Proc. of SPIE Vol. 1619, Vibration Control in Microelectronics, Optics, and Metrology, ed. C G Gordon (Feb 1992) Copyright SPIE

Matching Performance Requirements with Technology: An Applications Approach to Vibration Isolation

Thomas A. Cellucci

Newport Corporation, Vibration Control Group
10800 Kalama River Road, Fountain Valley, California 92708

ABSTRACT

An *integrated solutions approach* to frequently encountered vibration problems is most useful in solving real-world problems. By "amalgamating" several levels of vibration control--in the form of both new designs and existing technologies--one is able to create a foundation upon which a variety of requirements can be met. The combination of time-proven damping of optical bench tops and a novel technological advance involving a new damping technology for pneumatic isolators, leads to enhanced performance of passive isolation systems.

1. BACKGROUND

All too often, not enough attention is given to understanding, determining and addressing the special needs of a variety of applications requiring vibration isolation. Some standard, "off-the-line" vibration control systems are considered "good enough" for the majority of applications. But are they?

This paper elucidates the merits of fine tuned damping techniques developed in our laboratories--as well as discusses the concept of laminar flow damping.[1] Instead of the single damping orifice found in older designs, we will describe a unique damper comprised of thousands of tiny orifices. Simultaneous air movement through this new type of orifice creates a laminar flow which improves damping efficiency for both large and small displacements over a wide range of operating conditions.

2. TUNED DAMPING OF OPTICAL BENCH TOPS

There is a plethora of literature [2] which describes the concept of dynamic compliance. Refer to Figure 1. This figure yields a comparison of the compliance seen in optical bench tops incorporating our tuned damping versus broadband damping methodologies. We have been pioneering fine tuned damping for the last twenty years and have found--in independently audited tests[3]--that the use of dampers (see Figures 2 and 3) increases the effective damping of optical bench tops.

