

## VIBRATION ISOLATOR

This invention relates to a vibration isolator for inhibiting transfer of vibration to an apparatus during evacuation thereof by a pump.

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Vibration isolators are used to reduce the vibration transmitted to an apparatus from a high-vacuum pump, for example, a turbomolecular pump, during evacuation of the apparatus. The use of a vibration isolator is particularly desirable when the apparatus under evacuation is sensitive to mechanical vibration. For example, the transmission of vibrations to an  
10 electron microscope can lead to a loss of resolution of the microscope, whilst the transmission of vibrations to a process tool can lead to manufacturing errors in products located within the tool.

15 With reference to Figure 1, a vibration isolator 10 is typically connected between the fluid exhaust of the apparatus 12 to be evacuated and the fluid inlet of the vacuum pump 14.

Figure 2 illustrates in more detail one example of a known vibration isolator  
20 10. The isolator 10 comprises a steel bellows 20 that defines a flow path through the isolator 10 for fluid pumped from the apparatus 12 by the pump 14. A first annular flange 22 is welded to one end of the bellows 20 for connecting the isolator 10 to the apparatus 12 to be evacuated, and a second annular flange 24 is welded to the other end of the bellows 20 for connecting  
25 the isolator 10 to the pump 14.

The bellows 20 is surrounded by an elastomeric cylinder 26 mounted on the second flange 24 that prevents the bellows 20 from collapsing under compression when the fluid within the bellows is at a sub-atmospheric  
30 pressure, and provides damping of vibrations generated during use of the pump 14.

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The isolator 10 further comprises a pair of interlinking members that prevent the bellows 20 from extending under the weight of a pump 14 connected to the second flange 24 when the apparatus is not under evacuation. Each interlinking member is in the form of a V-shaped metallic strap, with the first  
5 strap 28 being welded to the first flange 22, and the second strap 30 being welded to the second flange 24 so that the straps 28, 30 are linked. In the illustrated example, when the isolator 10 is not connected to any other components, the straps 28, 30 are spaced apart by a distance  $x$  extending along the axis of the bellows 20.

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The parameter governing transmission of vibration from the pump 14 to the apparatus 12 is the stiffness of the isolator 10. As the bellows 20 typically has a relatively low inherent axial stiffness, there is minimal transmission of vibration to the apparatus 12 through the bellows 20. Furthermore, during  
15 evacuation of the apparatus, the isolator 10 is under compression, and so the straps 28, 30 are not in contact. Consequently, the primary route for the transmission of vibrations to the apparatus 12 is through the elastomeric cylinder 26, which becomes sandwiched between the flanges 22, 24 during evacuation of the apparatus. However, when the elastomeric cylinder 26 is  
20 compressed in this manner, its hyperelasticity, reflected in a non-linear progressive stiffness characteristic, causes its axial stiffness to gradually increase. The increasing axial stiffness of the cylinder 26 reduces the ability of the isolator 10 to deflect, which progressively enhances the transmission of vibration to the apparatus 12.

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In a first aspect, the present invention provides a vibration isolator for inhibiting transfer of vibration to an apparatus during evacuation thereof by a pump, the isolator comprising a bellows for conveying fluid drawn from the apparatus to the pump, the bellows having first and second open ends, and a  
30 resilient element substantially co-axial with and surrounded by the bellows, the resilient element having a first end connected to one of the first and

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second open ends, and a second end connected to the other one of the first and second open ends.

The invention can thus provide a vibration isolator having a relatively simple structure and with relatively low axial, shear and tilt stiffnesses.

The bellows may be integral with the pump, with the second open end of the bellows being connected to the body of the pump. For example, this open end of the bellows may be connected to an annular flange integral with the housing of the pump. Alternatively, a separate flange may be connected to this second open end of the bellows for mounting the isolator to a pump, with one end of the resilient element being connected to the second flange. In either case, another flange is preferably connected to the first open end of the bellows for mounting the isolator to an apparatus to be evacuated, with the other end of the resilient element being connected to the first flange.

