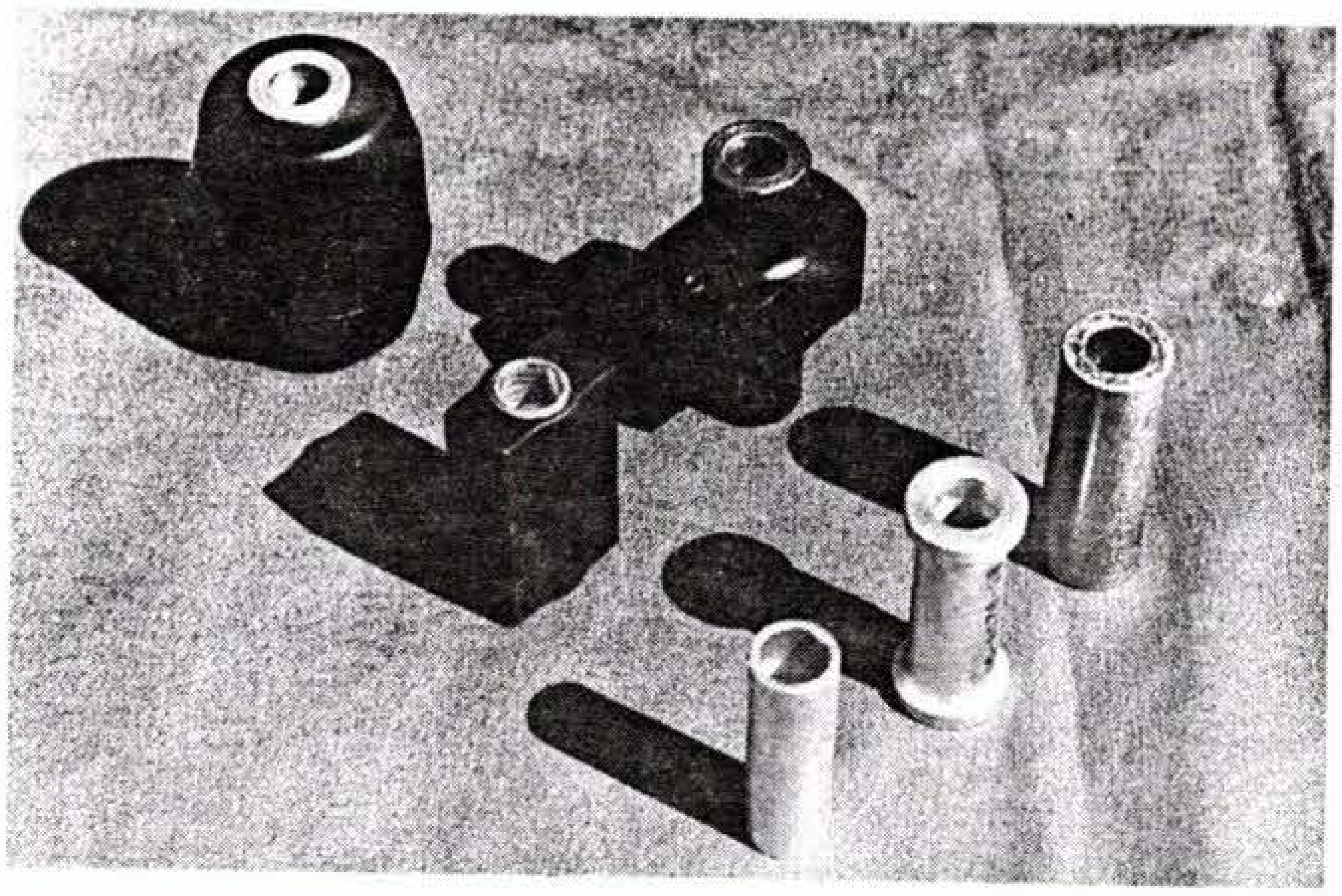
Defeating Bad Vibes

Without good engine vibration isolators, there's a whole lot of shaking going on.

BY PAUL BARNES



Vibration-isolation systems use many types of spacers, including (from top, left) silicone gel, molded rubber and plain metal.

