How to select isolators for a long service life

R. Racca, Sr., Project Engineer, Barry Controls, Barry Wright Corp., Watertown, MA

I'm looking at four isolators that didn't make it. Each went to an early death. And each provoked the same question, "Why did it fail?"

The first one reached a point where it hardly seemed to react to anything anymore. It was selected for vibration isolation—not the large strains of shock that wrecked it.

Here's a sorry-looking specimen that had a run-in with the wrong washer. The snubbing washer diameter was too big for the tube. When it was bolted down it extruded material on the tube and crushed the elastomer.

This one looks as if it had been sandpapered to death. It was. It was installed on a crawler used for digging out a sand almost as fine as talcum powder. Sand got to it because the mount was unbonded.

The last is a natural rubber mount. It was mounted on a transmission using a very detrimental oil. It also was subjected to extreme heat. The heat made the rubber gummy and the oil did the rest.

Unusual failures? They should be, but, unhappily, they aren't. They represent four common sources of trouble—elastomer fatigue, improper installation, incompatible external and internal environments.

Then how can we make sure that the isolators we install in our products will continue to give enduring value? How to guarantee that these relatively inexpensive items aren't suddenly going to make a costly product look, feel and sound bad—whether it's a recreational vehicle, a heavy-duty truck, or farm or construction equipment?

Let's look at the factors that determine the longevity (or early retirement) of isolators—and build a checklist.

The first five factors seem so elementary that sometimes an "obvious" requirement is overlooked. The next seven separate the engineers from the accountants.

Five preliminary factors

Let's keep in mind, of course, that a dynamic system has three basic elements: the equipment (machine, motor, instrument, etc.); the support structure (floor, baseplate, etc.); and the isolator or mount (elastomeric pad, spring, etc.).

1. *Product application.* What's the recommended or likely use of the product? What extra degree of protection should be provided? What serviceable lifetime can be expected? We want to avoid both underprotection and expensive overprotection.

2. *Personnel and equipment to be protected.* The isolators must provide for both the safety and the comfort of the operator and, possibly, passengers. Often they must reduce noise that affects personnel in surrounding areas. They must reduce fatigue in the structure of the vehicle. Sometimes they must protect communication or other special equipment.

3. *Sources of vibration, shock and noise.* These include the power plant and, often, pumps. Recreational vehicles are usually subject to rough terrain or choppy waters. Farm equipment must operate on rough terrain, often while hauling attachments. Construction equipment may have special requirements necessitated by such operating functions as loading, digging and scrapping.

4. *Other destructive conditions.* If the major demons are vibration, shock and noise, there is a legion of smaller ones including: lubricants; fuels; hydraulic fluids; chemicals; sunlight; ozone; humidity; corrosive atmosphere; sand and dust; excessive heat and cold.

5. *Applicable specifications with anticipated vibration, shock and noise input levels.* These include: operating speeds of power plant; EPA noise regulations; human vibration tolerance criteria; rollover protection for off-highway construction equipment; typical shock input expected (perhaps 2 to 5 g for a

