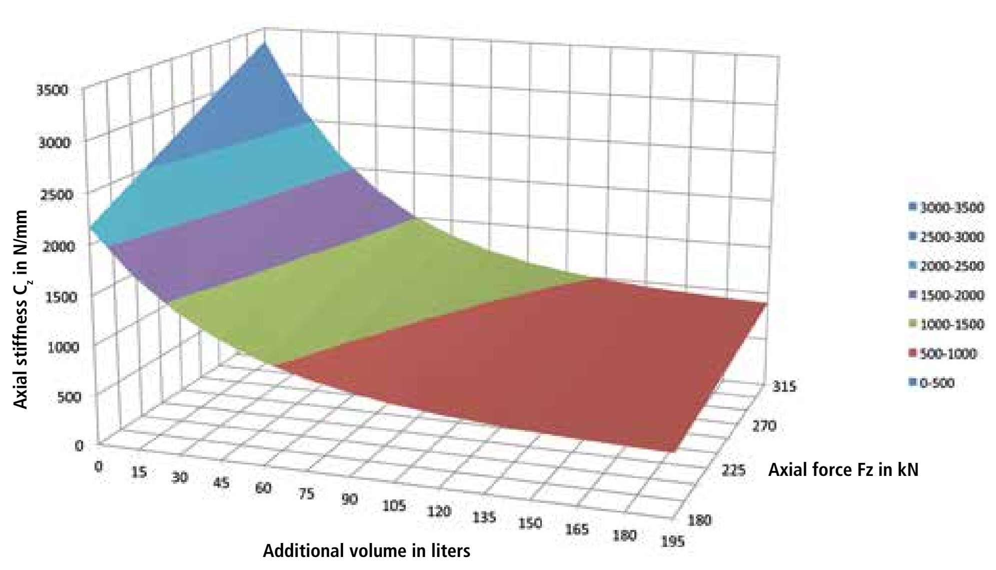


RLA 390:
Natural frequency f_z over additional volume and axial force

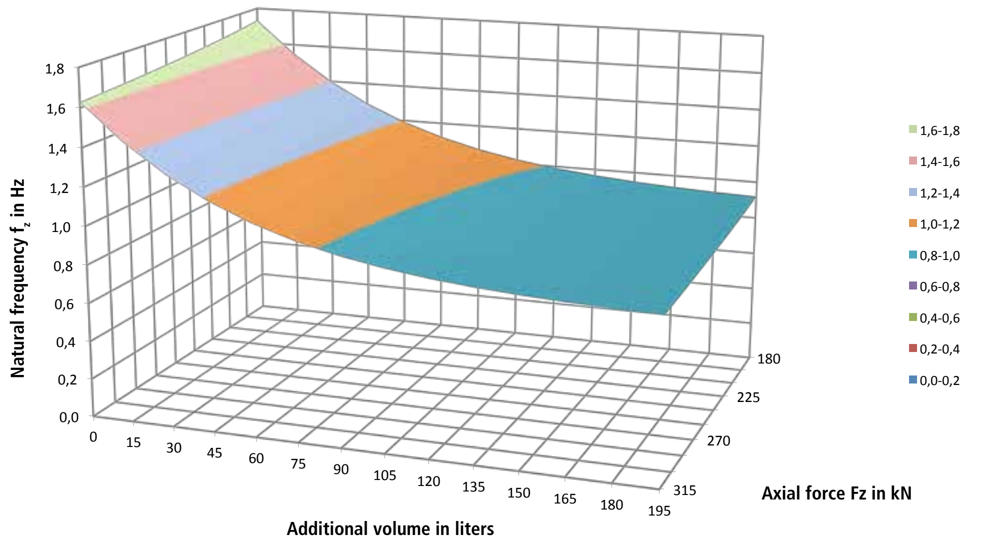


FABREEKA PRECISION AIRE
BELTED BELLOWS
TYPE RLA650-14

RLA650: Axial stiffness C_z over additional volume and axial force



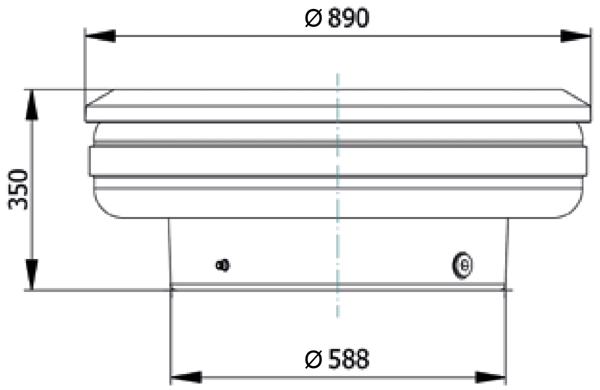
RLA650: Natural frequency f_z over additional volume and axial force



