



Wire Rope Isolators

TECH NOTES



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A rebound from a compressive shock, back down the compression curve and snubbing into the tension curve is usually not a problem.

By their nature, wire rope isolators are self-snubbing, fail-safe and captive to the ultimate limits of the metals. They are insensitive to temperature from cryogenic up to near anneal. They resist most industrial and natural environments. The VMC Group's manufacturing process is set up to create special winding configurations to customize spring rate and deflection.

VMC Group presents tables of isolator recommendations based on type of application and applied static weight per isolator. The indicated isolator is a convenient starting point when performing selection analysis.

The tables referenced are not a substitute for proper analysis of system requirements. The key elements to performing a meaningful selection and analysis are:

- Payload weight, geometry, center of gravity, isolator location
- Dynamic input (shock spectrum, vibration amplitude and frequency)
- The level to which shock and vibration should be attenuated

Payload geometry and center of gravity are particularly important to determining induced rocking. If a shock input is defined in terms of pulse peak (g) it is necessary to also specify pulse shape and duration, i.e. 30 g, 11-millisecond half sine. A half sine pulse shape is the most common one found in specifications. Shock can also be in terms of a drop distance combined with a drop mode, i.e. vertical flat drop, edge drop, elastic or inelastic. The most common drop specified is the inelastic vertical flat drop. Vibration can be expressed as a cyclic amplitude (acceleration or distance) or varying amplitude over a defined frequency band. It could be a single disturbing frequency or it can be specified in terms of power spectral density (PSD). The latter is a means to characterize random vibration and is popular in military and space applications.

The transmission of shock and vibration can be looked at as an input and output through a box. Within the box, we may or may not modify the input to obtain the output. Given an input, and in order to define the box so it is not a "black box," we must determine what the customer's desired output is. Shock output, or response, is usually in terms of the peak acceleration that can be tolerated. This can also be called the equipment's fragility. Vibration output is usually expressed as the suspension's natural

frequency, or filtering point. From this information, we can determine the percentage of energy attenuation for various frequencies above the natural frequency. Sometimes the customer's desired output is the most difficult part to ascertain. Many equipment manufacturers will not provide the maximum acceleration and vibration levels that their products can tolerate. When they do provide data, it may be incomplete or extremely conservative.

Quite often, we size the isolation system to do the best job within reasonable size constraints. Any theoretical isolator selection must be reconsidered in light of real world limitations on equipment sway space and the isolator's physical size and stability.

Some very simple equations are used in selecting wire rope isolators. When considering shock, we use an energy method. We reduce a shock pulse to an equivalent velocity step. For a few typical shock inputs, the velocity steps are as follows:

$$\text{Half sine:} \quad V = \left(\frac{2g}{\pi} \right) A_0 t$$

$$\text{Triangular:} \quad V = \left(\frac{g}{2} \right) A_0 t$$

$$\text{Square:} \quad V = g A_0 t$$

$$\text{Inelastic vertical flat drop:} \quad V = \sqrt{(2gh)}$$

$$\text{Mil-S-901 medium and heavy weight tests:} \quad V = 120 \text{ inch/sec}$$

$$\text{Mil-S-901 light weight test:} \quad V = 150 \text{ inch/sec}$$

Where

V = input equivalent velocity step in inches/sec
 g = acceleration of gravity, 386.4 inches/sec²
 A₀ = peak acceleration of the pulse in g's
 t = time duration of the pulse in seconds
 h = drop height in inches

We can determine the amount of dynamic displacement (D_d) in inches necessary to reduce the input velocity step (V) to the desired output acceleration (G_t) expressed as g.

$$D_d = \frac{V^2}{(386 \times G_t)}$$

We can determine the shock natural frequency, f_{ns} (natural frequency of the suspension based on the shock spring rate):

$$f_{ns} = \frac{V}{(2 \pi D_d)} = \frac{(G_t \times 61.4)}{V}$$

Knowing the shock natural frequency, we can now solve for the shock spring rate from the classical equation