A lot of builders take the process of mounting an engine on their homebuilt aircraft for granted. But there's more to it than just bolting an engine onto the firewall and flying away. Without a vibration isolation system to reduce the vibration created by the engine and propeller, an airplane can feel like an eggbeater. Even worse, vibration can cause serious damage to the airframe in flight with disastrous results.

When a vibration isolation system is required for a particular aircraft/engine combination, several things should be considered before choosing one. These include engine type and attach point locations, propeller type and supported mass properties, engine support structure flexibility, aircraft role (aerobatic or cross-country cruiser), under-cowling temperature, and isolator envelope. If the parameters of any of these factors are changed because of builder modifications to the original plans, the type and performance of the engine vibration isolator may also need to be changed. Failure to do so can result in shortened isolator life, inadequate isolation or unacceptable engine motion.

Selecting an isolator simply because it fits the space provided for it is not a good idea because the wrong isolator can actually amplify engine vibrations transmitted to the airframe. This can make instruments in the cockpit unreadable or cause engine/airframe components to shake loose.

This kind of extreme cockpit vibration is usually experienced when the driving force—engine/propeller imbalance—excites a natural frequency of the total installation. The system can be tuned by changing isolator characteristics to avoid the normal operating rpm of the engine.

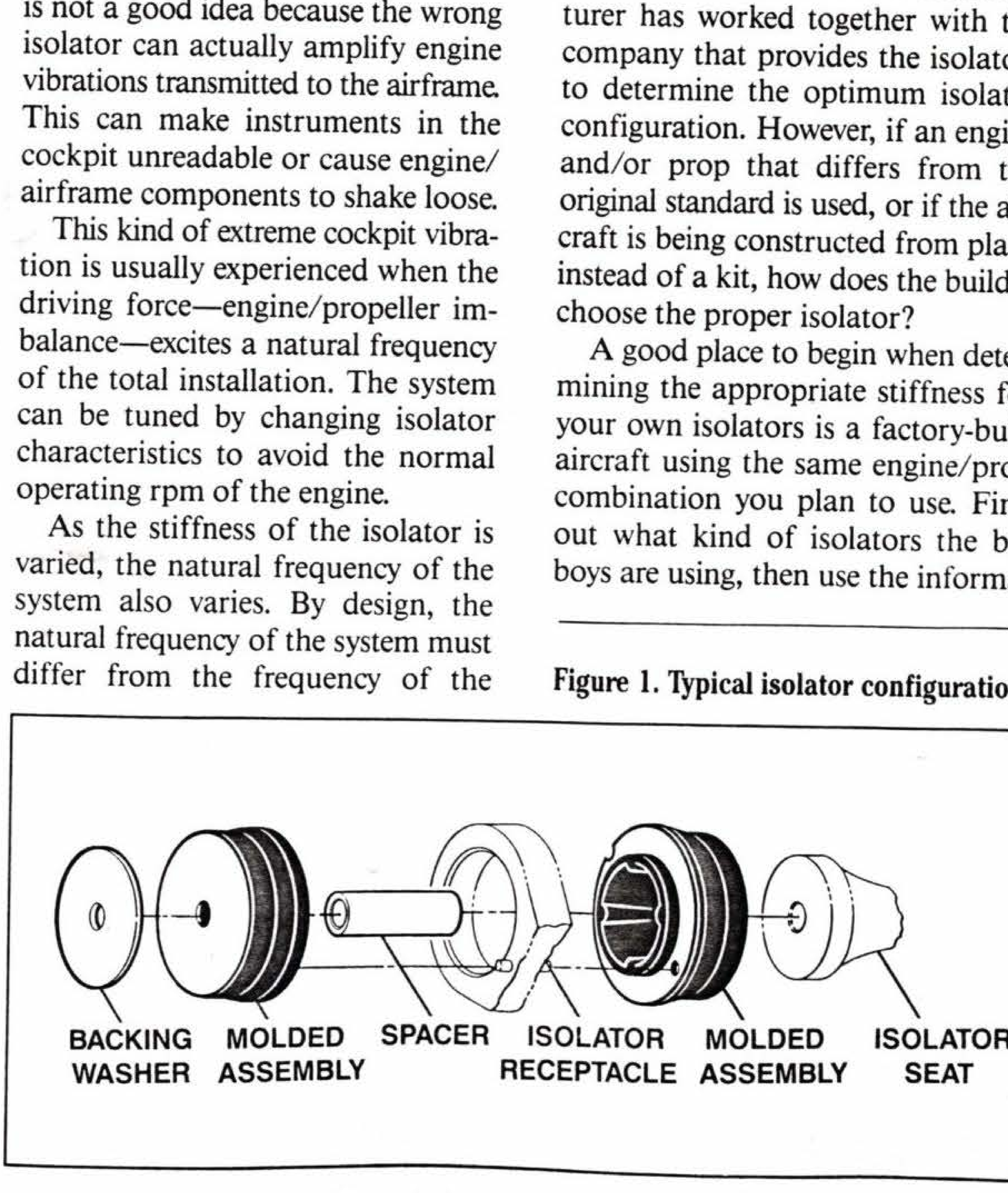
As the stiffness of the isolator is varied, the natural frequency of the system also varies. By design, the natural frequency of the system must differ from the frequency of the driving force. Simply stiffening the mounts will drive the resonant modes up, but it may also reduce the desired isolation effect. Softening the mounts will bring the resonant modes down, but increase engine deflections. In the end, determining the stiffness/softness of a mount is a compromise between comfort and allowable engine motion.

