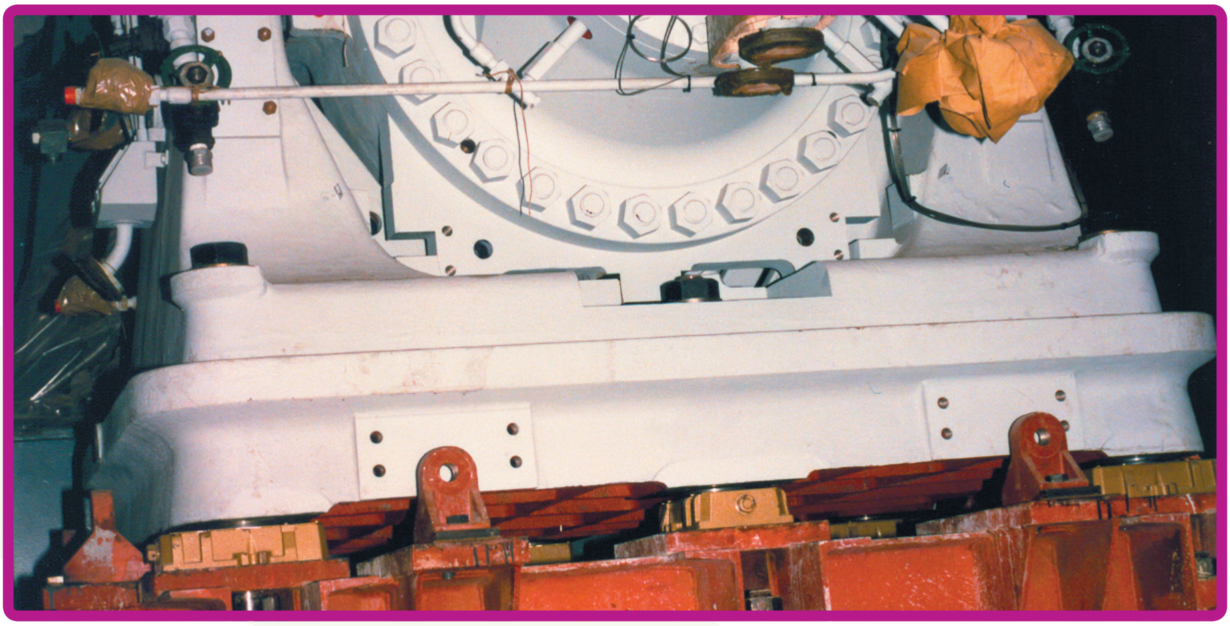
Farrat
Engineering Excellence

Mounting, Levelling and Vibration Control of:

PUMPS/ COMPRESSORS



Pumps

Pumps are the most widely produced machinery in the world. They are used for raising, compressing, or transferring fluids. Sizes vary from small laboratory pumps to massive pumps weighing many tens of tonnes such as power station boiler feed pumps.

The various pump types include:

- Displacement
- Reciprocating
- Diaphragm
- Piston
- Plunger
- Gas or vapour displacement
- Rotary Displacement
- Gear and Lob
- Flexible Vane
- Peristaltic
- Progressive Cavity (Mono)
- Open screw
- Velocity
- Rotary Continuous
- Axial Flow
- Centrifugal (volute, turbine, regenerative)

Compressors

Compressors are in many ways similar to Pumps and are used specifically to increase the pressure of a gas and direct it into a pneumatic system. Compressors come in various types:

- Centrifugal - compresses air and expels it with a centrifugal force from a rotating wheel with radial vanes. Centrifugal compressors are often used for fans and cooling units.
- Axial - gas flows parallel to the rotation of the axis.
- Turbine - used within gas and steam turbines
- Rotary Screw - derives its pressurizing ability from two interlocking threaded cylinders. The male-female thread interaction traps and compresses air.
- Piston / Reciprocating compressors - use a piston driven by a rotating crankshaft to pressurize air in a pneumatic system. Delivery is usually to a receiver which is effectively a store of energy used to drive compressed air tools etc. As with an engine, the out of balance moving parts (piston, crank shaft, con rod) can cause considerable vibration disturbance.