Options:

Standard without additional volume or additional damping

- ED with an adjustable pneumatic damping, $D_{max} = 0.15$
- VD with viscous safety damping, D = 0.15 to 0.25
- LF with additional volume and very low natural frequency (up to 0.83 Hz vertical)



1. Load-bearing capacity to pressure curve

Pressure [bar]	3	4	5	6	7
Fz [kN]	139	184,5	229	274,5	319,5
Diameter [mm]	875	875	876	877	878

2. Quasi-static axial (15 mm prestressing at 265 kN / 0 L., 10 min waiting time)

		Axial stiffness [N/mm]		Natural frequency [Hz]	
Axial force Fz [kN]	additional volume	274.5	184.5	274.5	184.5
Axial Cz ± 10	Vzu = 150	677	587	0.85	0.91
Axial Cz ± 10	Vzu = 50	1085	813	0.98	1.05
Axial Cz ± 10	Vzu = 0	1665	1215	1.23	1.29

3. Quasi-static radial (10 x 60 mm prestressing, 15 min waiting time)

		Axial stiffness [N/mm]		Natural frequency [Hz]	
Fz [kN]		274.5	184.5	274.5	184.5
Radial Cz ± 10		805	747	0.86	1.01

PRECISION LEVELLING MOUNT
PLM AIR SPRINGS

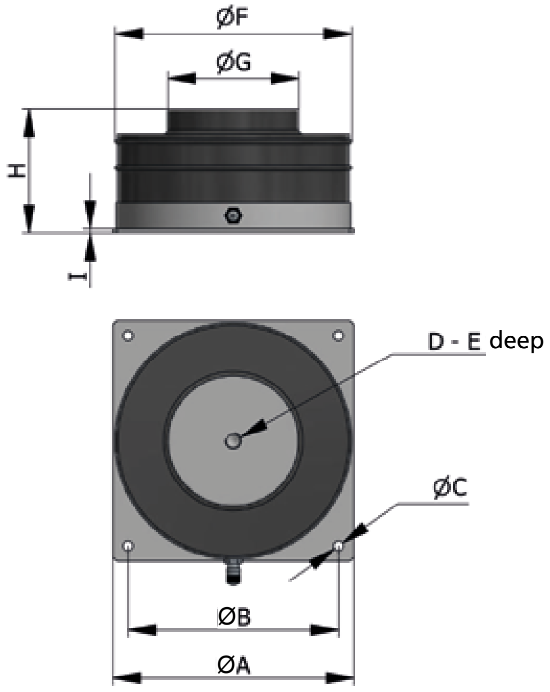
Precision Aire™ air spring elements provide low-frequency vibration and shock isolation for equipment such as:

- Measuring stations
- Coordinate measuring machines
- Fans
- Air compressors
- Motor and generator units
- High-speed presses

Our Fabreeka® PLM air-spring series includes low-frequency vibration and shock isolators to reduce unwanted vibration while levelling the devices they support. Used as a vibration damper, the internal air chamber ensures significant isolating effects from as low as 5 Hz. Its natural frequency is only 3.0 Hz.

Precision Aire™ air spring elements also isolate while unpressurized. The vertical natural frequency of the elastomer body is around 10 Hz for isolating interference frequencies above 14 Hz.

The ratio of vertical to horizontal natural frequency is approximately 1:1 with high horizontal stability. The elastomer wall design in PLM air springs ensures large dynamic spring travel for applications vulnerable to shock and impact. External stops are advisable to prevent air-spring strikethrough where low natural frequency of 3 Hz is still required.