FIGURE 1

DESIGN CURVE

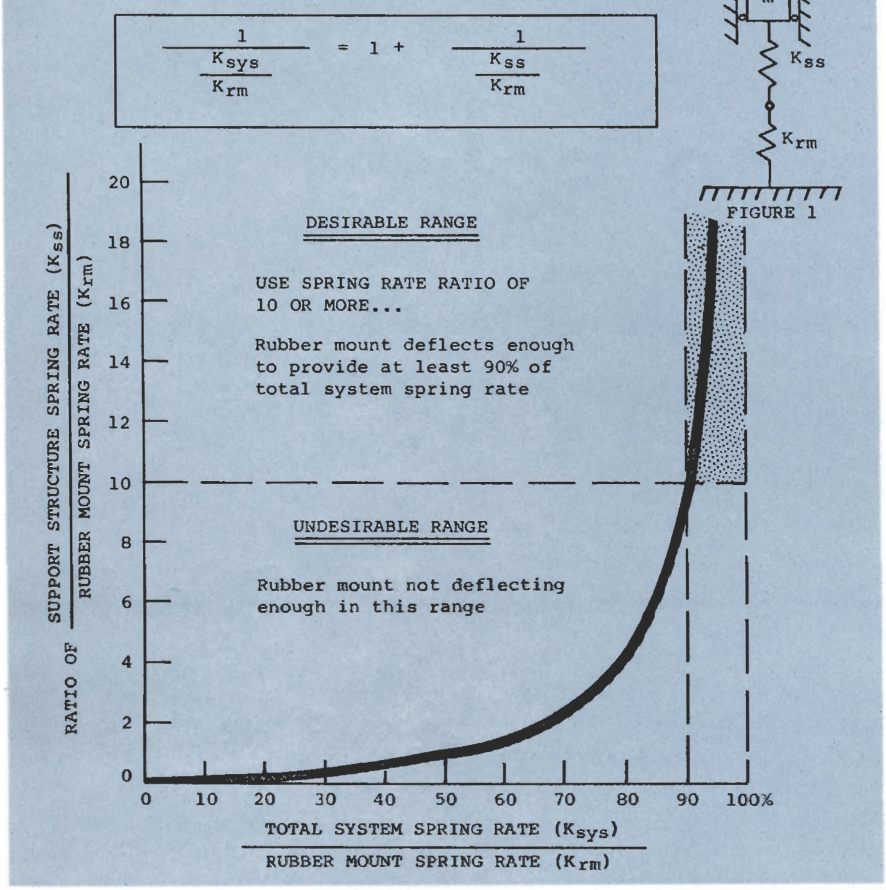


FIGURE 2

TYPES OF LOADING

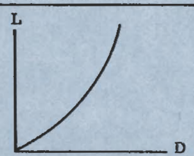
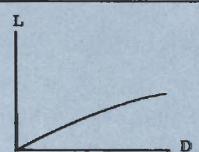
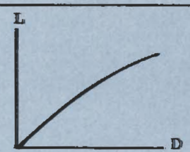
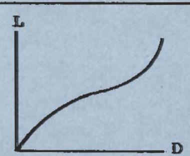
NO.	TYPE OF LOADING	LOAD DEFLECTION (L/D) CHARACTERISTICS	COMMENTS
1.	Compression		Good for gradual snubbing and for shock mounts.
2.	Shear		Good for relatively large deflections and vibration mounts. May be poor for shock inputs since severe or abrupt bottoming of equipment may occur.
3.	Tension		Generally poor for most vibration and shock mounts due to tension load on bond.
4.	Buckling		Good for energy absorption under shock inputs due to relatively large area under L/D curve.

TABLE 1

planter, 8 to 10 g or greater for a motorcycle).

Those of us who work all the time with isolators see a surprising number of failures caused by oversight or miscalculation of these "easy" factors. But if we handle them properly we'll have less difficulty with the following group of not-so-easy factors.

6. *Recommended spring rate and frequency of the support structure.* An elastomeric mount must move if it's to isolate vibration. And generally, the more it moves or deflects, the better the isolation. But relative motion across the mount may be inadequate if your support structure, equipment structure or test fixture isn't stiff enough.

These items are stacked in a series arrangement with your mount, so they carry the same force and will deflect proportionally to their respective spring rates. If they move more than the mount, they actually nullify or limit the isolation you need from the mount itself.

The spring rate of your support structure should be at least 10 times that of the mount(s) you are using. This will ensure that at least 90% of your total system spring rate is from the mount, and only 10% from the support structure.

Your support structure spring rate can be calculated from the classical strength of material formulas, or obtained from experimental load deflection tests on your system.

Now let's consider an example of the recommended frequency for a support structure.

Since frequency is proportional to the square root of stiffness with weight and damping held constant, Figure 1 (Design Curve) can be used to conclude that the natural frequency of the support structure should be at least three times that of the mount.

This three-times factor is based on using the square root of a stiffness ratio of 10 or more. (It's assumed that the system is a one-mass and one-degree-of-freedom system.)

Your supplier can give you the natural frequency of his mounts at insert inside or outside an elastomeric section in a mount is to obtain more constant stress on the elastomer. Unbonded inserts can easily set up relatively high local stress concentrations in the mount and reduce service life. The bonded insert helps to distribute the stress throughout the volume of the elastomer, thus reducing unit stress.

To avoid local stress concentration, we can use fillets, radii and generous overhangs of the elastomeric section. We have to round off sharp corners of metal inserts and support structures where the elastomer will be making contact. We must be sure that metal snubbing washers and/or support structures installed against the elastomer are big enough so that their edges don't cut into the elastomeric surfaces.

A caution: some mounts designed to support loads in the vertical direction shouldn't be used to support loads in the lateral direction —if the metal inserts cause high local stress concentration in that direction. Double check your supplier about how to load a mount.

Preloading helps prevent zero stress reversals. It also helps to keep a constant stress on the bond to increase the service life of the bond itself. That's why a shear mount is usually preloaded in the compression direction–to keep stress on the bond.

12. *Selecting specific isolators, mounts and systems.* Now that we're in a position to know what we want, we go to a supplier's catalog.

Let's say we're looking for bonded ring and bushing mounts to protect against severe shock and vibration and to reduce structure-borne noise. Against our known desirable features for the isolators we want, we check the supplier's brief description: "Bonded metal center cylinder. Built-in preload. All attitude load capacity. Natural frequency down to 12 Hz. Rebound protection against severe shock inputs. Load ranges of 15 to 1600 lbs."

