Shock and Flexibly Mounted Machines

What is meant by Shock ?

Any transient non repeating force or displacement can be considered a shock. Usually the period of such an event is similar to or shorter than the natural period of motion of the equipment being considered.

The disturbance may be a force as might be created by a short circuit across an alternator or a displacement such as an earthquake.

The magnitude of a shock is normally large enough to give rise to concern that damage will occur to the machine or its supports. In some cases the functioning of the machine will be affected during the shock although no permanent damage will result.

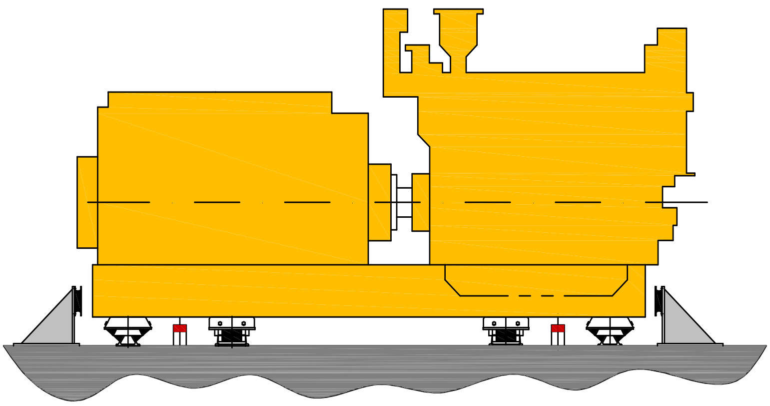
1) Earthquakes - A typical ground motion of about 0.5 g acceleration with most energy below 5 Hz and mainly horizontal. One earthquake may last 30 seconds and the amplitudes of the ground may be considerably amplified by most building structures. Mounted equipment may be subject to significant floor motions at well defined frequencies.

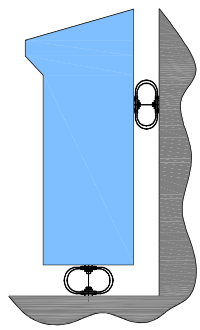
2) Explosions - Short duration impulsive forces which can give rise to long period resonances in buildings or other structures. Examples include charges used for seismic surveying, quarrying, terrorists' bombs and naval gunfire or under water mines.

3) Collisions - These include problems with vehicles, items on conveyor belts and packages being dropped.

4) Internal forces - These particularly affect electrical generators and reciprocating machines, as with passing through resonances during start up, shut down and short circuits.

Typical Shock Isolation of a Generator Set





Isolation of an Electronic Cabinet

Methods of Shock Analysis

There are two main approaches to determining the response to shock.

1) Time history - A model is created on the computer and its responses over successive small time steps are calculated to form a continuous history of the machine motion.

2) Spectral response method - A more general method based on the theoretical response of a single degree of freedom damped spring/mass model at each frequency of interest. The individual responses for each mode of motion are built up in a complex response for three dimensional methods.

Time History Calculations

At Christie & Grey the time history method is preferred which allows for non linear stiffness and a more accurate modelling of the shock. The results are 'mathematically accurate' although only as good as the input shock data. The spectral response method is mainly applied to earthquake responses. The linear spring model and statistical nature of the shock data permit only an estimate of the worst probable response, rather than an accurate calculation.

The models used to represent the machine include rigid masses with springs and viscous dampers allowing for translation and rotation in the three dimensions. A number of masses can be interconnected to represent, for example, a system of three machines flexibly mounted on an isolated floor. The analysis generally leads to a report of the maximum acceleration and relative displacements at positions of interest enabling the probability of damage or malfunction to be assessed. Particular care is taken over the flexible connections such as pipe bellows or shaft couplings which are frequently vulnerable to damage during shocks.