Type	A	B	C	D	E	F	G	H max. rebounded	I	Max. load	Max. operating pressure
	mm	mm	mm		mm	mm	mm	mm		kg	bar
PLM1	76	60.5	6.9	M10	12	73	25	62.5	3.2	45	5
PLM3	106	89	6.9	M12	13.5	105	56	63.5	3.2	150	5
PLM6	130	108	7.4	M12	13.5	127	60	89	3.2	250	6
PLM12	175	152	7.4	M12	13.5	171	100	89	3.2	550	6
PLM24	254	216	14.2	M16	19	245	138	89	4.8	1100	6
PLM48	343	305	14.2	M16	19	338	190	89	4.8	2200	6
PLM96	470	406	20.6	M24	22.4	468	267	89	6.4	4400	6
PLM192	610	508	20.6	M24	22.4	610	400	89	6.4	8800	6

Installation note: The machine needs to be supported on ventilated PLM air springs with subsequent gradual inflation to working height H ± 6 mm. The machine is unmounted in reverse order. Automatic levelling is optional.

FUNCTION
PLM AIR SPRINGS

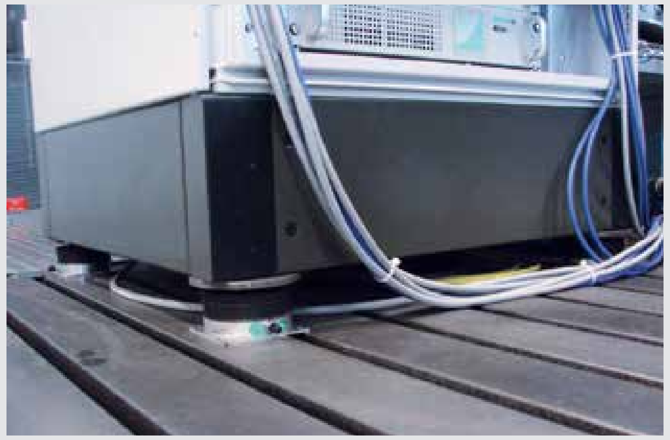
The PLM design has a vulcanized threaded inlet for inflating the air springs up using either a standard tire valve or pneumatic screw attachment. No special connections are needed.

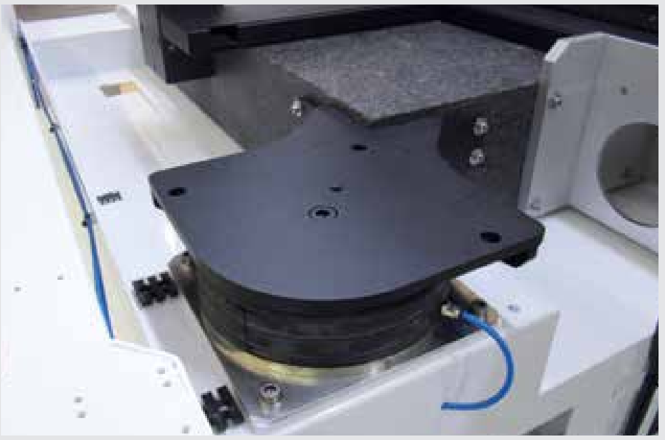
The isolators are supplied with a tank valve and are inflated and levelled manually using hand pumps or adapters connected to an air supply. Air springs with pneumatic screw connectors can be connected to the respective controlled air supply, which eases pressurization and levelling. A controller (right) is optionally available to regulate the pressure and the height of the interconnected air springs if no level control valves have been fitted.

Apart from that, PLM air spring elements come with optional automatic level control valves for height control. Each main isolator has an attached level control valve that functions as a load and position sensor. Any number of parallel air springs can be added to increase the carrying capacity of the entire system.

Each system comes with a control unit, automatic level control valves, tubing and all pneumatic accessories necessary for complete system installation.

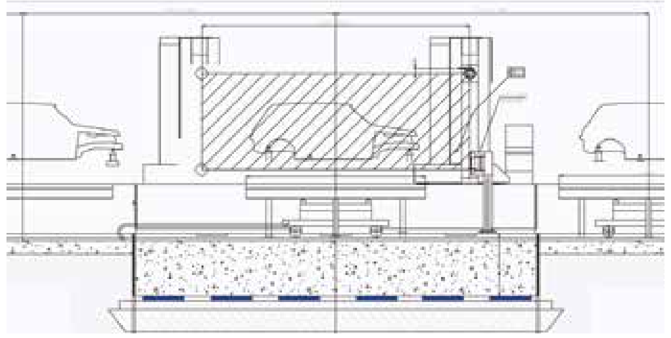

Brake test bench – air spring in detail


Switch cabinet


Laser printing machine courtesy of Notion Systems

RDS
(RAPID DEFLATE SYSTEM)

RDS is ideal for applications where the isolated machine needs to be positioned in one reference plane before workpiece loading or unloading.