Design Consideration 01

Vibration control

By the nature of their high speed and powerful operating requirements pumps and compressors can cause significant noise and vibration disturbance. Specific sources of vibration can also occur due to damage and incorrect installations. Sources of Pump Vibration

Source	x rpm (Frequency Hz=rpm/60)
Bearings (typical)	0.3 - 5.0 (If bearings are in good condition vibration should not be significant)
Primary out of balance	1.0
Secondary out of balance	2.0
Shaft misalignment	2.0
Bent Shaft	1.0 & 2.0
Gears	N (N=Numbers of teeth)
Drive Belts	N.2N.3N.4N (N=belt rpm)
Aerodynamic or hydraulic	N (N=number of blades on rotor)
Electrical	N (N=synchronous frequency)

If the pump and motor are well balanced and in good working order the only vibration likely to be a problem on rotary pumps is that caused by aerodynamic/hydraulic forces (blade passing frequencies). Nevertheless it is critical to avoid any low frequency resonance effects between the pump / compressor and the surrounding floor (could be upper storeys), building structures, and subsoil therefore it is important to ascertain;

- The likely operating frequencies can be ascertained either from the equipment manufacturer and the end user or by measurement on a similar installed machine
- The natural frequency response of the surrounding floor, building structures, and subsoil may be estimated by a structural engineer using finite element analysis
- The maximum permissive movement of the equipment

Typical natural frequencies of ground and structures	
Steel structures	~2-15Hz
Suspended concrete floor	~10-15Hz
Ground floor	~12-34Hz
Soft Clay	~12Hz
Medium Clay	~15Hz
Stiff Clay	~19Hz
Loose Fill	~19Hz
Dense mixed grain sand	~24Hz
Limestone	~30Hz
Hard Sandstone	~34Hz

If vibration control is required then the natural frequency of the elastically supported system (pump + motor + baseplate) must be selected in order to;

- Effectively isolate the lowest significant disturbing frequency
- Avoid any significant support structure natural frequencies (resonance) when known

Isolation is achieved if the dynamic natural frequency of the supported mass is less than 50% of the lowest significant (fundamental) disturbing frequency. Other points to consider are;

- Even if vibration isolation is not required, it is usually the case that the entire machine needs to be installed on a single, specially designed concrete foundation of suitable strength and stiffness to ensure alignment is maintained between all interconnected parts.

Vibration control

- Smaller compressors comprising Motor, Gearbox and Compressor on a common bedplate are generally supplied with Rubber/Metal Isolators.
- Large compressors suit elastically supported Inertia Base installation which as with pumps can be supported on and isolated by coil springs, rubber metal isolators or Isomat Pad Isolators.
- When pump sets are mounted on a flexible mounting system care must be taken to ensure that any electrical and pipework connections are flexible enough to absorb any machine movement during start up or shut down.
- Pumps and compressors are often installed in isolated locations where vibration is not expected to cause a disturbance. However not considering vibration control or adequate fixing and levelling may affect operating performance and could force early failures or maintenance.
- By isolating, damping and removing energy from the equipment it will reduce the dynamic stresses on the building structure and floor.

Solution 1.1

Isomat Isolated Foundation / Isolated Plinth Systems:

If vibration isolation does need to be incorporated into the design then an Isomat Isolated foundation or isolated plinth system designed to isolate the lowest operating frequency has proved to be an ideal solution.