Choosing the Right Isolator

Engine isolators are normally supplied as part of the engine installation portion of a kit. The kit manufacturer has worked together with the company that provides the isolators to determine the optimum isolator configuration. However, if an engine and/or prop that differs from the original standard is used, or if the aircraft is being constructed from plans instead of a kit, how does the builder choose the proper isolator?

A good place to begin when determining the appropriate stiffness for your own isolators is a factory-built aircraft using the same engine/prop combination you plan to use. Find out what kind of isolators the big boys are using, then use the informa-

Figure 1. Typical isolator configuration.



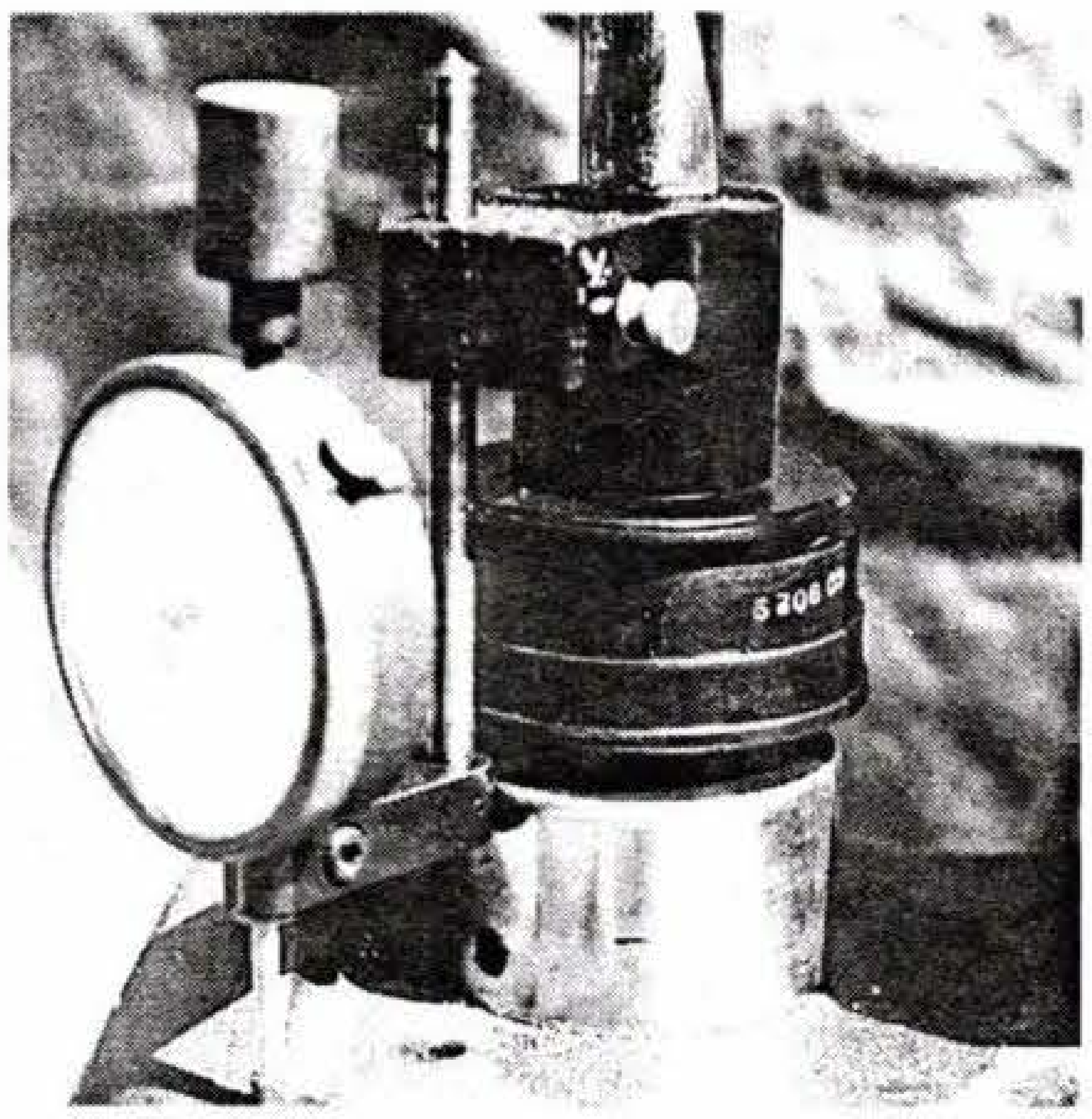
ILLUSTRATIONS: PAUL BARNES & IAIN MACPHERSON tion in this article to determine if that same hardware is acceptable for your purpose.

