

# AIRMOUNT VIBRATION ISOLATION

## SELECTION AND ISOLATION FORMULA

Refer to the selection guide on page 33 for Airmount load and isolation capabilities. Follow this procedure:

### 1. LOAD CAPACITY

Select one or two Airmounts that can support the load at each mounting point. It is normally best to design for pressures in the 4 to 6 bar range. Consider only the 1M1A and the single and double convoluted types at first. Please notice that in the range of 1 to 285 kN you will, in most cases, find both a single and double convoluted style part which will support the load.

### 2. DETERMINE ISOLATION EFFECTIVENESS

Select the disturbing frequency that is closest to the actual forced frequency 7, 13, or 25 Hz. Then check the percentage of isolation for the parts that were selected in 1 above.

### 3. DETERMINE DESIGN HEIGHT

THE AIR SPRING SHOULD BE USED AT THE DESIGN HEIGHT GIVEN. The double convoluted part is used at a design height somewhat higher than its single convolution equivalent. Make sure that the design height falls within the height restrictions. Also, the double convoluted part will show a higher percentage of isolation (less transmitted vibration) than the single convoluted air spring. The reason for this is that the double convoluted part has a greater internal volume of air than the single convoluted version of the same size. At disturbing frequencies in the 7 to 13 Hz range, the double convoluted part is a significantly better vibration isolator than the single convoluted part. At disturbing frequencies of 13 to 25 Hz, the gap closes considerably. At frequencies of 25 Hz and above, the difference is negligible.

### 4. DETERMINE EXACT INTERNAL PRESSURE AND ISOLATION EFFECTIVENESS

The chances are that your specific vibration problem does not fall neatly into the load and disturbing frequency criteria as presented in the selection guide.

Therefore, once a preliminary part selection has been made, turn to the individual data page for that part in order to determine the specific internal pressure required and the percentage of isolation attainable.

## CONSIDER THIS EXAMPLE:

Isolate a vibrating screen which weighs a total of 6000 kg, preferably with ONE isolator at each corner. The vibrating mechanism is rotating at a speed of 14.2 Hz with a total stroke of 8 mm.

#### a. Determine the Load at Each Mounting Point:

$$\frac{6000}{4} = 1500 \text{ kg or } 14.7 \text{ kN force}$$

Scan down the 5 bar load column in the selection guide. It appears that either a #19 or a #22 will support the load at a pressure between 4 and 5 bar.

#### b. Determine Isolation Effectiveness.

Read the % of Isolation at 13 Hz for the #19 and #22 (since 13 Hz is closest to our machine speed of 14.2 Hz). A #19 is at 96.0% and a #22 is at 98.2%. Looking at isolation effectiveness in terms of % TRANSMISSION, the #19 will transmit 100 – 96.0, or 4.0% of the vibrations. A #22 will transmit 100 – 98.2, or 1.8% of the vibrations. So, even though there does not seem to be much difference between 96.0% and 98.2% isolation, the #22 is in fact a better isolator by approximately a factor of two when comparing transmitted vibration.

#### c. Determine Design Height.

Let's say we have chosen the #22 because 96.0% isolation for a #19 is considered to be too low. A #22 SHOULD BE USED AT 240 mm as shown in the second column on page 33.

#### d. Determine Exact Internal Pressure and Isolation Percentage.

Turn to page 61 for detailed information on the #22.

a) What exact pressure will be required to support the load of 15 kN? Refer to the information in the block entitled "Dynamic Characteristics at 240 mm Design Height."

$$\frac{16.6 \text{ kN} \times (100)}{5 \text{ bar}} = 331 \text{ cm}^2 = \text{effective area @ 240 mm @ 5 bar}$$

Divide the actual load by the effective area:

$$\frac{14.7 \text{ kN} \times (100)}{331 \text{ cm}^2} = 4.5 \text{ bar required to support } 14.7 \text{ kN at 240 mm}$$

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b) What exact isolation will be attained?