We'll want such specifications, of course, as size and weight. We may require mounts that provide a cushioned bottoming, or that have other features such as strong secure attachment, built-in snubbing, fail-safe design, and ease of installation.

So far so good. Now our checklist pays off as we go for critical information. How do the mounts stand up to this or that destructive or deteriorative condition? What's the natural frequency of the mounts within a particular range of varying loads? What's the suggested limit for Q for a particular application? At the durometer we plan to use, what's the acceptable static strain level? What are the loading recommendations for this type of mount?

And that should bring us to a happy ending. When we've taken care of these 12 factors, we've sent the big and the little demons flying off for good—leaving us with isolators that should protect our product happily ever after. □

Reprinted from **DESIGN NEWS,** January 1982

First, then, we need to understand the variables affecting the heat absorbed. Figure 4 gives these.

The heat generated (P) by a mount when expressed as power (watts) dissipated at resonance is:

$P = 3.63 \times 10^{-2}\ (W)\ (f_n)^3\ (T_{(max)})\ (SA)^2$,

Note that the power dissipated at resonance is proportional to the natural frequency cubed. This is why an elastomeric mount should be relatively low in natural frequency to prevent heat build-up in the mount from becoming excessive. (Most commercially available mounts are in the 10 to 30 cps range of natural frequency.)

Now, for comparison of mounts, the power dissipated (watts) at resonance is divided by the volume (cubic inches) of elastomer used in a mount. This quotient

$$Q = \frac{P}{V}$$

should be limited to certain numerical values for optimum life service of mounts. Recommended is a Q value of 9.40W/cu inch for a torsional vibration mount in engine systems. Since these Q values have only relative meaning depending on the type or shape of elastomeric isolator and how it's used, we need to contact a mount supplier for the suggested limits of Q for an application.

10. *Determining strain on the mount.* This is another key factor that helps to make or break an isolator's longevity. Usually the lower the durometer of the elastomer, the more the permissible strain.

Static strain (SS) is equal to the total deflection (TD) of a mount divided by the free thickness (FT) of the elastomeric section thickness used in the mount. Total deflection (TD) is the sum of preload deflection (PD), static deflection (SD), and/or creep deflection (CD). For example:

TD = PD + SD + CD

Some typical input values:

PD = 0.03 inch

SD = 0.07 inch (for 12 cps natural frequency)

CD = 0.03 inch

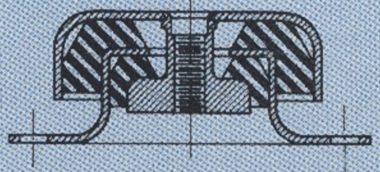
FT = 1.0 inch

$$SS = \frac{TD}{FT}(100\%) = \frac{PD + SD + DC}{FT}(100\%) = \frac{0.13}{1}(100\%) = 13\%$$

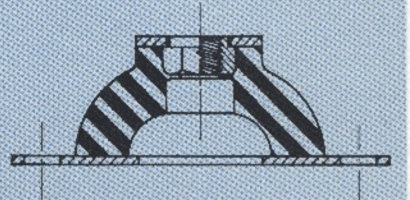
Figure 5 (Table for Recommended Static Strain Levels) indicates that this static strain level should be acceptable for a compression mount.

11. *How to handle stress on the mount.* For the longest service life of mounts, the stress should always be plus or minus and never pass through a zero stress value.

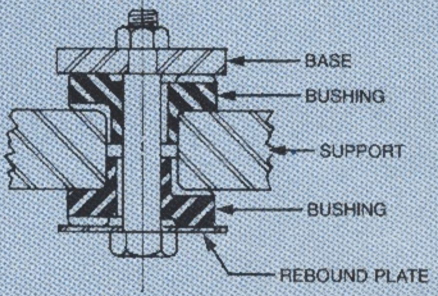
A major reason for bonding of an



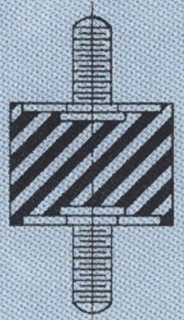
Typical compression isolator handles compression loads in all directions. Preloaded, unbonded rubber elements have load range from 12 to 1800 lb/mount.



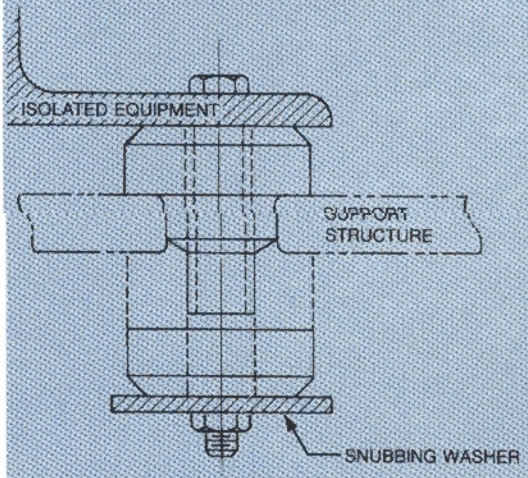
Buckling column isolator uses fully bonded element for load range from 60 to 260 lb/mount.