Bear in mind that the intended role of a factory-built aircraft may differ greatly from that of your homebuilt. For example, if you intend to perform aerobatics in your plane, the isolators in the factory plane will probably not be adequate to maintain the engine within its envelope and prevent it from contacting aircraft structure during high-load maneuvers. As a rule of thumb, use stiffer isolators on an aerobatic plane than those on a factory aircraft with the same engine/prop combination.

Commercially produced aircraft engine isolators have a fail-safe design. Home-designed and -built engine installations may utilize elastomeric elements that were not originally designed to support a heavy aircraft engine along with normal maneuvering and landing loads. Every installation should be checked to ensure it is fail-safe by incorporating the following provisions.

Large backing washers whose diameter is larger than the hole in the truss or engine attach points should be placed on the outside of the isolator. If the rubber portion of the isolator fails, the washer will still hold the engine on the airframe. These large washers should be steel and are normally 0.125 inch thick. Some commercial piston engine aircraft mounts incorporate this fail-safe feature simply by making the outer metal of the mount (which is vulcanize-bonded to the rubber) larger in diameter than the hole in which the isolators are placed. Check the isolator outer plate to see if it is steel or aluminum. If it is steel, you're all right; if it's aluminum, you should change to steel.

This photo shows how a molded spacer fits snugly inside the molded vibration isolation assembly.



A spring tester is used to determine the stiffness of molded assemblies.

Types of Engine Mounts

Homebuilts are powered by a wide variety of engines. Most engine mounts are either a bed configuration or a rear-attach configuration. A bed system has all four attach points in the same vertical plane like the four posts of a bed. A rear-attach system has all four attach points in the same fore and aft plane so that the engine is cantilevered from the firewall. Other attach points exist, but will not be discussed here.

The principle of focalizing a mounting system is used on a number of aircraft engines and is also used on many automobile engines. Bed, rear-attach or a combination mounting configuration can be oriented to focalize or semi-focalize the installation. In a focalized mount system, the bolts running through the mounts all point to a common location. In a semi-focalized system, the bolts point toward a common axis. The angle and location of the focal point is determined by the orientation of the pads where the isolators are attached to the engine. The point of focalization is usually beyond the c.g. of the entire supported mass, or in the case of a semi-focalized system, a longitudinal axis that runs through the c.g.