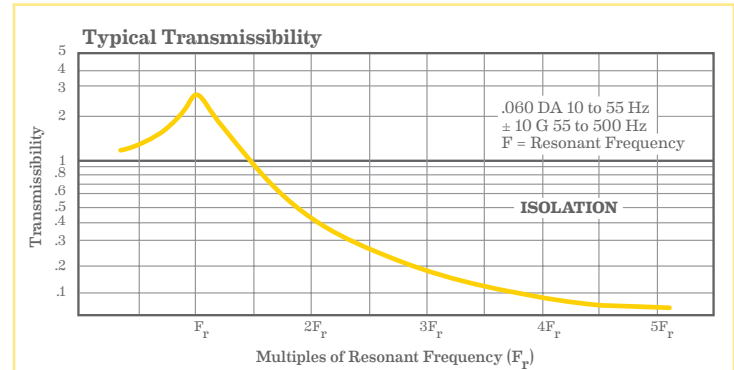
$$f_n = \frac{1}{2\pi} \sqrt{\frac{K}{m}} ; \quad K_{shock} = (2\pi f_n)^2 \times m$$

where m is mass in terms of lb-sec²/inch and *not* weight.

With spring rate (K) and dynamic displacement (D_d) established, we can now select an isolator. However, designers should take caution: The spring rates published are average. The placement of the static load on the load-deflection curve modifies the spring rate, available dynamic deflection capability and cross-axes stability. The load-deflection curves for the principal and cross axes should be requested and considered when making any selection. VMC Group's modeling software takes both the full third order curve and damping into account.

The vibration response of a wire rope system can be calculated from the equation for natural frequency using the vibration spring rate.

$$f_n = \frac{1}{2\pi} \sqrt{\frac{K}{m}}$$



Here again, we must caution designers: The published vibration spring rates are average and subject to actual dynamic conditions. Vibration attenuation efficiency for a given input frequency can be determined from either the classical transmissibility equation for first order systems or its graphical representation.

Particularly with wire rope isolators, a robust system should be designed such that variances in the effective natural frequency due to dynamic damping do not significantly alter performance in the desired band.

In other words, allow a good margin between the calculated suspension natural frequencies and input frequencies that are to be attenuated. A 3/1 or 4/1 ratio of input frequency to suspension frequency is sufficient in most cases to avoid an unwanted amplification condition.

VMC Group pioneered the wire rope isolator more than fifty years ago. Steel wire rope is strong, flexible and fatigue-resistant because it is made up of many individual strands of high-tensile strength drawn wire. When bent or buckled, it is as much an elastic element as any tempered coil spring or elastomeric mount. Due to frictional forces between the individual strands, wire rope can provide a significant level of dynamic damping — typically 15% to 20% of critical damping. This level of damping makes wire rope isolators attractive for applications that involve sweeps through resonance and transients such as shock.

To create a shock and vibration isolator from wire rope, VMC Group creates buckling elements either in the form of helical loops (Helical Series isolators), or individual arcs (Arch and Circular Arch Series). Like any buckling element, a third-order force deflection curve results. This can also be called a “softening curve.” Graphically, the curve starts from zero and is nearly linear. As load and deflection increase, the curve eventually begins to flatten. At some further point along the load-deflection curve, it becomes steeper, creating an inherent snubbing effect.

Shock is attenuated by spreading the input energy over time and distance. The flattened section of the curve is excellent for this. The load-deflection curve of a wire rope is very long given the isolator’s physical size. The isolator is a hollow, slender device capable of collapsing in on itself. For its size, it can deflect far more than elastomer and more than a coil spring. This is not to say that wire rope isolators are strictly shock attenuators and not vibration isolators. As an elastic element in a spring-mass system, it will exhibit a natural frequency and thereby form a low-pass filter for vibration energy in the same manner as any coil spring or elastomeric isolator. VMC Group does not list load ratings for individual wire rope isolators and we publish two different average spring rates. We have average static load-deflection curves available in both hard copy and electronic form for the principal isolator directions. They are always available on request. We have also chosen not to include load deflection curves for wire rope isolators and encourage you to obtain assistance from VMC Group’s Engineering Services Division at 1-800-569-8423. In almost all cases, applications assistance, including analysis and modeling, is performed free of charge and without obligation to the customer.