Use the formula:

$$\% \text{ Transmission} = \frac{100}{\left(\frac{f_f}{f_n}\right)^2 - 1}$$

Where:  $f_f$  = Forced Frequency (Hz)  
 $f_n$  = Natural Frequency (Hz)

The forced frequency is 14.2 Hz. Read the natural frequency from the line at the load and pressure closest to the actual situation, or 1.80 (@ 5 bar and 16.56 kN): Design Ht. 240 mm

$$\% \text{ Transmission} = \frac{100}{\left(\frac{14.2}{1.80}\right)^2 - 1}$$

% Transmission = 1.63%  
 % Isolation = 100 - % Transmission  
 % Isolation = 100 - 1.63  
 % Isolation = 98.4%

Notice that the natural frequency of an Airmount changes only slightly with variations in pressure and load. Therefore, when working at pressures other than 4, 5, 6, or 7 bar, % isolation can be calculated quite accurately using the "closest" natural frequency and the formula above.

## DYNAMIC SPRING RATE FORMULA

Spring rate is a different matter. Unlike most conventional springs, the rate of an Airmount is not constant. It is a function of the change in effective area, volume, and pressure from design height. To determine the rate of an Airmount, use the following formula:

$$K = \frac{[(P_g + 1.01) \times 100] \left[ \frac{A_c}{10,000} \left(\frac{V_1}{V_c}\right)^{1.38} - \frac{A_e}{10,000} \left(\frac{V_1}{V_e}\right)^{1.38} \right] - \left[ 101 \times \left(\frac{A_c - A_e}{10,000}\right) \right]}{.02 \text{ m}}$$

WHERE:

- K = Vertical Spring Rate in kN/m
- $P_g$  = Gauge Pressure at design height (bar)
- $A_c$  = Effective Area at 10mm below design height (cm<sup>2</sup>)
- $A_e$  = Effective Area at 10mm above design height (cm<sup>2</sup>)
- $V_1$  = Internal Volume at design height (cm<sup>3</sup>)
- $V_c$  = Internal Volume at 10mm below design height (cm<sup>3</sup>)
- $V_e$  = Internal Volume at 10mm above design height (cm<sup>3</sup>)

Consider the same #22 example: What is the vertical spring rate with a load of 15kN at a design height of 240 mm? Refer to the static data chart on page 61. Again, our "closest" pressure is 5 bar, so we'll need to read the appropriate data from the 5 bar curve.

The 5 bar information at +10 mm above design height would fall at the 250 mm height line, and -10 mm below design height would fall at the 230 mm height line. (In this example, we can read loads from the force table). The information at design height is located in the "Dynamic Characteristics Block." So,

K = Unknown

$P_g$  = 4.5 bar

$$A_c = \frac{(\text{Load}) \text{ kN} \times (100)}{\text{Pressure (bar)}} = \frac{16.05 \text{ kN} \times (100)}{4.5} = 357 \text{ cm}^2$$

$$A_e = \frac{(\text{Load}) \text{ kN} \times (100)}{\text{Pressure (bar)}} = \frac{13.55 \text{ kN} \times (100)}{4.5} = 301 \text{ cm}^2$$

$V_1$  = 12,800 cm<sup>3</sup>

$V_c$  = 12,400 cm<sup>3</sup>

$V_e$  = 13,100 cm<sup>3</sup>

$$K = \frac{[(P_g + 1.01) \times 100] \left[ \frac{A_c}{10,000} \left(\frac{V_1}{V_c}\right)^{1.38} - \frac{A_e}{10,000} \left(\frac{V_1}{V_e}\right)^{1.38} \right] - \left[ 101 \times \left(\frac{A_c - A_e}{10,000}\right) \right]}{.02 \text{ m}}$$

$$K = \frac{[(4.5 + 1.01) \times 100] \left[ \frac{357}{10,000} \left(\frac{12,800}{12,400}\right)^{1.38} - \frac{301}{10,000} \left(\frac{12,800}{13,100}\right)^{1.38} \right] - \left[ 101 \times \left(\frac{357 - 301}{10,000}\right) \right]}{.02 \text{ m}}$$

K = 195 kN/m

## NATURAL FREQUENCY FORMULA

Once the spring rate is determined, calculate the Airmount natural frequency (for an UNDAMPED system) as follows:

$$f_n = .50 \sqrt{\frac{K}{L}}$$

Where:

$f_n$  = Natural Frequency in Hz

K = Rate (kN/m)