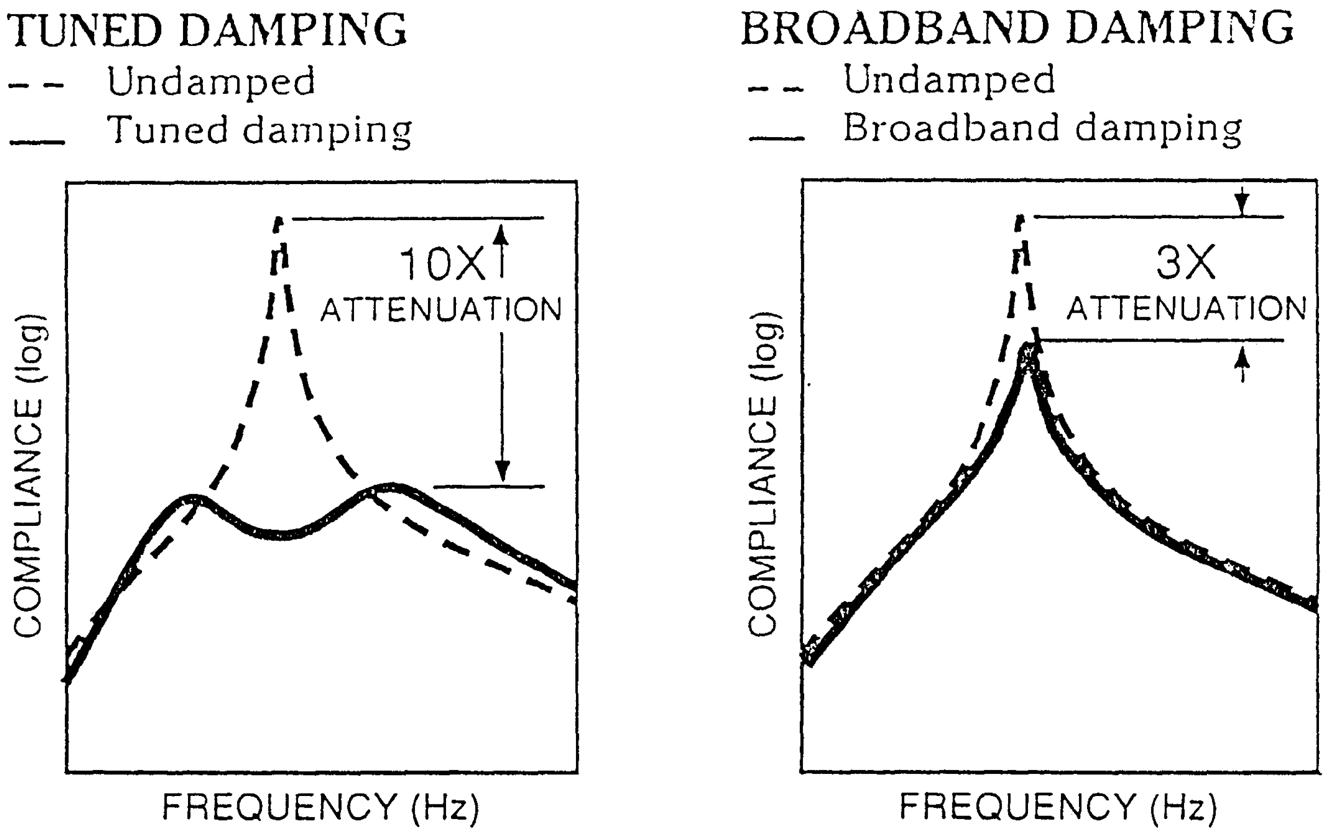


Figure 1: Tuned dampers (left) concentrate damping where it's needed most, at the frequencies of dominant resonance modes. Since broadband dampers (right) are designed to provide moderate damping over a wide range of frequencies, they are not as effective at damping the dominant modes of table vibration.[3]

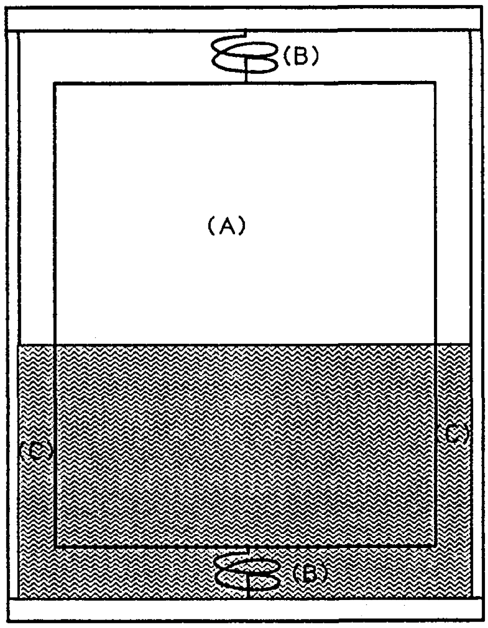


Figure 2: Schematic of a damper used to tune damp optical bench tops. A damper mass (A) is suspended between two springs (B) and partially immersed in a viscous oil (C).

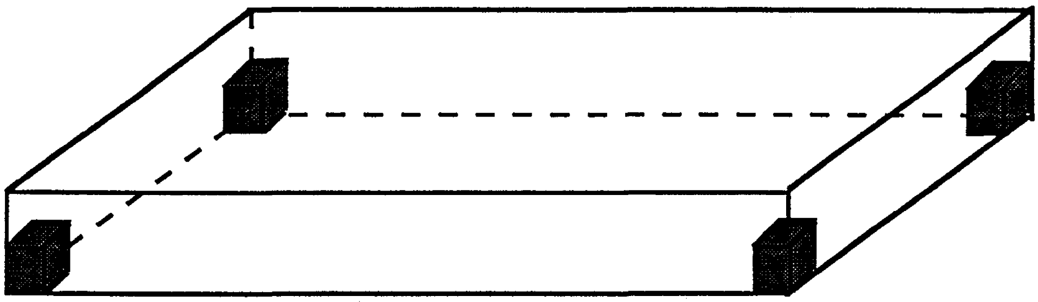


Figure 3: Schematic showing typical placement of dampers in an optical bench top. Dampers are specifically tuned to natural frequencies inherent in the bench top. Unlike the typical broadband damper which utilizes alternate layers of visco-elastics and steel, these frequency tuned dampers lead to lower compliance values.

3. NEW PNEUMATIC ISOLATOR DESIGN

In order to provide the ultimate isolation from environmental vibrations, we have developed a totally new pneumatic isolator which efficiently attenuates both vertical and horizontal vibrations at amplitudes down to the submicron level. In addition, the isolator offers superior performance with loads ranging from 150 to 2,000 lbs, a considerable increase in effective load range over other known commercial products. Refer to Figure 4.