Existing systems can be easily upgraded with RDS in the field.

RDS components may be added at any pneumatic control unit for the operator to lift or lower machines mounted on an air spring system quickly. This is especially necessary with large measuring machines, which require foundations and many isolators.

Conventional systems vent compressed air through the level control valves, whereas RDS systems vent compressed air five to ten times faster. Only 1.0 bar pressure reduction is used, allowing isolators to remain under pressure until they are vented again. RDS can be connected to existing PLC systems for integration into an automation process.

Equipped with RDS Rapid Deflate System

APPLICATION AREAS
PRECISION MANUFACTURING MACHINES

Demands on the accuracy of precision machine tools are constantly increasing. Devices that cut, lathe, polish or position using nanotechnology allow fine work and measurements in the micron and even angstrom range.

Many industries such as semiconductors and wafer processing, optics and lens manufacturing as well as non-standardized materials processing use ultra-high precision machines.

High-precision positioning machines such as diamond lathes, XY stages and CD meters typically use laser interferometry (position feedback) to position materials to nanometer accuracy. Measuring devices such as profilometers, shape and surface roughness testers and roundness measuring machines are also required for submicron measurements.

These devices are further used for ultra-precise cutting and microgrinding on materials such as optical glasses, crystals, nonferrous metals, polymers and ceramics. The surfaces of these materials are processed so accurately that little or no subsequent polishing is typically needed; the surfaces already have a submicron grain. CDs, contact lens tools, components for optical lenses and mirrors for laser applications are made in this way.

Low frequency vibration and shock isolation systems from Fabreeka® provide an ideal basis for precision machine tool manufacturers and users to ensure the intended accuracy of their devices. Some applications require special system and structural analyses. The substructure and frame design used for the isolation system and integrated into the machine design can also be customized.

Laser interferometer courtesy of LT-Ultra

Courtesy of Motion X

Courtesy of Precitech

MEASURING AND TESTING EQUIPMENT


Hexagon CMM

Wenzel CMM

Coordinate measuring machines (CMMs) have been seeing increasing measurement speed and accuracy year by year. Newer CMMs are designed for use in workshops and manufactured for production environments with high repeatability. Factors that may affect the accuracy and repeatability of a CMM include interference vibration.

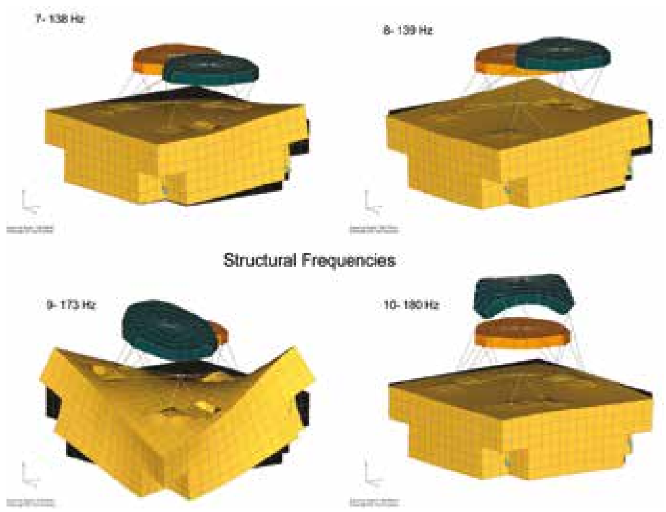
The ideal state has been reached once all of the components in a CMM, including the part to be measured at a particular frequency, amplitude, phase and alignment vibrate in harmony – the measured power will not decrease. This situation is equivalent to a state of complete freedom from vibration in a CMM with all of its parts moving synchronously. Measurement inaccuracies may arise once components start to vibrate out of phase, or if structural resonance arises.

CMM manufacturers define vibration level tolerances at which their equipment still works properly for the respective machine to avoid any potential loss in accuracy. This permissible vibration value is an important factor in a decision as to whether a machine requires vibration isolation.