Simplified Models

Shock problems create large displacements which cause mountings to buffer. Indeed many mountings incorporate flexible stop units to control this effect. Whilst these non linear effects can be included in complex models, the results are often difficult to understand. Often a simpler one or two dimensional model will provide accurate enough results to enable the basic system to be refined. The calculation shown here is an example of such a time history. Comparison with a more complex method using a three dimensional non linear analysis has shown maximum displacements and accelerations to be very similar, the simpler method requires less time to set up and run.

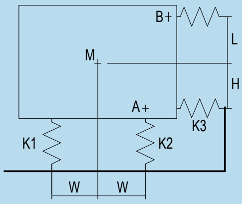
INPUT SHOCK — DAMPED SINE WAVE SEISMIC DISPLACEMENT.

Amplitude : 10.0 mm
Frequency : 12.0 Hz
Damping : 0.15 of critical

Mechanical Data for the Model

Mass (M)	:	5000.0	kg
Mass Moment Of Inertia	:	2500.0	kg.m.sqd
Dimensions	W :	500.0	mm
	H :	600.0	mm
	L :	500.0	mm

Limiting stops to stiffen 15 % per mm
Damping : 7.0 percent of critical



Isolator Dynamic Stiffnesses (N/mm)

	Mass Side Stop	Central Element	Floor Side Stop	Limiting Stop
K1	30060.0	2388.0	30060.0	4.5
K2	30060.0	2388.0	30060.0	4.5
K3	25600.0	4602.0	25600.0	6.0

Figure 1

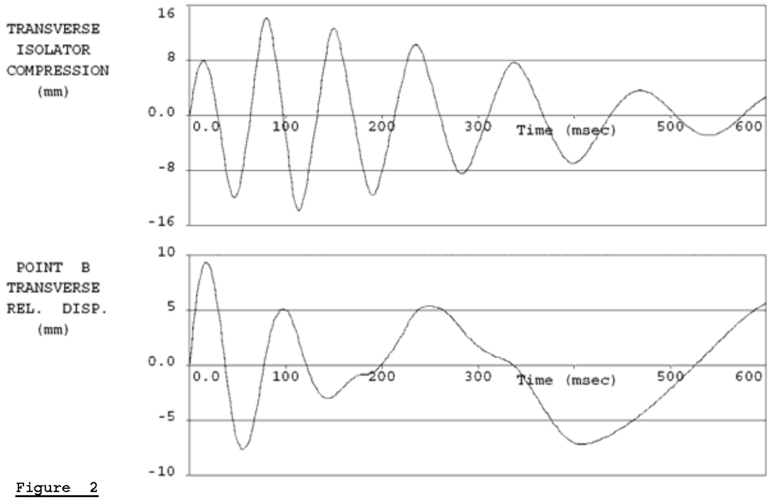
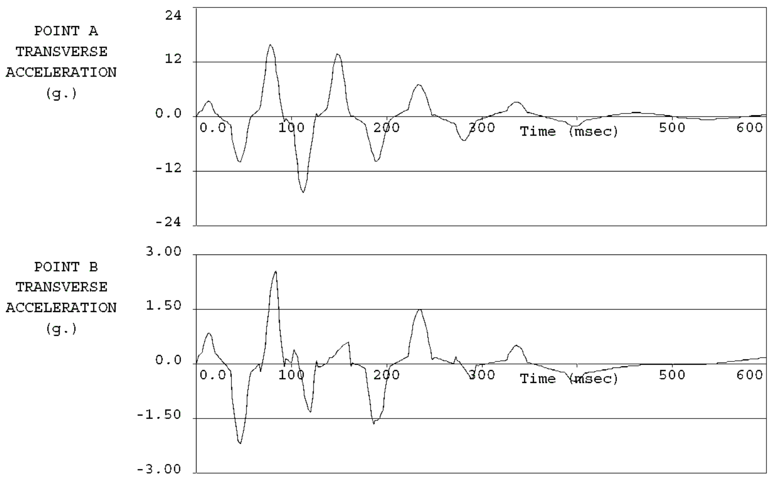


