TAYLOR DEVICES HERMETIC DAMPERS
DESCRIPTION, APPLICATIONS, AND DESIGN

by

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This unique damper was developed during the 1980's for use on platforms based in outer space. NASA and the U.S. military had experienced difficulties over the years with all types of oil-filled products in space. Conventional sliding surfaces that were sealed acceptably on earth proved unacceptable for spacecraft use. The reason was simply that even the tiniest amount of fluid weepage past conventional seals turns into a dense fog in a vacuum, contaminating optics and electronic systems.

Taylor Devices' solution was to develop a damper that used a flexural seal – thus sealing by non-sliding methods. The seal itself was a so-called metal bellows made by laser welding thin discs of stainless steel into a bellows configuration. For maximum reliability, a two-ply disc configuration was used, with each disc comprised of two sheets of .003 inches thick 17-7 stainless steel. The successful use of metal bellows to seal gases in space was well established, but the Taylor Devices' damper design was the first to use this technology to seal fluids. To insure absolute zero leakage, each finished bellows assembly is placed in a vacuum chamber and filled internally with helium gas. A mass spectrometer is then used to search for zero leakage of even individual helium molecules from the completed bellows. Extensive testing by NASA revealed a second design feature of this product – its near zero operating friction. This is simply because the use of non-sliding seals essentially eliminates seal friction. Thus, the Taylor Devices Hermetic Damper provides an extremely high fidelity response to shock and vibration over a frequency band of 0-500 Hz.

This damper proved highly successful, but due to security regulations was not disclosed outside the U.S. space program until 2002. Today, more than 100 satellites are in space using Taylor Devices' Hermetic Dampers with metal bellows seals. In addition, numerous high altitude military aircraft programs are using the same Taylor Devices' technology for use in the near-space environment on reconnaissance cameras and sensors. Taylor Devices has been awarded six U.S. patents on the design.

In 1999, Taylor Devices requested that the U.S. Government allow commercialization of the company's technology for use on civilian structural engineering applications. This request was granted and three civil engineering applications have been made to date. These include:

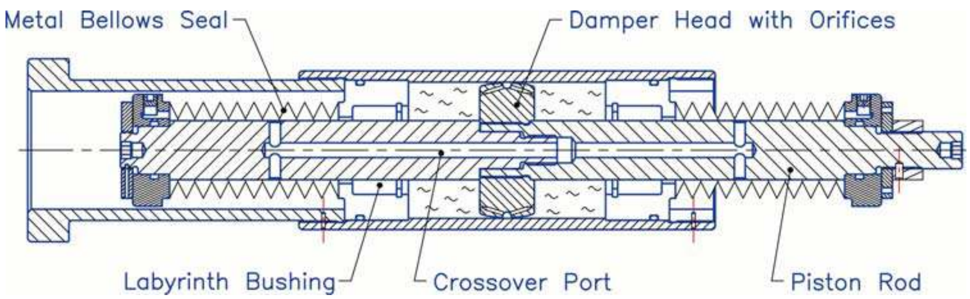
1. Hyatt Park Tower – Chicago, IL: This new build 67-story high-rise uses tuned mass damping at the building's top floor to reduce wind vibrations. Ten Taylor Devices Hermetic Dampers are used, rated for up to 20 tons output force and up to ± 500 mm deflection.

2. Millennium Bridge – London, UK: This pedestrian bridge over the Thames River became known as the "Wobbly Bridge" in 2001 when it was opened for only 48 hours and subsequently closed due to dangerous lateral and vertical swaying. The bridge was retrofitted with 37 Taylor Devices Hermetic Dampers and re-opened in 2002. Since the dampers were added, millions of tourists have used the bridge in complete comfort to cross the Thames from St. Paul's Cathedral to the New Tate Art Museum.