When a system is focalized, the isolators attempt to act as if they were in the same plane as the c.g. This is the ideal situation, but it is just not practical for most aircraft engines. Instead, you can vary the stiffness of the isolators to create a situation where the system is soft in the torsional direction to isolate out-of-balance vibrations, but remains stiff in the fore and aft direction to restrain engine motion and react to thrust loads.

Flight loads on an engine are effectively applied at its c.g. Because the c.g. and the point of focalization are in approximately the same location or plane, the isolators react equally to any load applied to the engine.

Couple forces such as pitch and yaw primarily produce a rotation about the focal point, a property that enables isolator stiffness to be tuned

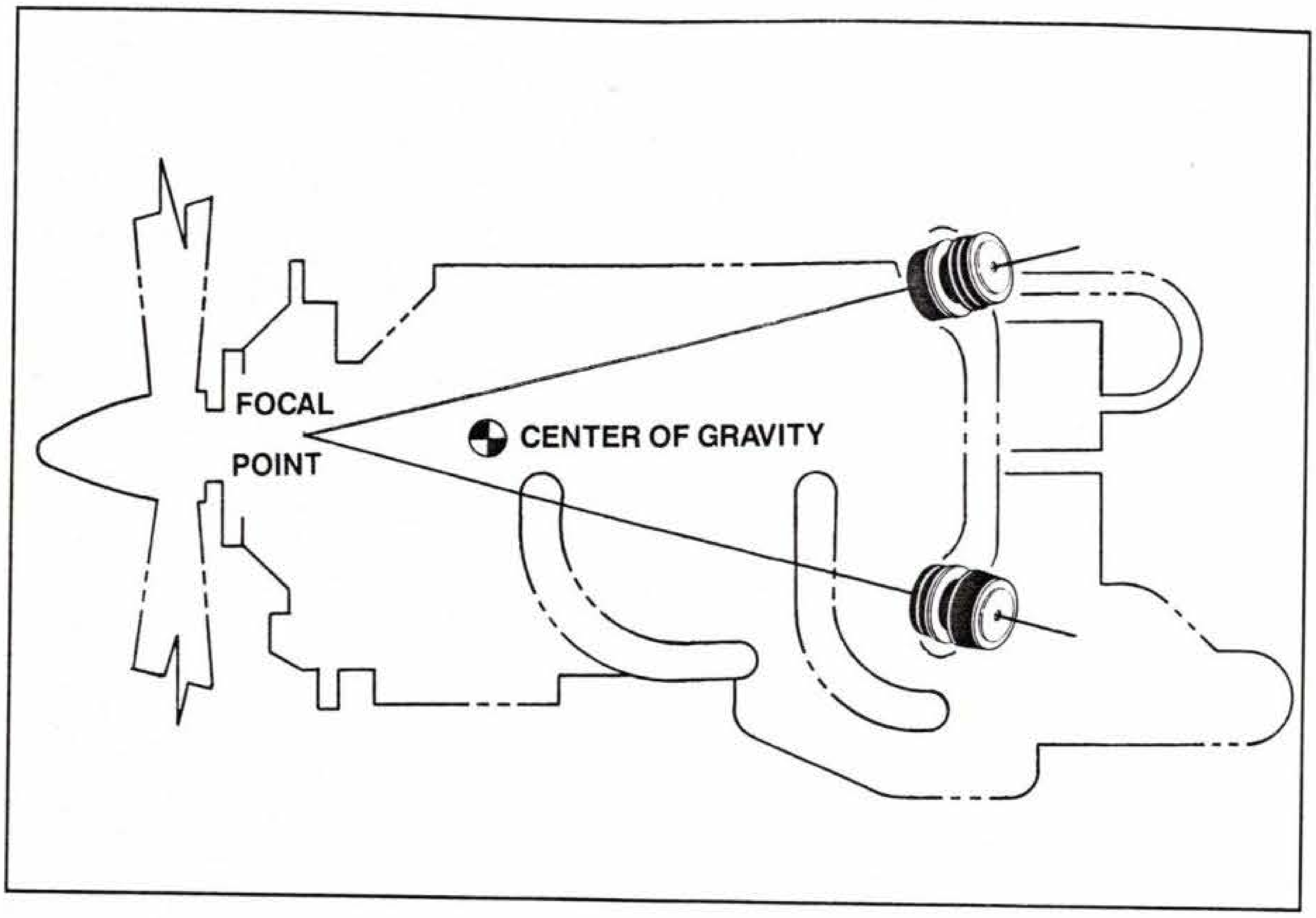


Figure 4. Isolator system in a fully focalized rear-mount configuration.

