

NOISE & VIBRATION DESIGN GUIDANCE
VIBRATION ISOLATION & FOUNDATIONS
(Prepared by Noise Control Engineering, Billerica, MA)

Introduction

The purpose of this document is to provide design guidance for vibration isolation. As a minimum, the following units should be vibration isolation mounted: Diesel Generators (D/G), Air Handling Units (AHU's) Steering Gear Hydraulic Units & large exhaust and supply fans. Any rotating auxiliary machinery units with horsepower greater than 100 hp should be vibration isolated. In general, equipment less than 5 horsepower does not require vibration isolation. The noise consultant should investigate equipment greater than 5 and less than 100 hp for vibration isolation.

General Requirements, Design Parameters

1. Resilient mounts must be sized so that the ratio of the machine driving frequency to the mount's vertical natural frequency is in the range of 3 (minimum) to 10 or above (preferred). The machine disturbing frequency is generally equal to the machine's rotational rate. The rotation rate, expressed in rpm, is divided by 60 to determine frequency in Hertz (Hz or cycles per second). The calculation of the resonant frequency is shown on Figure 1.

TABLE 1: Natural Frequency vs. Degree of Isolation.

Ratio of Drive Frequency to Mount Natural Frequency	Degree of Vibration Isolation
Below 1.4	None (Amplification)
1.4 – 3	Negligible
3 – 6	Low
6 – 10	Fair
Above 10	High

2. In sizing resilient mounts the total weight on the mounts should include the machinery, subbases (above the mounts), associated fluids, and weight of piping carried by the mounts.
3. The resilient mounts should be located equidistant from the isolated equipment's center-of-gravity (CG) in both horizontal planes. In many cases, mounts are located equidistant from the machinery's center-of-geometry. This is only acceptable if the CG coincides with the center-of-geometry.
4. It is preferable to locate resilient mounts in the CG vertical plane. This is generally not possible, and vertical distance from mounts to the CG should be minimized, as shown in Figure 2.
5. Keep the isolation mounts to a reasonable number. It is preferable to have fewer rather than more mounts. Four is usually the minimum number of mounts.
6. A minimum one-inch clearance envelope should be maintained around the mounted equipment to prevent the unit from striking adjacent ship structure, adjacent machinery or other objects during maximum deflection.

NOISE & VIBRATION DESIGN GUIDANCE
VIBRATION ISOLATION & FOUNDATIONS
(Prepared by Noise Control Engineering, Billerica, MA)

7. Resiliently mounted equipment should have flexible hose, exhaust, and/or cable connections. The preferred design for fluid systems is to incorporate double arch piece flexible hose, with motions that match the maximum possible excursions of the mounted equipment without over stressing the attached piping or components. Tie rods on flexible hose should only be used as limit stops and should be supplied with rubber grommets to prevent metal-to-metal contact. The first three pipe hangers should have resilient elements. Electrical connections should be made with generous service loops.

Material Requirements, Isolators

8. There are many suppliers of vibration isolation mounts. The mounts should be designed to have captive elements (i.e., equipment does not come loose if mount fails). Choose from vendors who make mounts designed for marine applications. US Navy type rubber mounts should be considered along with commercial manufactures of spring/rubber marine mounts. Barry Controls, Lord, Shock-Tech, Metalastik, and Christie Grey are a few manufacturers. The isolators should have inherent limit stops. If not, external, adjustable-limit stops will need to be designed into the system.
9. For applications in oily environments such as the Engine Room, the resilient element should be made of neoprene or nitrile rubber. Natural rubber may be used if a protective housing is provided. Mounts used on hot equipment, such as exhausts systems, shall be protected from the direct radiation of heat, unless the mount is rated to take the expected heat. Thermal break material shall be installed between the hot side and the mount to limit the mount temperature to the manufacturer's tolerance. Mounts used in wet areas, where there is a possibility for more than occasional immersion of the mount in sea or bilge water, should be installed using non-corrosive hardware.
10. The drawings should note the load direction and orientation for the mounts.
11. Fasteners should follow directions of the mount manufacturer.
12. For dynamic analysis, each mount vendor should provide both the static and dynamic stiffnesses of the isolation mount. Furthermore, the following equipment information will need to be provided: total dry & wet weight (including subbase & attached equipment), location of center-of-gravity, translational (NOT rotational) mass moments of inertia of the equipment, and location of mounting feet.

Material Requirements, Pipe Hangers

13. Resilient pipe hangers are necessary with the use of flexible connections.
14. Resilient pipe hangers must be attached to heavy, rigid parts of the ship structure for the isolation treatment to be most effective. Pipe hangers must not be attached to plating sections between stiffeners.
15. Resilient pipe hangers should be used for first three hangar locations from a resiliently mounted component.