L = Load (kN)

in our example:

$$f_n = .50 \sqrt{\frac{195}{15}}$$

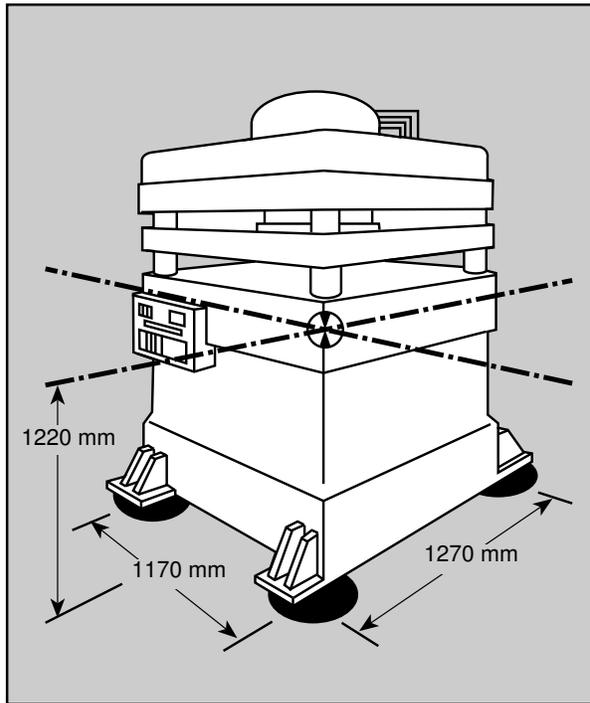
$f_n$  = 1.80 Hz

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Up to this point, only the weight and disturbing frequency have been discussed. THERE ARE MANY OTHER IMPORTANT CONSIDERATIONS:

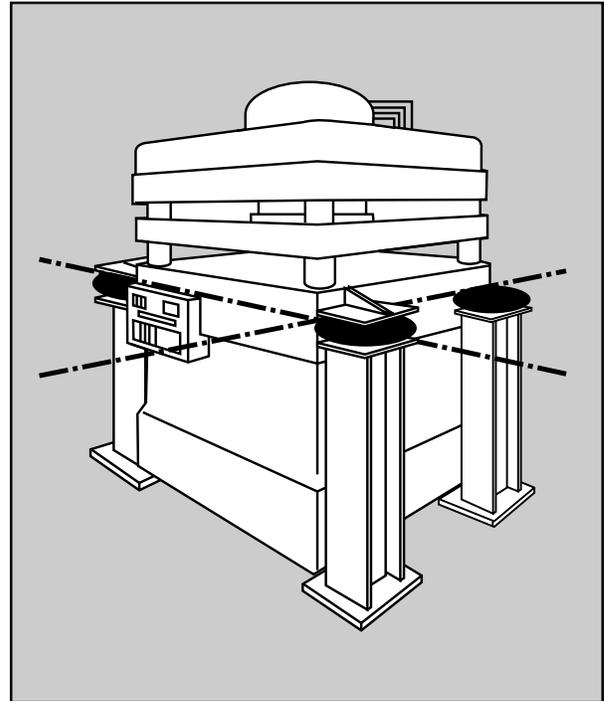
## CENTER OF GRAVITY

An Airmount isolation system is inherently soft (easily deflected); therefore, precautions must be taken to insure that the system is stable. First, consider the location of the center of gravity (c.g.). Ideally, the Airmounts should be located on the same plane (parallel to the ground) as the center of gravity. Where this is not possible, follow this guideline: The distance between the most narrow mounting points should be at least twice the height of the center of gravity.



In the above example, the most narrow distance between two Airmounts is 1170 mm. The height to the c.g. is 1220 mm; therefore, this system does not meet our guideline. Two possible solutions would be:

1. Increase the base dimensions to meet our guideline by increasing both the width and length to at least 1220 x 2 or 2440 mm.
2. Locate the Airmounts at the c.g. as shown above (in the next column).



## LATERAL RATES AND STABILITY

A single or double convoluted air spring **SHOULD BE USED AT THE DESIGN HEIGHT GIVEN**, because that is the point of maximum lateral rate or stability. The lateral rate **DECREASES** as the Airmount height **DECREASES**. Consider a #22 again at 6 bar:

Height	Lateral Rate	Vertical Rate
240 mm (design height)	51.0 kN/m	215.0 kN/m
215 mm	33.0 kN/m	140.0 kN/m
190 mm	Unstable	—

Notice that the #22 becomes unstable in the horizontal or lateral direction when moving down only 50 mm from design height.