VIBRATION

continued

underneath a cowling. These fluids attack the elastomer-to-metal bond and the elastomer itself, causing it to swell. Use a household degreasing solution such as Formula 409 or Fantastic, or even plain alcohol to wipe residual fluids off the mounts during periodic inspections.

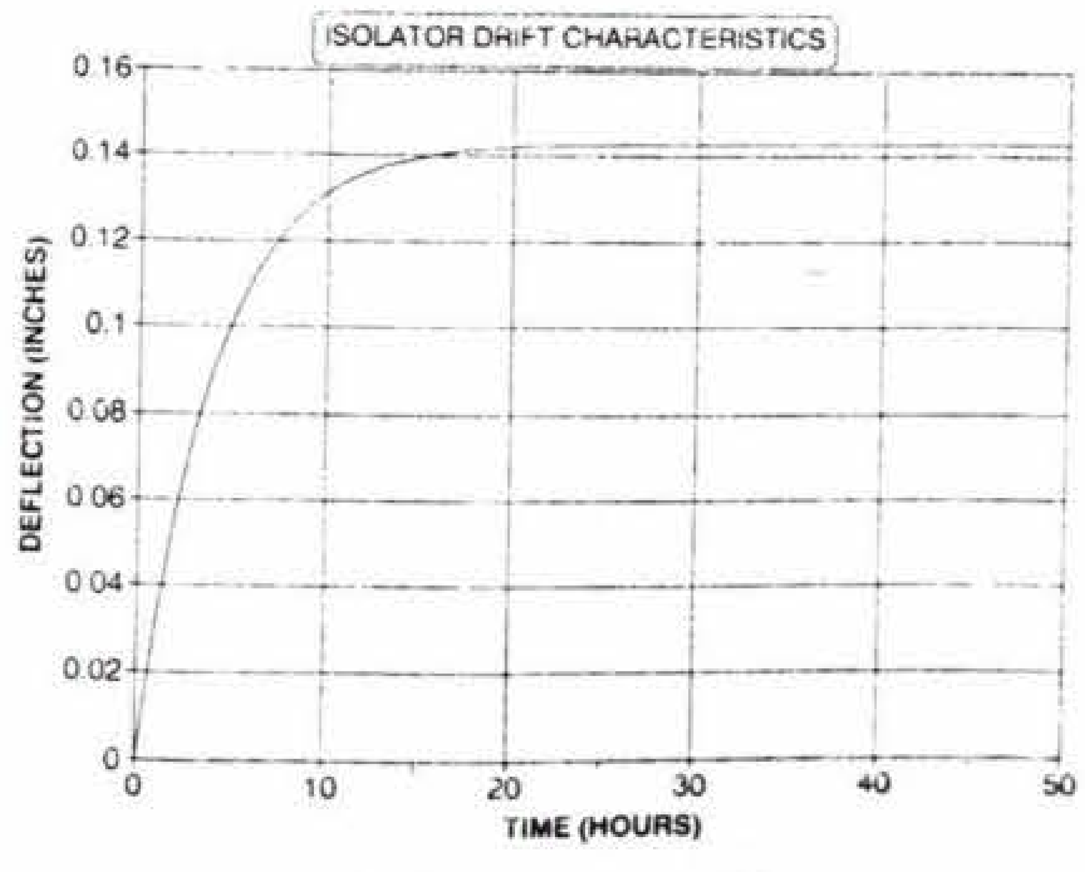
Elastomers, like other viscous fluids, "creep" during their service lives. After installing an engine but before making any adjustments such as spinner-to-cowling alignment, the engine should be allowed to sit for a 24-hour period. Elastomer creep is logarithmic, so the creep measured during the first 24 hours will exist forever, but the deflection will not double for many years under normal operating conditions. The isolators take their initial set at this time (See Figure 5). Afterward, the engine can be aligned by placing shims between the isolators and the engine. The fail-safe washers already discussed make for great shims and are available from any isolator manufacturer. These same shims are also useful when aligning the engine to allow for dimensional discrepancies that may have been inadvertently built into the installation. But be careful not to remove any engine offset that is intended to compensate for torque, gyroscopic moments or aerodynamic forces.