A pneumatic rolling diaphragm design and a new laminar-flow damper provide superior vertical motion isolation. Instead of the single damping orifice found in older designs (see Figure 5), the damper is comprised of thousands of tiny orifices. Simultaneous air movement through the orifices creates a laminar flow which improves damping efficiency for both large and small displacements.

Another major technical advance inherent in the isolator is a novel, hybrid chamber design. This chamber configuration also enhances damping efficiency by minimizing the air volume between the piston and damper. Reducing this air volume links piston motion more directly with damper air flow for improved damping performance.

The result of these improvements is *less motion amplification* at the isolator's natural resonance and *faster settling time*, two key measures of isolator performance. We have seen several major benefits of the isolator's laminar-flow damper and chamber design and describe them below:

3.1 Faster settling time

Rapid settling time is an important factor in most applications, from laboratory experimentation to production-line systems. The higher efficiency of this laminar flow damper reduces settling time after both large and small magnitude table disturbances. In addition, the isolator's smaller total isolator volume improves isolator responsiveness because less air transfer is required to re-establish equilibrium.

3.2 Better high-center-of-mass stability

A smaller total isolator volume generates a larger restoring force for very low-frequency disturbances, resulting in superior high-center-of-mass stability--a critical consideration in applications with heavy equipment.

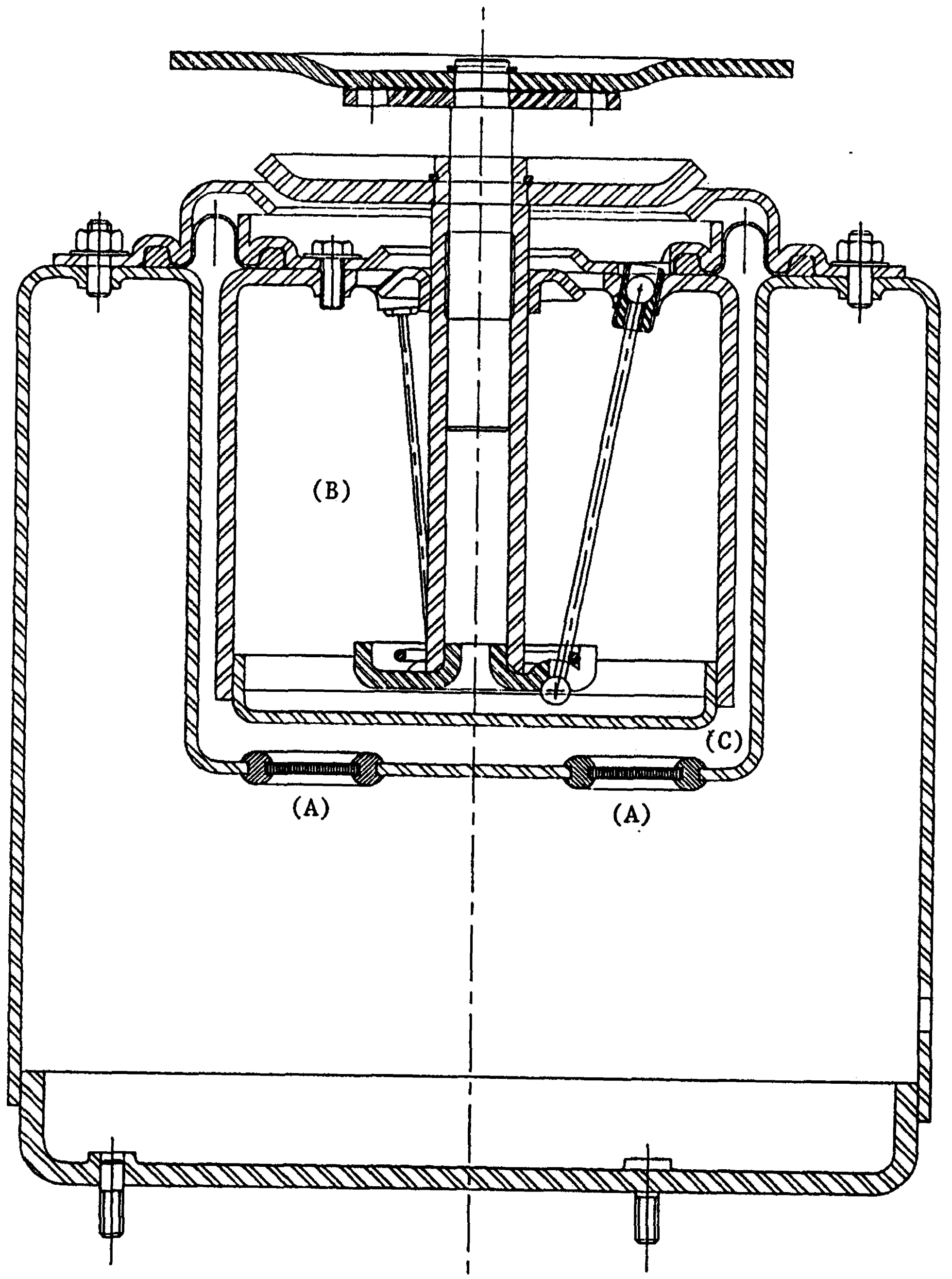


Figure 4: Schematic of hybrid chamber pneumatic isolator. With the close piston fit of the laminar flow damping orifices (A) minimizing air volume (C) between the piston (B) and damper, there is better linkage between piston motion and air flow. This generates a higher damping force for a given displacement--for faster, more efficient damping of vertical motion

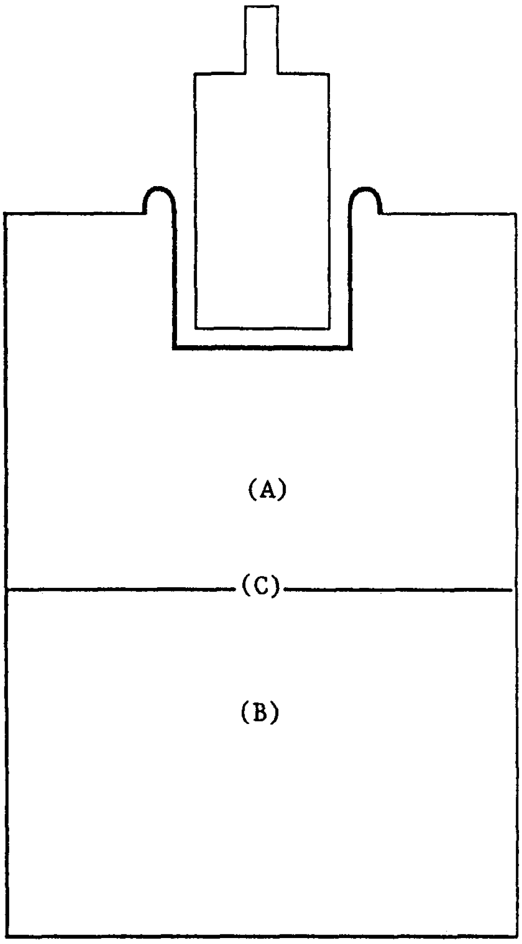


Figure 5: Schematic of an older-style two chamber isolator incorporating a spring (A) and damping (B) chamber separated by a single orifice (C).

3.3 Lower natural frequency

The lowest possible natural frequency provides the best protection against difficult-to-control low-frequency vibrations below about 5 Hz.

Even though isolator volume is a major factor in the natural frequency of an isolator, the result of standard two-chamber designs is that only the volume of the top chamber is operative, unless the vibrational amplitudes are much higher than found in a typical environment (i.e. large enough to be forcing air through the orifice). Our laminar flow damping allows us to reduce the total volume of the isolator while actually increasing the volume of the chamber that is most related to an isolator's performance.