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At design height and without an auxiliary reservoir, the single and double convoluted parts follow this pattern: i.e., the lateral rate varies from 1/5 to 1/2 of the vertical rate (only the larger high strength parts get as high as 1/2). Notice the #22 is approximately  $1/4(\frac{51}{215})$ . Going back to the original example of a vibrating screen which weighs 6000 kg mounted on four #22's (@ 240 mm), a side load of 2.04 kN ( $\frac{51.0 \times 4}{100}$ ) would deflect the entire suspended mass by 10 mm.

## TRIPLE CONVOLUTED AND REVERSIBLE SLEEVE TYPE PARTS

Both of these types are unstable laterally (except for the 1M1A). Due to low natural frequencies, both can be excellent isolators; however, do not use these two types as Airmount isolators without consulting Firestone.

## DESIGN ENVELOPE

Adequate clearance should be provided around the Airmount to prevent puncturing or rubbing of the bellows. The maximum diameter @ 7 bar for each Airmount (bellows) is shown just above the cross sectional view of the air spring.

## SAFETY STOPS

It is normally recommended that positive stops be installed IN ALL DIRECTIONS; i.e., into compression, extension, and laterally. Positioning of the vertical stops depends upon the amplitude of movement, both during normal operation and during startup and shutdown. A good "rule of thumb" is  $\pm 15$  mm from design height for vertical stops and also  $\pm 15$  mm (horizontally) for lateral stops.

## INITIAL INSTALLATION

NEVER use Airmounts to lift the equipment into place, due to the lateral instability at lower air spring heights as discussed previously. The equipment should be rested on stops set slightly below design height and raised into position for isolation.

## STARTUP AND SHUTDOWN RESONANCE AND AMPLIFICATION

Resonance is the condition where the forced frequency of the vibrating system is at the natural frequency of the suspension. When this happens, AMPLIFICATION of movement occurs. Going back to our vibrating screen example again, if the normal stroke is 8 mm, during startup and shutdown (as the machine goes through resonance), the amplitude of movement will be multiplied somewhat. So, while the machine is building up to speed and slowing down, the stroke may be amplified in the range of 10 to 35 mm if undamped. The longer the machine takes to go through resonance (to build up to, or slow down from full operating speed), the larger the amplitude of movement.

## ISOLATING AN UNBALANCED MASS

The primary concern in this case is the amplitude of movement. It is dependent on:

- 1) The ratio of the unbalanced moving mass to the total suspended mass and,
- 2) The ratio of the speed of the unbalanced moving mass (forced frequency) to the natural frequency of the Airmounts.

**The addition of damping to the isolation system (shock absorbers) will reduce the large amplitude of movement experienced during resonance.**

If the amplitude of movement is too great, one possible solution would be to add an inertia base in order to increase the ratio of the total suspended mass to the moving unbalanced mass. A good "rule of thumb" is 10:1, respectively.

## LOW PRESSURE OPERATION

The lateral rate of a single and double convoluted style Airmount DECREASES with decreasing internal air pressure (becomes less stable). Consult Firestone if you plan on operating an Airmount at less than 3 bar.

## EFFECT OF AN AUXILIARY RESERVOIR

There is a direct relationship between natural frequency and isolation effectiveness. Generally, the lower the natural frequency, the better the isolator (or higher percentage of isolation). As previously mentioned, a double convoluted Airmount has a lower natural frequency than a single convoluted type (of the same size) because it has more internal air volume. We can use this principle to lower the natural frequency of an air spring by adding an auxiliary reservoir (pressure vessel) externally to the Airmount. This effectively increases the air spring volume and reduces its natural frequency.

In order for the reservoir to work properly, there must be a free flow of air between the Airmount and reservoir. Therefore, it should be mounted as close as possible to the Airmount. Additionally, a bead ring attachment is the best end closure choice as the hole in the upper mounting plate can be sized as large as the inside diameter of the bellows (at the top). A 3/4 BSP air inlet will restrict the flow of air somewhat, but can be used as long as it is understood that there is some throttling effect.

Going back to the #22 example, an auxiliary reservoir of three times the internal volume of the air spring at design height (approximately 38 liters) will reduce the natural frequency from 1.8 Hz to 1.5 Hz.

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## DAMPING

$$\frac{C}{C_c}$$

Damping is defined as the ratio:

WHERE:  $C$  = System Damping  
 $C_c$  = Critical Damping

The damping ratio inherent in an Airmount is in the order of .03. This damping number is so small that the formulas presented in this section assume it to be zero.