Anatomy of an Isolator

A typical isolator is made of two molded elastomeric pads and a spacer placed between them. This spacer ensures the attachment bolt, which runs through the isolator, can be torqued to its desired value. The spacer must be used and the through-bolt must be properly torqued or the bolt will fail from fatigue. In many cases, the two molded pads are of a slightly different configuration or stiffness. These molded components must be installed correctly. Usually, the stiffer molded components are loaded in compression when the aircraft is in a 1-g configuration. The manufacturer can clarify the correct installation configuration for your application.

The stiffness of the two molded components can be determined with a valve spring tester. A load of about 200 pounds is applied to the outer plate of the molded assembly and the amount of compression measured. The molded assembly with the least deflection is obviously the stiffer and should be placed on the aircraft so as to be loaded in compression by the weight of the engine. The softer molded assembly should be placed on the other side of the mount with a spacer tube between it and the mount. The spacer tube allows the bolt to be torqued and ensures the correct preload on the elastomer.

Figure 5. Isolator drift/set characteristics.



Preload (the strain resulting from the installation) is critical. If it is excessive, isolator life is dramatically reduced; if it is insufficient, isolator stiffness is reduced.

When an isolator is loaded in a radial direction (perpendicular to the direction of the bolt), the spacer tube will—if deflected enough—contact the structure around which the molded pads are placed. This ensures that the isolator is not over-stressed during high loading. When the spacer tube contacts the structure, a metal-to-metal contact is made, stopping the mount from functioning as an isolator. The stiffness of the isolators should be great enough so that this "short-circuit" of the system does not occur under normal operating conditions, but occasional metal-to-metal contact can be expected even in a well-designed installation.

As a precaution, some isolators have either a spacer with a thin layer of stiff elastomer molded around the spacer or a molded assembly with extra rubber on the inside diameter of the flanged metal plate to soften the impact when the spacer contacts the structure during high-load operations. Other spacers have a block of elastomer molded around them to stiffen the entire isolator in the radial direction. Because engine torque loads are reacted in the radial direction, use of a molded spacer should be considered for high-torque or aerobatic installations.

Special Precautions

If you use a molded spacer, drill

and pin the engine support truss to prevent isolator rotation during use. The spacers are captured inside the isolator and their orientation is dependent upon the orientation of the isolator. Again, the isolator manufacturer can provide the pin size and location for the specific mount being used. Molded spacers are not the same as those that are surrounded by a bag filled with a silicone gel.

These special gelled spacers are used on some isolators to improve their damping characteristics. The uncured silicone provides auxiliary damping for an isolator much the same way a shock absorber does a car. There are also isolators available with an internal damping capacity made possible by special elastomer compounds. These perform the same as isolators with silicone gel dampers, but without the potential for leaking.

Once the isolators are installed, the engine should be run at various power settings, and vibration levels monitored. If transmitted vibrations are above acceptable levels, a different isolation system should be considered. Pay close attention to engine motion during high-power settings and shutdown because that is when engine motion is the most severe and most likely to cause cowling interference.

The bolt that runs through the isolator must be a high-grade aircraft-quality bolt with appropriate torque values. Locking wire, a cotter pin or tab washers must be used to ensure the proper amount of torque is maintained.

If you've done your homework and used the recommendations in this article to select the proper isolators for the job, they should be capable of performing satisfactorily for as long as 10 years. If not, it won't take you long to realize it. □

Paul Barnes is an application engineer with Barry Controls, of Burbank, California. He manages a program that designs engine vibration isolators for general aviation aircraft. Ever since his first visit to Oshkosh in 1989, he has been an avid homebuilding enthusiast. He flies a KB-2 Gyroplane and is also involved in a Stewart S-51 Mustang project. —Ed.