In the preferred embodiment, the first end of the resilient element is located proximate to the first open end of the bellows and connected to the second open end of the bellows, and the second end of the resilient element is located proximate to the second open end of the bellows and connected to the first open end of the bellows.

The isolator may be in the form of a component which is mounted to both the apparatus and the pump, and so in a second aspect the present invention provides a vibration isolator for inhibiting transfer of vibration to an apparatus during evacuation thereof by a pump, the isolator comprising a bellows for conveying fluid drawn from the apparatus to the pump, a first flange connected to one end of the bellows for mounting the isolator to the apparatus, a second flange connected to the other end of the bellows for mounting the isolator to the pump, and a resilient element co-axial with and surrounded by the bellows, the resilient element having a first end located proximate to the first flange and connected to the second flange, and a

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second end located proximate to the second flange and connected to the first flange.

The vibration isolator preferably comprises a first connector connected to the first flange, and a second connector connected to the second flange, with the first end of the resilient member being attached to the second connector, and the second end of the resilient member being attached to the first connector. These connectors are preferably overlapping, and thus are preferably angularly offset. In the preferred embodiment, the first connector is substantially orthogonal to the second connector. Each connector may be provided by an arch-shaped connector having ends connected to its respective flange and a central portion attached to the resilient element.

The isolator may comprise damping means for damping oscillation or vibration of the resilient element. The damping means may preferably comprise a plastics element which contacts at least a portion of the resilient element during use.

Damping means may be located between each end of the resilient member and its respective connector. Alternatively, or additionally, an elastomeric sleeve may surround the bellows.

The isolator may comprise an auxiliary mass which can be located to increase a resistance to axial compression of said bellows when a fluid within said bellows is at a sub-atmospheric pressure. Preferably, the second flange comprises connection means for connecting said auxiliary mass thereto.

The resilient element is preferably under tension, and thus may be provided by a helical tension spring. The tension spring is preferably pre-tensioned.

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Features described above in relation to the second aspect of the invention are equally applicable to the first aspect, and vice versa.

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The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

- 5    Figure 1 illustrates an isolator connected between a pump and an apparatus to be evacuated by the pump;

Figure 2 is a cross-section through a known vibration isolator;

- 10   Figure 3 is a top view of an example of a vibration isolator according to the present invention;

Figure 4 is a cross-sectional view of the isolator of Figure 3, as viewed along line A-A;

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Figure 5 is a cross-sectional view of the isolator of Figure 3, as viewed along line B-B; and

Figure 6 is an isometric rear view of the isolator of Figure 3.

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- Figure 3 illustrates a vibration isolator 50 for connection between the fluid exhaust of an apparatus to be evacuated, and the fluid inlet of a vacuum pump. The isolator 50 comprises a steel bellows 60 of generally cylindrical form having a first open end 62 and a second open end 64. The bellows 60 defines a flow path through the isolator 50 for fluid pumped from the apparatus by the pump. A first annular flange 66 is welded to the first open end 62 of the bellows 60 for connecting the isolator 50 to the apparatus to be evacuated, and a second annular flange 68 is welded to the second open end 64 of the bellows 60 for connecting the isolator 50 to the pump.
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The bellows 60 surrounds a resilient element 70, which is preferably under tension in the normal, unloaded condition and therefore is preferably in the form of a helical tension spring. The tension spring is preferably a pre-tensioned spring. The resilient element 70 is substantially co-axial with the  
5 bellows 60. The resilient element 70 has a first end 72 located proximate to the first flange 66, and a second end 74 located proximate to the second flange 68.

A first connector 76 is provided for connecting the resilient element 70 to the  
10 first open end 62 of the bellows 60, and a second connector 78 is provided for connecting the resilient element 70 to the second open end 64 of the bellows 60. In this example, the first connector 76 is in the form of an arch-shaped connector, having a central portion 80 attached to the second end 74 of the resilient element 70 and ends 82 welded or otherwise connected to the first  
15 flange 66. The second connector 78 is similarly in the form of an arch-shaped connector, having a central portion 84 attached to the first end 72 of the resilient element 70 and ends 86 welded or otherwise connected to the second flange 68. The first and second connectors 76, 78 are angularly offset, and in this example are substantially orthogonal.