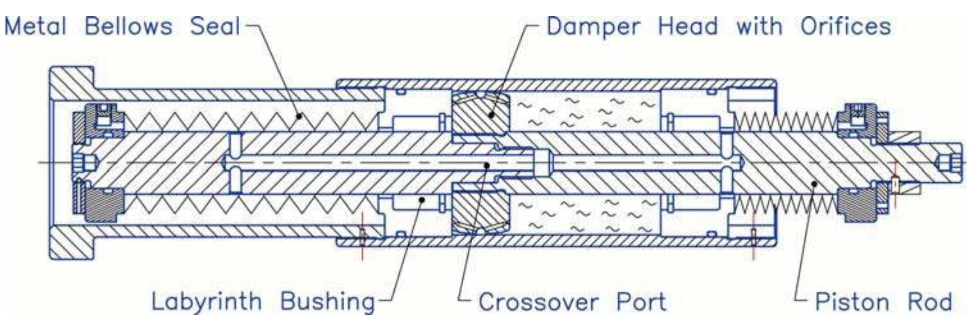
3. Bercy Tolbiac Bridge – Paris, France: This new pedestrian bridge uses four pieces of the Millennium Bridge dampers to eliminate lateral swaying of the bridge deck.

Illustrations are provided of a typical Taylor Devices Hermetic Damper in the neutral, fully compressed and fully extended states.

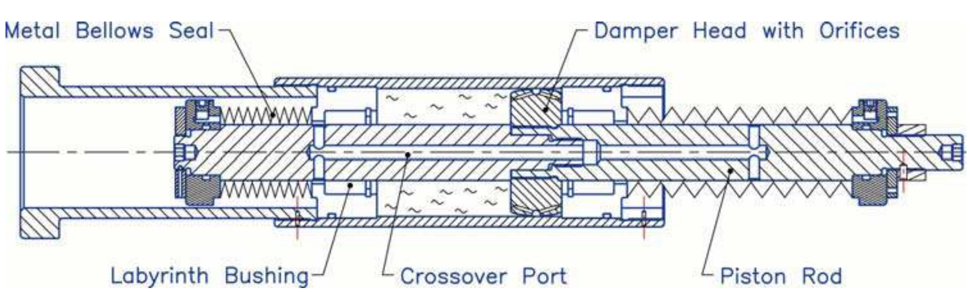
The damper primarily consists of a fluid containing cylinder, a piston rod running entirely through the cylinder, and a piston head with orifices located at the center of the piston rod. Two end caps support the piston rod, with two metal bellows attached between each extreme end of the piston rod and the associated end cap. Each end cap contains a tightly clearanced hydrodynamic labyrinth bushing to allow essentially frictionless rod motion with the piston rod supported on a thin hydrodynamic layer of fluid.



Damper in Neutral (Mid-Stroke) Position



Damper Fully Compressed



Damper Fully Extended

As the piston rod strokes at a velocity, damping pressure is generated by sweeping fluid in the cylinder across orifices located in the piston head. Depending on the type of orifice shape and type selected, damping functions ranging from $F = CV^{.3}$ to $F = CV^{2.0}$ can be achieved. The labyrinth bushings provide a restriction to damping pressures entering the metal bellows seal cavity. As the piston rod is displaced, the metal bellows extend or retract by flexural motion, which is essentially frictionless, with the bellows stresses remaining well in the elastic range. As any single bellows expands or contracts, fluid displaced by its volumetric change is transferred through crossover ports in the piston rod to the bellows at the opposite end of the damper which, by its orientation, is able to accept the entire displaced fluid volume, since its volume is changing completely out of phase with the first. Operating fluid for the damper is a pure high viscosity silicone, and primary construction materials can be stainless steel or titanium, depending on end use for the device.

Thermal expansion and contraction of the fluid must be accommodated over extremely wide temperature ranges, including those of outer space. This is done by interleaf flexure of the metal bellows. The damper is “hot filled” in a thermal chamber set for the maximum expected operating temperature, plus a suitable thermal overload factor. At all temperatures below the filling temperature, contraction of the fluid causes each bellows convolution to assume a slightly concave form when viewed from the outside. This easily accommodates the expansion and contraction of the fluid medium, and precludes the existence of any lost motion or “dead band” in the damper’s force-deflection curve. Damping tests on the long 500 mm stroke Millennium Bridge dampers revealed normal damping response to inputs of less than .004 inch deflection. Tests on military versions of this damper showed excellent fidelity to inputs of less than .0001 inch deflection.

For long service life, all damper parts are stressed for cyclic fatigue loads. The metal bellows are stressed below the endurance limit stress for the stainless bellows material, insuring a life in excess of hundreds of millions of cycles.