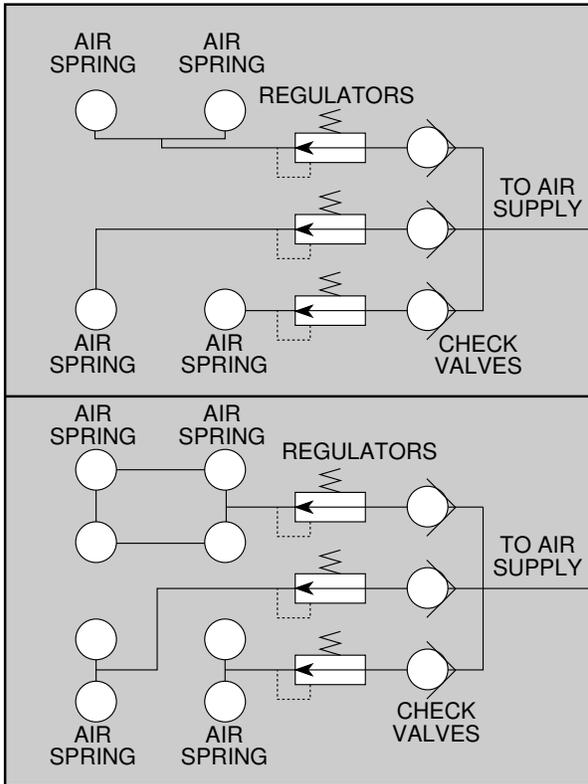
## PLUMBING SYSTEMS

There are three basic ways of controlling an air suspended isolation system:

1. With a TANK VALVE in each Airmount. Each air spring is then inflated individually. The pressure in each must be checked periodically, because air will permeate through the bellows.

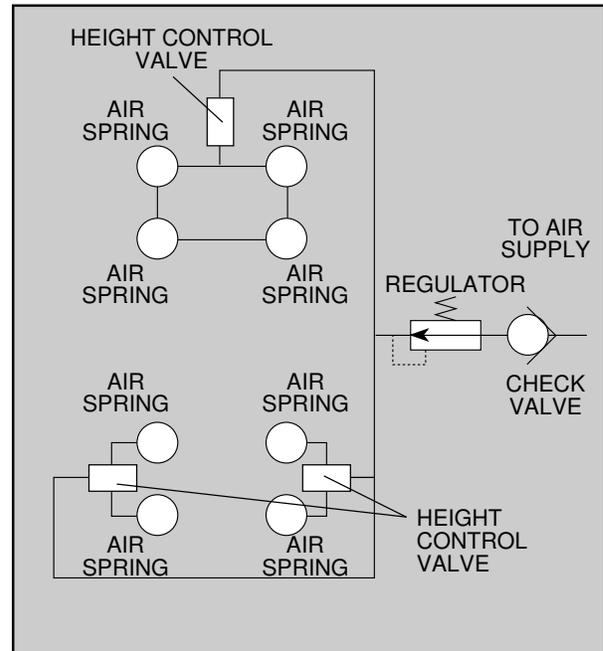
For an idea of the permeation rate, a #116 will lose approximately 2 bar over a period of one year (from 7 bar to 5 bar). Please see page 7 for a picture of a 1/4 BSP tank valve.

2. **Three Point Regulated System** The Airmounts can be connected directly to the factory compressed air



system using pressure regulating valves. This eliminates the need for periodic inspections. The air springs should always be connected in clusters so the mass is supported with only THREE REGULATORS. This is illustrated below (in the previous column) for both a four and eight Airmount system:

3. **Three Point Levelled System** Height control can be provided by adding height control valves to the system. Again, there should be only THREE POINTS OF CONTROL, or in this case, three height control valves. Attempting to use more than three control points often results in the valves hunting or fighting one another. There are sensing systems available to control heights within .03 mm. Truck type leveling valves can provide accuracy to 1.6 mm. A three point, eight air spring, leveled system is illustrated below:



Firestone supplies height control valves and the accompanying linkages from the valve to the supported system.

Description	Order No.
Immediate Response Valve	WC1-358-3597
Immediate Response Valve Linkage	WC1-358-3594
Time Delay Valve	WC1-358-3599
Time Delay Valve Linkage	WC1-358-3598

**An Airmount Design Parameter Worksheet can be found on page 105.**

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## ISOLATION CHART