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A damping element (not shown) may be located for damping oscillation or vibration of the resilient element 70 during evacuation. The damping element may be made from plastics, such as Viton or PTFE, which is suitable for use at high vacuum. The damping element preferably contacts at least a portion  
25 of the resilient element during evacuation to achieve a required damping effect.

The damping element may be located between each end 72, 74 of the resilient member 70 and its respective connector 76, 78. For example, an  
30 elastomeric o-ring or other elastomeric member may be provided about the resilient element 70 to dampen the surge frequency of the resilient element 70 and/or dampen lateral vibration of the connectors 76, 78. In other

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arrangements, the damping element comprises a sleeve around a circumference of the resilient element 70; an element extending through a bore of the resilient element; or an o-ring supported by first and second connectors 76, 78 so that it contacts the resilient element during use.

- 5 Alternatively, or additionally, an elastomeric sleeve (not shown) may be located about the bellows 60. Such a sleeve would be relatively thin in comparison to the elastomeric cylinder 26 of the known isolator 10 so that the sleeve has only minimal contribution to the stiffness of the isolator 50.

- 10 The resilient element 70 provides an axial constraint which limits the axial expansion of the bellows 60 both in a normal, unloaded condition of the isolator 50, and when the isolator 50 is connected between a vacuum pump and an apparatus to be evacuated, and thus when a gravitational force acting on the pump tends to expand the bellows 60.

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During evacuation of the apparatus, a large static load acts on the pump as a result of the difference between external atmospheric pressure and the internal sub-atmospheric pressure, which load acts to axially compress the isolator 50. The flanges 66, 68 of the isolator 50 are urged together, which in turn urges apart the ends 72, 74 of the resilient member 70. In response, the resilient member 70 acts in tension to provide a resistance to the compressive axial loading experienced by the isolator 50.

- 25 End stops may be provided to limit compression of the bellows 60 in the event of a failure of the resilient element 70 during evacuation of the apparatus connected to the first flange 66, and/or to limit extension of the bellows 60 in the event that the resilient element 70 becomes coil bound. For example, suitable end stops may be provided by interlocking tabs located on the connectors 76, 78. In the event of a catastrophic failure of the pump connected to the second flange 68, which will tend to cause the second flanges 68 to rotate relative to the first flange 66, the connectors 76, 78, which
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are angularly displaced with respect to each other, will engage and dissipate the energy generated by the pump failure.

- A mass of the pump acting under the effect of gravity provides resistance to
- 5 axial compression of bellows 60 in addition to the resistance provided by resilient element 70. To a lesser extent, a mass of the lower flange 68, connector 78 and bellows 60 also resists such axial compression. If a mass of the pump is relatively low, the axial compressive force on the bellows 60 may be sufficient for the bellows to buckle. It may be desirable to provide an
- 10 auxiliary mass (not shown) which can be fixed to one of the pump or the isolator to resist axial compression of the bellows 60. Preferably, a lower flange 68 of the isolator is provided with connection means for connecting an auxiliary mass to the lower flange.
- 15 The inhibition of the transmission to the apparatus of an oscillating force associated with vibrations of the pump during evacuation of the apparatus is determined by the axial, shear and tilt stiffnesses of the isolator 50. The axial stiffness of the isolator 50 is determined by the axial stiffness of the bellows 60, and the axial stiffness of the resilient element 70. As the resilient element
- 20 70 may have a very low axial stiffness in comparison to the elastomeric cylinder 26 of the known isolator 10, the isolator 50 may have an axial stiffness which is significantly lower, for example around ten times lower, than the axial stiffness of the known isolator 10.
- 25 The shear and tilt stiffnesses of the isolator 50 are determined by the radial locations of the bellows 60 and the resilient element 70 about the axis of the isolator 50. Due to the axial location of the resilient element 70 within the bellows 60, the resilient element 70 contributes very little to the shear and tilt stiffnesses of the isolator 10, whilst the elastomeric cylinder 26 of the known
- 30 isolator 10, which surrounds the bellows 20 of that isolator 10, contributes substantially to the shear and tilt stiffnesses of the known isolator 10.