NOISE & VIBRATION DESIGN GUIDANCE
VIBRATION ISOLATION & FOUNDATIONS
(Prepared by Noise Control Engineering, Billerica, MA)

16. Resilient pipe hangers should have a natural frequency less than or equal to that of the mounts supporting the machinery to which the associated piping is connected.
17. Do not attach pipe hangers to a machinery subbase or piping directly to rigid ship structures without a rubber grommet isolator or pipe hangar. Downstream of the pipe hangers, the piping should be held in rubber lined supports attached to structural frames.

General Requirements, Foundations & Sub-bases

18. The foundations used for vibration isolated equipment have a different criterion from hard mounted equipment. As mentioned in item 3, the foundation must be able to accommodate mounts located at the center-of-gravity, not at the center-of-geometry.
19. Local stiffeners should be added to points where mounts attach to the foundation. This should generally consist of gussets on either side of the isolation mount. The goal is to have local stiffness at least one hundred (100) times the stiffness of the resilient mount. A minimum acceptable ratio of local to mount stiffness is ten (10). The local foundation stiffness can be computed by empirical or finite element analysis (FEA).
20. Built-up foundations should be anchored to hull framing. Noisy equipment should be attached to structures having high impedance such as stiff bulkheads or hull frame-stringer intersections. Foundations should be designed to stress structural members in tension or compression, bending and torsional stress being undesirable.
21. The foundation should accommodate shock excursion of various appendages of the mounted equipment, (such as oil pan, cantilevered motors, etc.).
22. If a resiliently mounted machinery item consists of two or more components connected by shafting, use of a common subbase under both units should be considered as a means to provide proper alignment. A subbase may also be used when it is necessary to secure resilient mounts at some position other than that of the mounting feet provided with a machine. Subbases should be rigid.
23. Cantilevered foundations should be avoided. Foundations should not be attached to surfaces that are common with noise sensitive spaces, e.g., accommodations, offices, and passageways in those areas.

Installation Details

24. Welding or flame cutting near the mounts shall be finished prior to installation of the mounts. A note to this effect should be put on appropriate drawings.
25. The actual height of each isolator should be measured before and after¹ the mounts are completely loaded. This determines the mount deflection. Equal deflection indicates equal loading. Deviations of greater than 15% from equal loading should be investigated. The mount should not be cocked by more than 5 degrees.

¹The after measurement should occur after at least 24 hours after the mount is fully loaded or within manufacturer recommendations.

NOISE & VIBRATION DESIGN GUIDANCE
VIBRATION ISOLATION & FOUNDATIONS
(Prepared by Noise Control Engineering, Billerica, MA)

26. The mount height should be measured again after ten days to determine the amount of creep.
27. The resilient elements should never be painted. A note to this effect should be put on appropriate drawings.
28. Locate resilient mounts or pipe hangars such that they can be inspected regularly without having to remove structural work.
29. Provision should be made for periodic removal and replacement of resilient mounts or pipe hangars. The requirement should be reflected in headroom space and lateral clearance.

FIGURE 1: Calculation of Vertical Resonant (Natural) Frequency and Requirements for Effective Isolation

Natural Frequency Calculation

$$f_o \equiv \frac{1}{2} \times \pi \sqrt{K \times 386 / W} \quad [\text{Hz}] \text{ Eqn. (1)}$$

Where:

K = Total Vertical Stiffness (= mount stiffness x # mounts).

W = Total weight on mounts (includes machinery, subbase and portion of piping).

Preferred Requirement for Effective Isolation

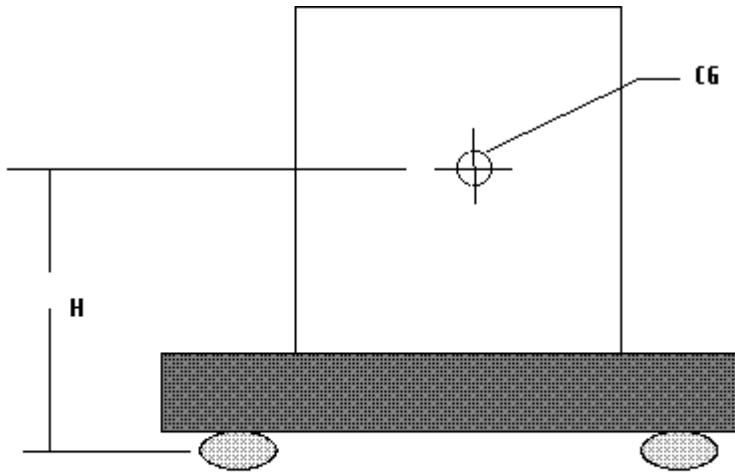
$$f_o \leq \frac{f}{6} \quad \text{Eqn. (2)}$$

Where:

f_o = Natural Frequency in Hertz per Eqn. (1).

f = Disturbing Frequency (Hz), which is generally the component's rotation speed in rpm divided by 60.

FIGURE 2: Resilient Mount Height Limitations



(a) Less Acceptable

(b) More Acceptable (Minimize H)