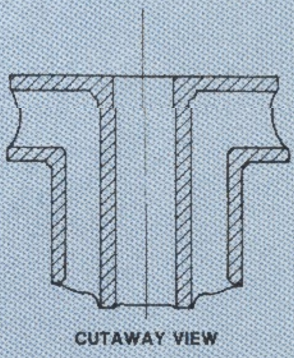
Unbonded ring and bushing isolators have ribbed protrusions for gradual snubbing under shock. Load range, 1 to 350 lb/mount.



Bonded shear or compression isolator has relatively high stiffness in compression compared to shear. Load range, 3 to 260 lb/mount in compression.



Bo.ded bushing with rebound ring is preloaded in axial and radial directions, can be loaded in all directions. Load range, 40 to 1600 lb/mount.



Shouldered core design has fully bonded element, can be loaded in any direction. Load range, 50 to 2700 lb/mount.

Figure 3. Changing stiffness and/or damping

Choice	To change stiffness and/or damping	Comments
1	Change durometer.	Start with 55 duro. Change two duro levels softer or stiffer. No tooling change required.
2	Change elastomer type.	Especially for damping changes. No tooling change required.
3	Change elastomer shape.	Tooling change required.

Figure 4. Variables affecting heat absorbed

Description of Variable	Symbol	Units
Weight carried per mount	W	lbs.
Natural frequency of mount	f_n	cycles/sec. or Hz
Maximum absolute transmissibility of mount at resonance	$T_{(max)}$	dimensionless
Single amplitude input at resonance	SA	inches

Figure 5. Table for recommended static strain levels

Type mount	Duro. (Shore A)	Rec. SS levels
Rubber in compression	35	15% maximum
	45	14
	55	13
	65	11
	75	10
Rubber in shear	35	45
	45	40
	55	35
	65	30
	75	25

various loads. He should also have a frequency vs. load table (or curve) to depict the affect of varying loads.

7. *Type of loading.* An isolator, mount or system can be a combination of two, three or all of the types of loading shown in Figure 2 (Types of Loading). For instance, an elastomeric compression mount, if installed at an angle instead of the usual vertical position, becomes a compression-shear combination mount when loaded in the vertical downward direction. When loaded in the vertical upward direction, it becomes shear-tension combination mount.

8. *Type of elastomer.* If your isolators are going to be subject to particular destructive or deteriorative conditions, you can either check your supplier for information or conduct your own tests, or do both.

A mount should have the highest possible tensile strength. A relatively high strength of 2500 psi or more usually means relatively high tear strength and a good fatigue or flex life for a mount. Here are some typical tensile strength values:

Material	*Tensile Strength (Psi)*
Natural Rubber	3500
Neoprene	3000
Silicone	1500
Polybutadiene	2500

(Additives may change the values.)

The best possible tensile strength has been achieved when, in a destructive test of the mount, the elastomer breaks before the bond.

How to choose a durometer? Our experience is that, especially for prototype mounts, we should start with a 55 durometer compound, then select the mount shape. Why? If we start with a 55 duro stock, we can go two compounds softer—to a 45 or 35 duro—or two compounds stiffer—to 65 or 75 duro...to change our spring rates as needed.

Here's a quick guide to usable durometer range compared with some everyday products:

Durometer	*Familiar Products*
35	Stationer's rubber band
45	Inner tube
55	55 duro stock
65	Tire tread
75	Shoe sole

By using a 55 duro stock, and shifting as necessary, we can make stiffness changes without tooling changes—and lower our prototype development costs. Changes in damping are also easy to make. For example, a change from natural rubber to polybutadiene produces more damping. Figure 3 is a handy guide to the most economical changes.

9. *Determining internal heat build-up in the elastomer under resonant conditions.* Rubber or elastomer converts the mechanical energy of internal friction into heat. Excessive heat can limit or end the service life of a mount. Controlling this factor helps to assure that the elastomer lasts at least as long as the product it serves.

When rubber is stretched, it gives off heat (becomes exothermic). When it contracts after being stretched, it absorbs heat (becomes endothermic). The Joule Effect in rubber also indicates that stretched or highly strained rubber will contract as heat is applied or absorbed.

Natural rubber and other elastomers are poor heat conductors. As rubber stretches and contracts in a mount, it absorbs heat and stores it. Compare rubber with about 1.2 relative thermal conductivity, for example, with steel at 310 and aluminum at 1475.