Noise Suppression

This Falco Construction Note replaces Advanced Builder Memo “Chapter 46 Noise Suppression”.

Noise Sources

Cockpit noise is simply unwanted sound that has become objectionable due to its high level. Most of this noise originates outside the aircraft and comes into the cabin. There are several sources of noise. These include canopy leak hiss, propeller noise, engine exhaust, other engine noise including accessories, and wind noise.

If the canopy is not sealed, there will be a high-pitched hiss which is extremely objectionable. On some aircraft, such as the SF.260, the noise can be an unbearable shriek of whistling sounds. On a Falco, this noise is easily eliminated with the canopy seals supplied with the canopy kit.

Propeller noise originates at the tips of the propeller and is a high, “singing” noise which you can hear when you change the propeller rpms. The windshield thickness determines how much of this noise enters the cockpit. The propeller noise in a Falco is not great, since we use a 1/4” thick windshield.

The engine exhaust noise originates at the exhaust tailpipe openings and is transmitted through the cabin walls, firewall, and nose gear bay into the cockpit. This is the loudest and most objectionable noise heard in the Falco. It is a low pitched sound that is made to sound “hollow” by the reflections of the canopy and windshield.

Other engine noise is the noise of the engine and accessories, excluding the sound of the exhaust. This is the noise you hear from a boat engine, where the exhaust is well muffled by underwater discharge.

Wind noise is the sound of the rush of air around the fuselage. If you have ever seen Bob Hoover or Duane Cole put on an acrobatic air show with the engines off, you’ve heard this noise. It is the same sound you hear in your house when the winter winds blow up a storm. For the most part, this noise is a “minor player” in the symphony of noises of the cockpit. It’s quite easy to quantify—all you have to do is to cut the engine off and measure the noise. When the landing gear is extended, the Falco can produce a surprisingly loud low-pitched whistle from the landing gear bays.

Transmission of Sound

Transmission of sound through a cabin wall is explained by the fact that a sound wave upon striking a wall forces it into vibration. Thus, the cabin wall itself becomes a source of noise. If vibration of the cabin walls could be eliminated, little or no sound would be transmitted. Unfortunately, you would have to increase the mass of the wall to a level high enough to absorb all of the energy of the sound wave. This is completely impractical. The problem is to simulate the sound-reduction characteristics of a heavy wall, while keeping added weight down to an acceptable level.

Heavy walls are inherently rigid—very little sound energy is converted into flexural vibration and most of the sound waves are reflected. Flexible panels tend of vibrate freely when disturbed by sound waves. With a metal aircraft, this can be quite a problem. Flexible panels are curved where possible; stiffeners are added; and heavy energy-absorbing foams are added to the inner face to dissipate the sound that does come through. These measures are not required with the stiff plywood fuselage walls of the Falco.

There is a big difference in the composition and function of a damping system and a sound absorbing system. Both may be foams, but there the similarity stops. A damping material acts like a shock absorber on a car, absorbing and dissipating energy. The material is designed to have a high loss factor—a measure of damping efficiency calculated by dividing energy stored into energy dissipated.

Scotch Y-370 is a vibration damping foam that is very widely used in metal aircraft. The heavy, 1/4"-thick, dense polyurethane foam has aluminum foil on one side and a pressure sensitive adhesive on the other. Aircraft Spruce and Specialty sells Scotch Y-370 as "Sound and Vibration Damping Tape." Remember, this type of material is a shock-absorber for vibrations in a panel—it is not a sound absorbing material.

Sound Absorption

Engineers concerned with the propagation of sound build echo chambers for the maximum reflection and sustained echoes. There are two requirements for such a chamber: (1) hard, smooth surfaces on the walls, and (2) non-parallel walls. Both of these requirements are fullfilled by the un-upholstered Falco cockpit. Once sound has entered the cockpit, it will continue to echo by reflection until its energy has been dissipated by encountering sound absorbing materials.

It will help to understand how sound is absorbed if we think of sound as purely mechanical energy—pressure pulses travelling through the air in wave motion. Sound absorbing materials convert mechanical energy to heat through the process of friction and viscous resistance. Using a sponge saturated with water as an example, we can observe the water moving in and out of the sponge pores each time it is squeezed and released. The flow of water in the pores of the sponge is impeded by friction with the walls and viscous resistance as the water is made turbulent. This same thing happens when air is pumped in and out of a typical sound absorbing material by the pulsing of a sound wave. The sound energy is converted to heat by the friction and viscous resistance which is then dissipated within the passages of the material.

For maximum efficiency, a sound absorbing material should have two important characteristics: first, it must have a low density and second, be highly compressible. Other considerations are: (1) light weight, (2) adequate strength for handling, mounting and resisting vibrations, (3) low thermal conductivity, (4) flame resistant, (5) must not absorb or hold moisture, (6) must not attract, nourish or conceal vermin and (7) must not deteriorate rapidly.

A material that fills this bill very nicely is fiberglass blanketing such as the mat used to insulate home heating furnaces. Sound reduction will be approximately proportional to blanket thickness. Soft, open-cell foam will absorb sound, as will fabrics.

What To Do?

Now that we have a good idea of how everything works, let's go into some concrete suggestions of what to do on the Falco.