To determine how much load can be placed on a wire rope isolator, we must first ask what the customer intends to do with the isolator. If small amplitude vibration is the input, we can place the static load along much of the lower two-thirds of a typical load-deflection curve. The effective static spring rate is the tangent of the curve at that load point. If large amplitudes, particularly deep shocks, are to be the input, we place the static load down in the linear first third of the curve. This allows the load to ride high up onto the curve in response to the shock. In this case, the effective average spring rate is a global straight-line, end-to-end slope of the curve over the excursion. To provide average values in the catalog for design purposes, we take the vibration spring rate as the tangent slope near zero and the shock spring rate as the overall end-to-end straight-line slope over the curve. VMC Group’s modeling software takes the entire third-order curve into account. The non-linear nature of the response curve and the presence of input-dependent damping are good reasons to work with our engineering department when selecting an isolator.

Another reason to consult with VMC Group before selecting your wire rope isolators is the interrelationship between the axes of the isolator. Wire rope isolators are elastic elements in all directions simultaneously. This makes them suited for all-attitude and mobile applications and applications that involve complex, off-axis inputs. The physics of the isolator is such that most inputs produce a response with components in more than one direction.

We can manage this characteristic using properly engineered solutions that take all axes into account. It should be noted that use of the tension direction for primary shock attenuation is not recommended. This is due to the predominance of tensile loading within the cable that results in a stiffening curve.



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WIRE ROPE ISOLATORS

PLATE ISOLATOR INTEGRATED SOLUTIONS

As the world leader in wire rope technology, our custom plate assemblies and custom designed isolators have been used in various applications for over 50 years. Whether for avionics and aerospace equipment, electronics apparatus, engine gensets, auxiliary power supplies or other sensitive equipment requiring isolation, our engineering group will work with you throughout the entire design process to provide the custom solution you require.

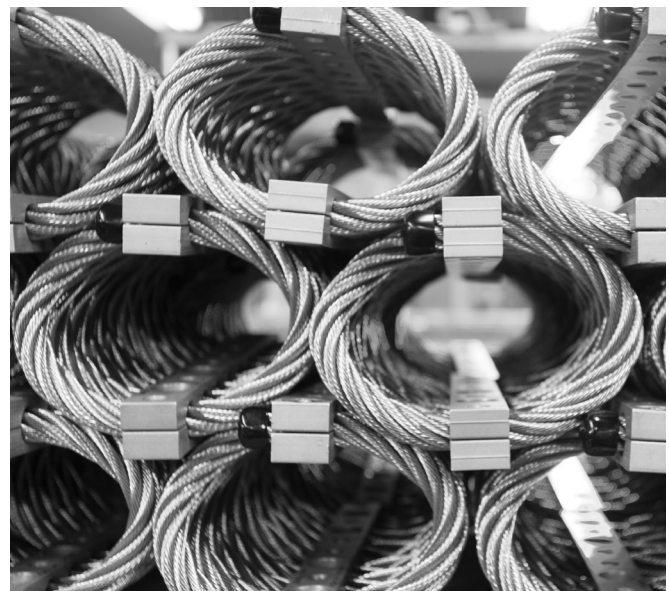
Our modeling software has an excellent reputation in the industry for its accuracy and will ensure your project is designed correctly from the beginning. Our plate assemblies and custom isolators have been designed to support weights from just a few pounds to over 100,000 pounds and take the form of special length bars, differing diameter wire and winds, custom rail systems, plate assemblies, trays and skids.

Our helical wire rope isolators have been qualified on numerous military projects requiring the following typical specifications for shock and vibration:

- MIL-STD-167
- MIL-S-901
- MIL-STD-740B
- MIL-E-5400
- MIL-DTL-62073
- MIL-STD-810
- MIL-E-5272
- MIL-C-172
- MIL-T-5422
- MIL-C-5584
- MIL-DTL-38195



Wire rope winding done at our Puerto Rico manufacturing plant.



Complete stacks of wire rope ready for delivery.



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