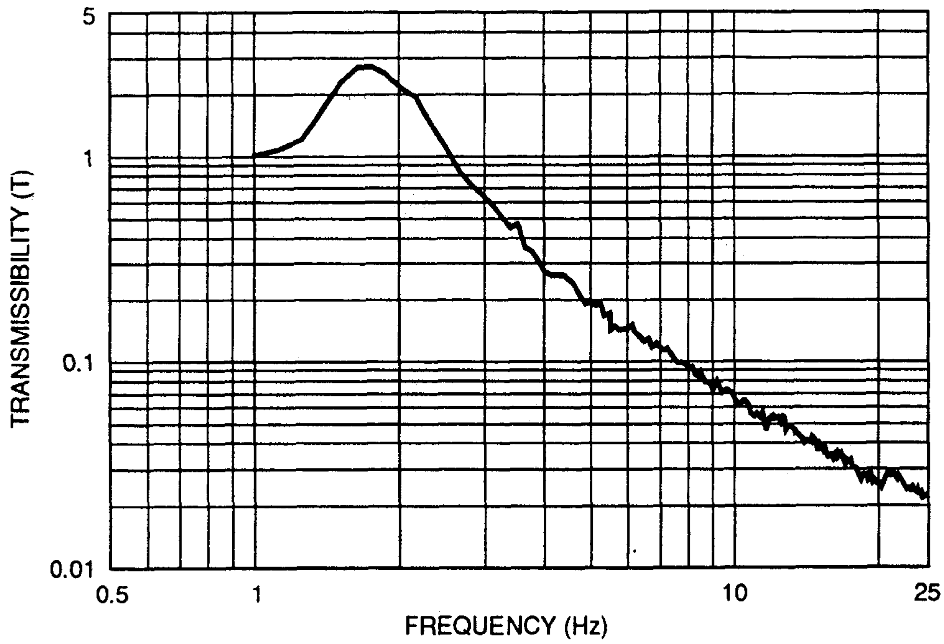
In addition, the stiffness of the air column is not the only factor in isolator performance. Additional stiffness is derived from the rolling resistance of the piston/diaphragm interface and the spring stiffness of the leveling valves. We refined the design of all these elements to work in concert with each other, making the new isolator a high efficiency integrated system--not just components bolted together. Refer to Figure 6.

3.4 Less amplification at resonance

Higher damping efficiency results from the laminar-flow damper design and the smaller volume of air between the piston and the damper. This reduces motion amplification at the isolator's natural frequency for better stability.

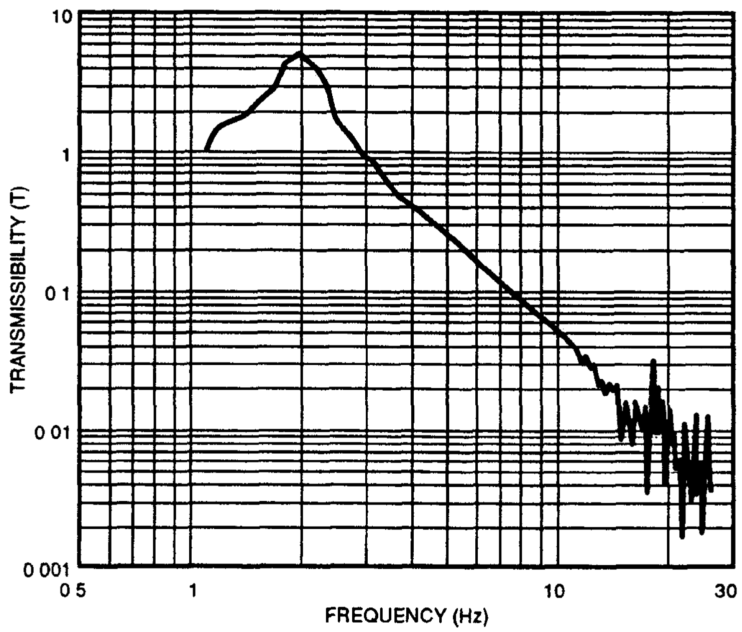
3.5 Self-centering piston design

Even under "normal" operating conditions, piston movement of ordinary isolators can be inadvertently restricted if care is not taken to ensure exact alignment. The result is that isolation performance can be severely compromised. This design automatically self-centers the piston at the top and bottom of its vertical stroke, ensuring unrestricted piston movement for best performance.



(a)

Figure 6: (a) Vertical transmissibility curve of a new hybrid chamber isolator showing that its natural frequency is approximately 1.6 Hz with amplification less than 3.0 at 250 lbs. load compared to (b) a conventional isolator that has a natural frequency of approximately 2.0 Hz with amplification of 5.0 at 250 lbs. load.



(b)

5. ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance--via technical discussions--of Bowie Houghton, Richard Eddy, Mark Filho, and Walt Kershaw of the Newport Corporation. In addition, the author wishes to thank Chris Schraff of DJR and Terri Covey of Newport for their assistance in preparing the figures and the typing of the text.

6. REFERENCES

1. Patent pending, Newport Corporation, 1991.

2. See any text on the subject of dynamic compliance or refer to a tutorial as presented in the Newport catalog, p. A-2 to A-15, c. 1989.

3. "A Performance Difference You Can See", Newport Corporation, c. 1991.