By attaching the pump set to an elastically supported concrete or steel inertia base it reduces the amplitudes of vibration of the pump set in the ratio;

$$\frac{Mp}{Mp+Mib}$$

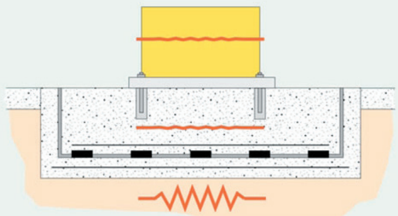
Mp= Mass of pump set

Mib=Mass of inertia base

This is known as Mass Damping

Mass damping is especially important in reciprocating pumps and compressors (especially single cylinder variants) which cause higher dynamic loads. By anchoring the reciprocating pump to an isolated inertia block one can dramatically reduce the movement of the system.

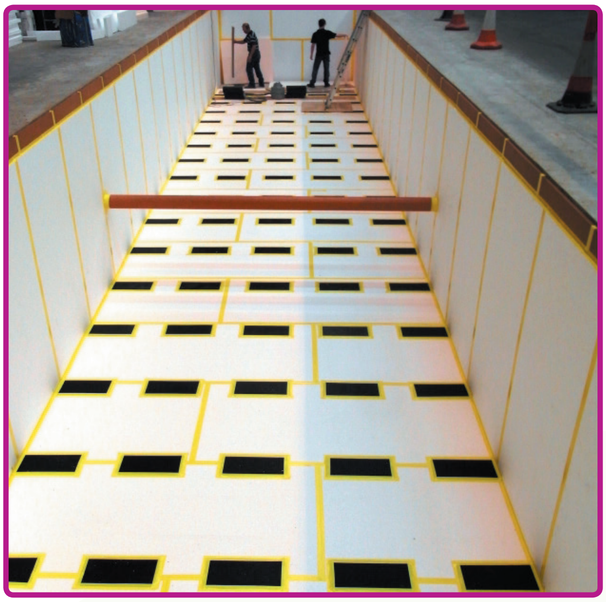
The System Natural Frequency can be determined by careful selection of the isolation system in such a way that the lowest significant pump set disturbing frequency is isolated from the support structure whilst at the same time avoiding any support structure resonance.



Machine on isolated foundation, passive shock and vibration

Advantages

- An Isolated Foundation is generally the most effective way of protecting high value machines and their operating performance from shock and vibration. Systems can be designed to isolate;
    - **Active Isolation** (vibration created by the pump or compressor operation affecting surrounding structures)
    - **Passive isolation** (externally induced vibrations affecting pump or compressor operation. Maximum levels at different frequencies which the pump or compressor can accept tend to be provided by the manufacturer)
- Effective isolation of vertical disturbing frequencies above 12Hz
- Effective isolation of horizontal disturbing frequencies above 4Hz
- Can be designed to avoid resonation with any disturbing frequencies
- An ideal blend of vibration isolation and damping
- Often used as a precautionary measure in case of unexpected shocks and future facility al-terations
- Isomat has a proven track record in a very wide range of industrial applications since 1977
- An economical solution
- Simplified foundation design
- Easy to install
- Long performance lifetime
- Maintenance free



Disadvantages

- Limited effectiveness (apart from damping) in isolation of disturbing frequencies below 12Hz

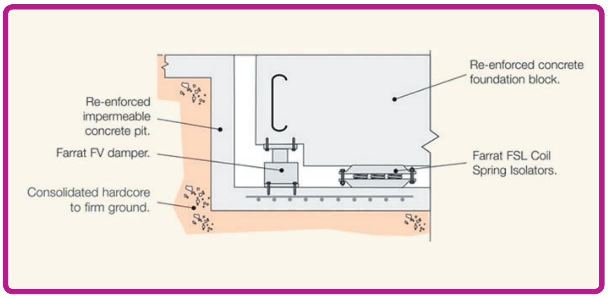
Suggested Farrat Isolator System: Isomat IMBR50-50

Solution 1.2

FSL Coil Spring and FV Damper Isolated Foundation System

An Isolated Foundation system generally involves the creation of a reinforced concrete foundation block which is then placed onto Coil Spring Isolators and if necessary FV Viscous Dampers.

FV viscous dampers are anticipated for reciprocating pumps.