Figure 2



Maximum Values Calculated from the Time History

Calculation end time : 600.0 msec.
Calculation interval : 0.20 msec

	Maximum Value		Time of Max (msec)
Foundation Displacement	10.02	mm	18.8
Foundation Velocity	940.82	mm/sec	0.2
Foundation Acceleration	- 6.21	g	15.0
C of Gravity Transverse Displacement	- 8.53	mm	78.2
C of Gravity Rotational Displacement	0.85	deg	111.8
C of Gravity Transverse Velocity	636.73	mm/sec	91.2
C of Gravity Transverse Acceleration	8.36	g	78.2
Transverse Isolator Compression	14.17	mm	79.8
Point A Transverse Acceleration	-16.84	g	112.2
Vertical Isolator Compression	7.46	mm	111.8
Point A Vertical Acceleration	7.37	g	111.8
Point B Transverse Re. Disp	9.37	mm	17.4
Point B Transverse Acceleration	2.56	g	83.6
Mounts Total Transverse Force	410005.66	N	78.8
K(2) Side Vertical Force	129846.66	N	110.4

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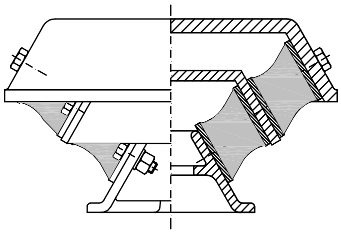
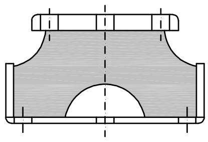
Shock Mounting Types

Shown below are some typical mountings. In many cases a 'shock mounting' is a vibration isolator used with resilient stops to control motion. In most cases damping is essential either using separate viscous dampers or using the internal damping of the rubber material.



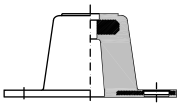
Type FCR.

Load range 300 - 2000 kg.
Static Deflection up to 30 mm.
Shock Deflection up to 60 mm.



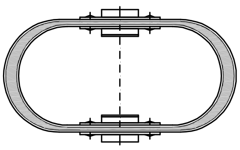
Type PD.

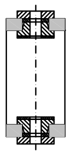
Load range 750 - 2500 kg.
Static Deflection up to 16 mm.
Shock Deflection up to 25 mm.



Type RM.

Load range 10 - 300 kg.
Static Deflection up to 6.5 mm.
Shock Deflection up to 15 mm.





Type X.

Load range 5 - 550 kg.
Static Deflection 6 to 12 mm.
Shock Deflection up to 60 mm.

Military Shocks - Land based control centres.

Many military bases include facilities hardened against attack. These may be subject to underground explosions and require protection of delicate machinery. The shocks are often specified in the form of machine response spectra and the equipment to be protected is usually of commercial standard with fragility levels below the anticipated shock levels.

The mountings are usually rubber or damped steel springs with travel of up to 60 mm in all directions. In order to reduce the peak forces on the equipment the springs need to be of linear stiffness. Examples are the Types FCR and X Mounts shown above.

The large relative amplitudes induced require highly flexible pipe and cable connections. These are often of considerable mass and may need shock analysis in their own right to ensure satisfactory performance.

For some projects the shock displacements are smaller permitting the use of mountings with stop units in built. These tend to transmit higher accelerations whilst restricting the relative displacements. An example is the Type MPM shown above.

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Naval Shock

Of the conditions met at sea, there are three that concern us here.