Start by lining the upper surface of the stainless steel exhaust port shields with Fiberfrax ceramic paper insulation for thermal insulation and then fill the entire exhaust port "box" with fiberglass insulation. It doesn't do any good to pack the insulation in place—just use it in the density that it comes.

The plywood walls of the Falco are stiff, and they do not require any of the vibration damping methods used on metal aircraft, except in very selective areas. On the upper (cockpit) side of the exhaust port "box", line all flat surfaces with Scotch Y-370 vibration damping foam and tape all joints with aluminum tape or duct tape to seal things up.

Many Falco builders have installed rigid foam insulation in the hollow spaces of the firewall frame and in the cockpit side walls. While this may supply some thermal insulation, it will do almost nothing to dampen the transmission of noise—the foam is too rigid. We don't believe any insulation is necessary, but if you do install insulation, it should be fiberglass insulation or open-cell sound absorbing foam.

Cover all exposed wooden surfaces forward of fuselage frame No. 2 with one inch of fiberglass insulation or one-inch flame retardant open-cell sound absorbing foam (such as Ensolite #?????). There is no need to cover the firewall frame any higher than the bottom of the front fuel tank.

Install one or two inches of fiberglass insulation or open-cell sound absorbing foam under the cockpit floor between fuselage frame 2 and 3. Ensure that the insulation will not rub the rudder control cables. As the floor will be permanently installed, it is probably a good idea to err on the high side and install two inches of insulation. Fiberglass insulation is very light, and you could completely fill the area under the floor. This is directly aft of the exhaust pipe, and it is likely sound enters the cockpit through this floor. At this time, do *not* install insulation under the floor boards at the control stick, or under the seats. This can be done later if tests prove that it is necessary.

Seal all openings on the firewall to insure that there is no place that sound can enter. The cabin heat valve should have been lined with a single layer of felt glued in with a RTV silicone rubber compound. The windshield defrost diverter valve box should be lined with felt.

Use 1/4" open-cell flame retardant polyurethane foam (Ensolite #?????) as padding for the cockpit side walls and rear bulkhead upholstery. Use this foam under the fabric, vinyl or leather covering the glareshield, the area immediately in front of it and on the turtledeck at the aft end of the cockpit.

If the upholstery is an impervious barrier like vinyl or leather, sound absorption will be reduced and reflection will be increased. Perforated vinyl may be used if the number and size of the holes are sufficient to allow sound to penetrate into the absorbing material.

Until we know that additional measures are justified, the above measures are all we suggest.

Sound Level Tests

After your Falco is flying, get a sound pressure meter and measure the level of noise in your airplane. Radio Shack sells an inexpensive meter (about $30.00) which is ideal for this purpose. It is impossible to isolate your problems without such a meter.

For the basis of standardization and comparison, we use the following tests: (1) use the "A" scale for dBA, (2) use power settings of 25/2500, 24/2200 and 20/2000 and (3) take readings for each power setting at "ear", "windshield" and "under panel". At "ear", hold the meter at ear level, facing forward in the center of the aircraft. At "windshield", hold the meter directly above the instrument panel, facing forward to measure the sound coming through the windshield. At "under panel", hold the meter directly below the instrument panel, facing forward to measure the sound coming from the engine. Use these tests for benchmark comparison with improvements in your airplane and with other Falcos.

With the "A" scale, all measurements are done in dBA—decibels of sound pressure adjusted for the frequency response to correspond to the "reception" of the human ear. The decibel scale is logarithmic, and each 3 decibels is a doubling of the sound level.

Here are the results of tests done in Karl Hansen's Falco N805SH on 10/17/87:

Power Setting:	25/2500	24/2200	20/2000
Ear:	98 dBA	95 dBA	94 dBA
Windshield:	99 dBA	97 dBA	95 dBA
Under Panel:	99 dBA	97 dBA	96 dBA

Use the sound pressure meter to find "hot spots" in the noise level. The nose gear bay is a possible source of noise, but it makes no sense to start throwing solutions and insulation at problems you do not know exist.

Be sure to check in the luggage compartment and lift the luggage compartment floor and measure the sound level in the tail cone. The tail cone will act like a megaphone and will amplify engine and wind noise. If it is noisy, add fiberglass insulation or sound-absorbing foam to the aft face of the rear bulkhead and under the luggage compartment floor. If you are truly interested in making the airplane quiet, you will have to shut the engine off and find the wind noise "hot spots" with the sound pressure meter.

Remember that sound pressure is additive. If the sound pressure is 98 dBA, shouting at 97 dBA will *raise* the noise level. This is why cocktail parties are so noisy—no one person is talking very loudly, but the combined noise is louder than any single voice. It is the same way for sports events, a crowd can make a noise much greater than the capability of one excited spectator. Thus, *any noise eliminated* will reduce the overall noise level in the cockpit.

Any discussion of noise suppression would not be complete without some mention of mufflers for the engine. The Series IV Falcos had a muffler, at great expense to engine power. We have flown in a Series III Falco which had fiberglass insulation installed on the aft face of the firewall frame, and it was as quiet as the Series IV Falco with the muffler. We think you can get an exceptionally quiet airplane with sound insulation and without resorting to the performance expense of a muffler.

To date no Falco builder has undertaken a systematic program to investigate the sources of noise in a Falco and to eliminate it. We can guarantee that the results will be worth the effort. Please keep careful records of your tests and report to us what you found to be necessary steps to reduce the noise level of the airplane.