Advantages

- An Isolated Foundation is generally the most effective way of protecting high value machines and their operating performance from shock and vibration disturbance (Passive Isolation).
- Effective isolation of disturbing frequencies between 6 and 12Hz
- Equal vertical and lateral performance
- High deflections can be accommodated with pre-compression

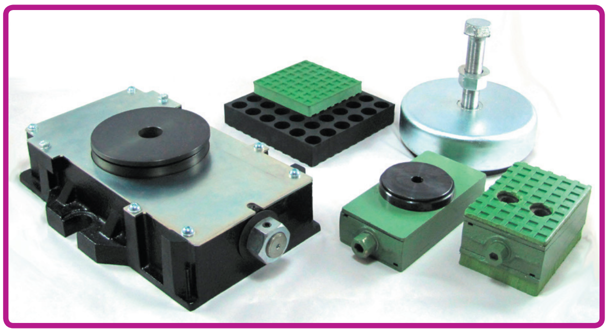
Disadvantages

- Risk of low frequency vibration amplification due to resonance
- Viscous dampers will be required if shock disturbance is likely
- Larger, deeper, more complicated and expensive foundations than Isomat systems are generally required
- Tilting of the machine and foundation outside permissible machine limits may occur due to differential loadings and load transfers
- Excessive foundation movement during run up or down due to low natural frequency
- High cost of equipment, foundation design and construction
- Longer isolation equipment delivery lead times and installation time
- Periodic inspection and maintenance is required of the coil springs and dampers

Design Consideration 02

Fixing and levelling

When pump sets and compressors are installed the connection between the pump set base and the inertia base should be rigid and accurately levelled. Even if vibration isolation is not required, it is usually the case that the entire machine needs to be installed on a single, specially designed concrete foundation of suitable strength and stiffness to maintain alignment between the motor and the pump.

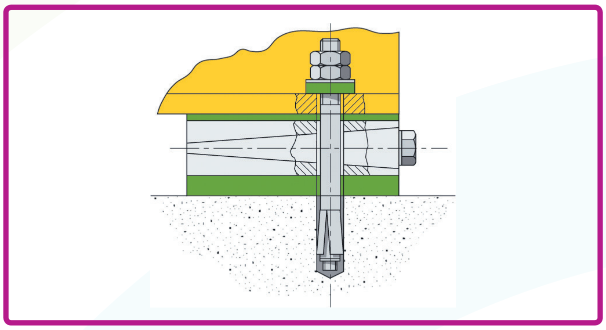


Farrat Machine Mounts are used to:

- Provide easy and accurate installation and levelling
- Ensure the machine has a stable and uniform support to maximise machine accuracy and performance and to reduce the risk of degradation from machine bed misalignments, inter-nal stresses and flex
- Overcome irregularities in floor slabs or foundations
- Increase vibration damping of the machine
- Provide layout flexibility

Pumps and compressors should be rigidly anchored to the foundation or floor. Such a connection is achieved with Bolt-Through (BT) mounts.

Bolt-Through BT: Bolting down is usually required for;



- Top heavy machines
- Certain long bed machines
- Machines with high inertia forces.
- Machine connection to an isolated or specialist foundation. A rigid connection to a foundation inertia block takes full advantage of the mass damping effect of a ma-chine plus foundation.

It should be noted that unless levelling elements such as Farrat Wedge Levelling Elements or Levalators are used there is a risk that bolting the machine down could cause distortions in the machine bed which may affect its performance.