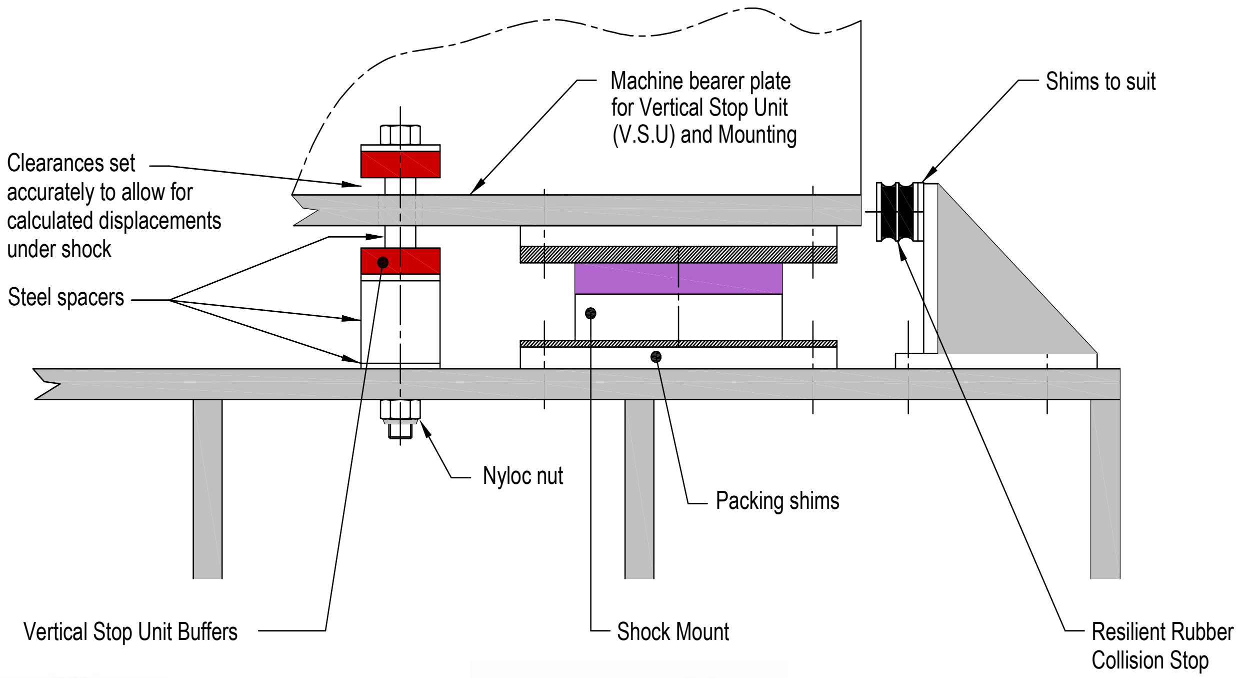
1) Collision with another vessel or wave induced shock - This results in relatively small hull accelerations (up to about 3 g) even on small craft. However, the relative displacement can be large if the duration of the shock is greater than the machine mounting system natural period. Approved naval mountings such as the type PD are used with separate resilient stop units to control the displacement under ship motion conditions. If no other shock is present, a commercial marine mounting with internal stops is often employed.

2) Intermediate shock from gunfire or wave slamming on fast patrol craft - Accelerations of up to about 10 g may be seen usually of short duration and small relative displacements. Commercial mountings with robust internal stops such as our type TSC may be employed although each application will require a response calculation to ensure adequate strength and deflection capability.

3) Underwater explosions - These produce much larger shocks with seatings acceleration of over 200 g. Most standard specifications show this maximum input shock reducing if a higher mass is attached to the seatings, since the force impulse can only create a finite momentum. However, flexible mountings reduce the effective mass since the system prevents the reaction force from being transmitted back to the seating. A calculation can be made of this effect so that a prediction of the seatings time history can be made from the motion curves presented in the specification. Since these shocks combine larger displacements and accelerations, the mounting system is usually a compromise incorporating resilient stop units set with sufficient clearance to permit some relative displacements whilst reducing the peak acceleration. A shock of 200 g and 40 mm displacement may be reduced to about 15 g and 25 mm displacement on the equipment, but much depends upon the shape of the shock pulse and the allowable clearances.

In some cases yielding devices such as stretchable bolts are incorporated to absorb more energy. However, these would normally require replacement after an attack and hence their design is to protect against higher shock forces only.

Typical details of an application for Marine Shock Mounts



For more detailed information and technical assistance please contact our Technical Department.

In the interests of continual development, the Company reserves the right to make modifications to these details without notice.

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