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Consequently, the isolator 50 has shear and tilt stiffnesses which are significantly lower than those of the known isolator 10.

Whilst the presence of a resilient element 70 within the bellows 60 may  
5 detrimentally affect the conductance of the isolator 50 in comparison to the  
known isolator 10 when the isolators 10, 50 have bellows 20, 60 of  
comparable internal diameter, it is to be noted that the internal diameter of the  
bellows 60 of the isolator 50 is not constrained by the presence of any  
elements located radially outside the bellows 60. In contrast, the internal  
10 diameter of the bellows 20 of the known isolator 10 is constrained by the  
presence of, and therefore the thickness of, the elastomeric cylinder 26, when  
there is a limit to the external diameter of the isolator. In this case, the  
internal diameter of the bellows 60 may be larger than that of the bellows 20  
of the known isolator 10, and may be such that the conductance of the isolator  
15 50 is greater than that of the isolator 10. As a result, there is a greater degree  
of freedom in selecting the conductance of the isolator 50, by appropriate  
choice of the internal diameter of the bellows 60, to suit the requirements of  
the evacuation system of which the pump and isolator 50 form part.

20 It is to be understood that the foregoing represents one embodiment of the  
invention, others of which will no doubt occur to the skilled addressee without  
departing from the true scope of the invention as defined by the claims  
appended hereto.

25 For example, the resilient member 70 may be provided by a compression  
spring, which may be surrounded by a sleeve or other constraining member.  
In this case, the first end 72 of the resilient member 70 would be connected to  
the first flange 66 by an alternative form of connector, and the second end 74  
of the resilient member 70 would be connected to the second flange 68 by a  
30 similar form of connector.

### CLAIMS

1. A vacuum pump vibration isolator for inhibiting transfer of vibration to an apparatus during evacuation thereof by a vacuum pump, the isolator comprising a bellows (60) for conveying fluid drawn from the apparatus to the vacuum pump, a first flange (66) connected to one end of the bellows for mounting the isolator to the apparatus, a second flange (68) connected to the other end of the bellows for mounting the isolator to the vacuum pump, and a resilient element (70) substantially co-axial with and surrounded by the bellows, characterised in that the resilient element has a first end (72) located proximate to the first flange and connected to the second flange, and a second end (74) located proximate to the second flange and connected to the first flange, wherein a first connector (76) is connected to the first flange, and a second connector (78) is connected to the second flange, the first end of the resilient member being attached to the second connector, and the second end of the resilient member being attached to the first connector, and the first connector is substantially orthogonal to the second connector.
2. A vibration isolator according to Claim 1, wherein the resilient element is under tension.
3. A vibration isolator according to Claim 1 or 2, wherein the resilient element is a helical tension spring.
4. A vibration isolator according to Claim 3, wherein the tension spring is pre-tensioned.
5. A vibration isolator according to Claim 1, wherein each connector comprises an arch-shaped connector having ends connected to its respective flange and a central portion connected to the resilient element.

6. A vibration isolator according to any preceding claim, comprising damping means for damping oscillation or vibration of the resilient element.
7. A vibration isolator according to Claim 6, wherein said damping means comprises a plastics element which contacts at least a portion of the resilient element during use.
8. A vibration isolator according to Claim 6 or 7, wherein said damping means is located between each end of the resilient member and its respective connector.
9. A vibration isolator according to any preceding claim, comprising an elastomeric sleeve surrounding the bellows.
10. A vibration isolator according to any preceding claim, comprising an auxiliary mass which can be located to increase a resistance to axial compression of said bellows when a fluid within said bellows is at a sub-atmospheric pressure.
11. A vibration isolator according to Claim 10, wherein said second flange comprises connection means for connecting said auxiliary mass to the second flange.