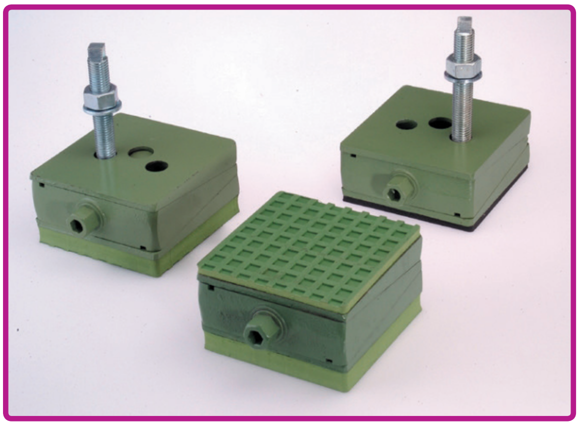
Solution 2.1

Wedgemounts

Farrat Wedgemounts are an ideal solution for many machine types and installation scenarios because they provide;

- Accurate, efficient and economical machine installations
- Precision vertical levelling adjustment with no horizontal forces applied when adjusting
- High ratio of lifting force to adjustment torque to ensure accurate and smooth levelling
- Enhanced machine stability (the machine is not sitting on the screw thread)
- Vibration Damping (in some variants)
- Allow factory layout flexibility through easy installation and relocation

For pumps and compressors Farrat recommends WLT Bolt through Wedgemounts with Damping Grades B or E which provide an excellent interface damping and stress relief which can produce quieter running and reduced maintenance. We are happy to discuss exact requirements and specifications to find the ideal match.

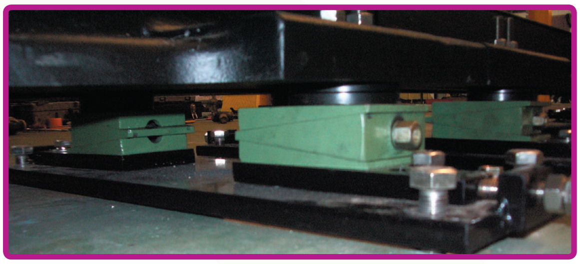


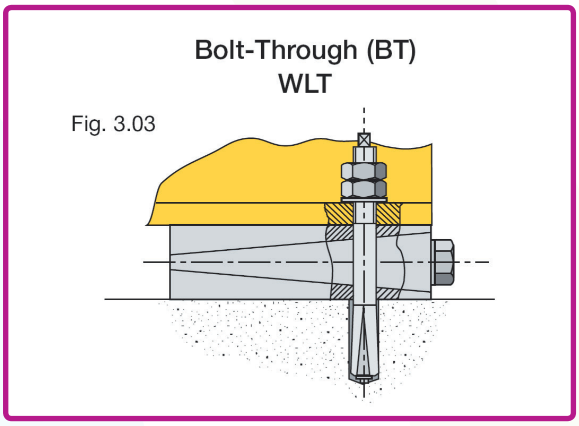
Solution 2.2

Farrat Wedge Levelling Elements

Farrat Wedge Levelling Elements are precision machined screw driven vertical rise wedge adjustment machine mounts ideally suited to stiff, accurate and efficient machine installations and the augmentation of machine performance by;

- Ensuring accurate alignment, rigidity and stability of machine
- Providing high vertical stiffness to prevent machine bed deflections occurring under dynamic load distributions
- Enabling high bolt tensions without bed distortions
- Increasing the vibration damping and bed reinforcing effect of the foundation
- Offering the facility to re-align machines with minimum production loss





Solution 2.3

Levalators

Levalators provide the highest level of equipment support and stiffness for total machine to foundation integration maximising the vibration damping and bed reinforcing effect of the foundation. They improve performance by increasing alignment accuracy, rigidity and stability with the following features;

- Low overall height to ensure a low machine centre of gravity
- The fixing bolt passes right through the centre line of the mount allow high bolt tensions through the centre of the mount without bed distortions
- Accurate precision alignment with micro-meter type height adjustment range of 12mm
- Spherical seating corrects misalignment and complex angles between machine and founda-tion
- High vertical stiffness to prevent machine bed deflections occurring under dynamic load dis-tributions
- Large contact support area with foundation surface
- Systemised, predictable and economical installation procedures to simplify machine installa-tions including pre-grouted prior to equipment installation
- Offering the facility to re-align machines with minimum production loss