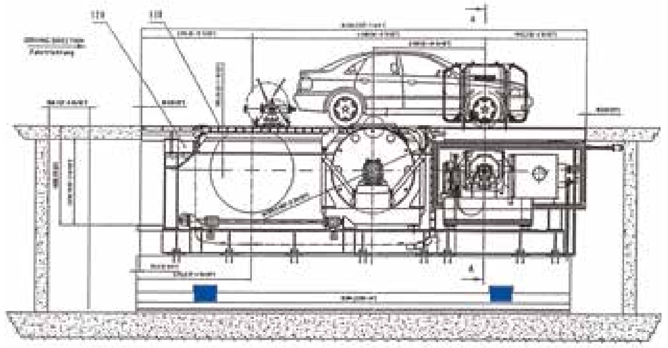
AUTOMOTIVE TEST BENCHES

We at Fabreeka® International play a leading role in damping systems and development services for automotive test benches, systems that satisfy the increasing demands of automotive testing and environmental simulation.

We regularly develop isolation solutions for many applications such as chassis dynamometers and engine test benches, road simulation test benches and multi-axis vibration tables. We also provide engineering services such as structural analysis on substructures and reaction masses, static and dynamic structural analysis and acceptance tests.



Multi-axis vibration table, vibration analysis, dynamic structural analysis


Chassis dynamometer on a vibration-isolated foundation


Motor test bench on PAL

AUTOMOTIVE TEST BENCHES

IPEK

SAF Holland

Uni Graz

MAN Munich

Leibnitz Uni Hanover

IAMT Plauen

AEROSPACE TESTING

At Fabreeka® we supply low frequency vibration isolation systems for difficult test applications in the aerospace and defense industry, which require a very low frequency isolation. Other applications include nanomeasurement with error limits in the micrometer range of tenths of arcseconds.

Tests on large missiles or satellites to be sent into orbit need to be conducted in simulated space conditions requiring a vacuum chamber or thermal vacuum chamber. This type of chamber creates an environment that simulates the pressure and the heat effects on launch and space flight.

The test object must be isolated within the vacuum chamber where the size or design of the chamber does not allow for the use of "external" isolators. This requires a vacuum-compatible isolation system. Isolators that are used within a vacuum chamber must meet material specifications aimed at limiting outgassing, and they also need to meet strict molecular purity requirements. Isolators need to operate under extreme temperatures during thermal vacuum operation, and heating mats may be necessary to maintain local temperatures in a range where isolators will still work properly.

The limits for vacuum-compatible, pneumatic isolation materials are around 0.85 % total mass loss (TML) and 0.09 % collected volatile consumable material (CVCM). Our Fabreeka® products operate in an environment of 1 x 10-6 Torr, and have a maximum leakage rate of 10-7 cc/sec.

Courtesy of B.F. Goodrich

SOFT SUPPORT SYSTEM (SSS) FOR GROUND VIBRATION TESTING

At Fabreeka® we have developed a number of soft support systems (SSSs) for ground vibration testing (GVT) for aircraft; these SSSs integrate into standard or bespoke air springs. Determining modal parameters in aircraft requires simulation of what is referred to as a free-free environment for accurate results during GVT; we work closely with structural dynamics specialists from the respective aircraft manufacturers in designing the SSS required for GVT.

The air springs support the aircraft and decouple it from the ground as it undergoes dynamic tests and modal analysis. The soft support system plays an especially important role in identifying structural resonance and evaluating vibration behavior. An SSS may also include a lifting system to lift the aircraft from its undercarriage.

Isolators used in GVT have vertical and horizontal natural frequencies down to 0.5 Hz.

Mitsubishi MRJ

Embraer 190

Lockheed Martin

MRI/NMR SPECTROMETER EQUIPMENT

(MAGNETIC RESONANCE IMAGING, NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY)

We provide a very high level of expertise, extensive product knowledge and design solutions in vibration isolation as well as vibration damping systems for all types of high-resolution MRI, NMR and cryostats in frequency ranges of 300 MHz to 900 MHz.

Air springs as used in NMR applications are always made of non-magnetic stainless steel, aluminum and brass. The working height of the isolators is adjusted to the requirements of the respective magnetic model to allow the existing support structures of the magnet to be used.

Solutions offered include vibration measurements and support structure design, including static and dynamic analysis.

The air springs come in heights ranging from 700 mm to 1,800 mm with vertical and horizontal natural frequencies of only 0.8 Hz.

600 MHz NMR on PAL18 gimbal air springs

Horizontal NMR on PAL55-6

Want to learn more about us, or have a specific isolation issue?

Ask us about it – we'll get together to find a solution.

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