We just made the task of securing "mission-critical" equipment amazingly simple.

The Seismic Mitigation Solution
for "mission critical" 24x7 equipment

- AT&T
- Boeing
- Qwest Communications
- Immunex
- Qualcomm
- 911 Centers
- CISCO SYSTEMS
- AMGEN
- Jabil Semiconductor
- AOL Time Warner
- Dept. of Energy - Bonneville Power
- FOX Studios
- ARCUS Data Security
- ALZA
- Macy's
- AMAT
- Remedy

IsoBase™ Seismic Isolation Platform

with exclusive Ball-N-Cone technology can keep your IT environment rolling along, right on through a major earthquake

Some of the worlds **most forward thinking companies** use *IsoBase*™ Seismic Isolation Platforms to achieve the highest level of protection available for their valuable IT mainframes and equipment. And they do it without bolting, drilling, strapping or anchoring, and without the inconvenience of a facility shutdown.

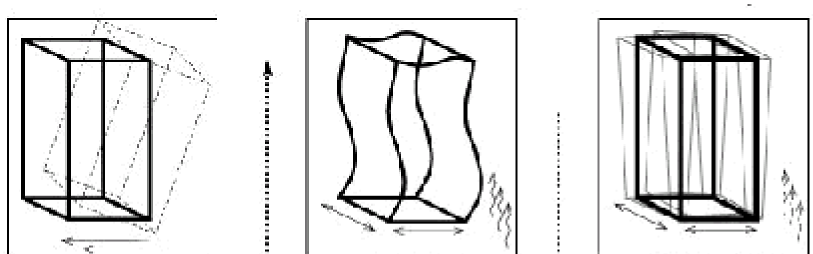
principles of base-isolation

earthquake effects

When the earth moves, the base of a bolted-down cabinet moves with it. The frame of the cabinet weakens under the forces of swaying, damaging the equipment with vibrations.

traditional measures

The traditional solution has been to stiffen the frame for it to accept more input energy. However, the impact of a stiffened frame on sensitive components within the cabinet (such as drive heads) can be devastating. A properly designed base-isolation system will offset ground motions by decoupling the top platform from the bottom one that moves with the ground. Damaging low-frequency seismic vibrations are filtered away before they can enter the top platform, protecting sensitive equipment.



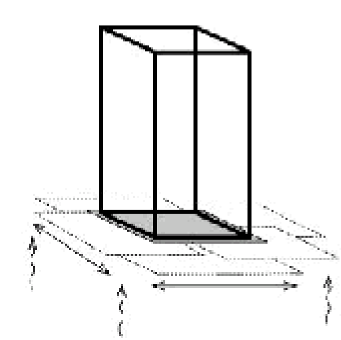
UNBOLTED — Shows reaction of cabinet to seismic ground motion

BOLTED — Depiction of stresses on a cabinet frame when bolted

STIFFENED — Shock and vibrations sent into a 'stiffened' cabinet

The new solution

properly designed base-isolation system will offset ground motions by decoupling the top platform from the bottom one that moves with the ground. Damaging low-frequency seismic vibrations are filtered away before they can enter the top platform, protecting sensitive equipment.



BASE - ISOLATED

illustrates use of base-isolation dual-platform which dislocates ground motion, thereby minimizing the effect on the top platform. The system filters out "white noise" (low frequency vibrations) and since the top stays relatively still, sensitive equipment can continue to operate during intense shaking.

benefits

easy installation

- no shut-down of facility required
- no hammer drilling
- no drilling into metal
- done during normal working hours

architectural and structural items

design strength

- **buildings** – Designed and built to current codes may withstand the destructive vibration forces of an earthquake, but content or non-structural items may not
- **nonstructural items** - During an earthquake the contents will be shaken violently inside the building irrespective of how strong the building is designed. These items are usually not included in the structural design (unless it is a Chip Manufacturing Fab., Telco, Co-Lo, or Hospital).

nonstructural items

- **computer cabinet frames** - Most computer cabinet frames provided by the computer industry are designed for static environments. When anchored, these cabinets will be subjected to vibration forces from an earthquake, resulting in racking (twisting and bending the design was never intended to resist)

IsoBase™ SIP Product Description

A modular, open frame platform comprised of Ball-N-Cone® (BNC) Seismic Isolation Bearings.

Performance Features

- **g Force Isolation** - The *WorkSafe* TECHNOLOGIES® *IsoBase*™ SIP decouples the computer equipment / cabinet from earthquake ground accelerations minimizing the acceleration transferred into the isolated computer as low as 0.2g. *This is below the max. "g" vibration forces for most operating disc drives.* (While the Richter Scale cannot be used for purposes of seismic design, acceleration levels of between 0.15g - 0.18g are the rough equivalent of an earthquake magnitude of less than 2.0 on the Richer Scale.)
- **Input Frequency Isolation** - The *WorkSafe* TECHNOLOGIES® *IsoBase* ™ SIP works effectively for a broad band of input frequencies because the Ball-N-Cone (BNC) seismic isolation bearing is a white noise filtering bearing. Neither the BNC bearing nor the computer *will ever be in resonance* with the ground shaking.
- **Design Criteria** - Horizontal ground acceleration limited to 0.2g for most earthquake scenarios with peak accelerations up to 2.25g.

Key Components

- **Ball-N-Cone® (BNC) Seismic Isolation Bearings** - Gravity restoring seismic isolation bearings comprised of one chrome steel ball sandwiched between two dishes with matching conical recesses.
- **Open Air Frame** - A modular designed frame that is field assembled to fit the actual plan dimension of the equipment / cabinet.

Transportability

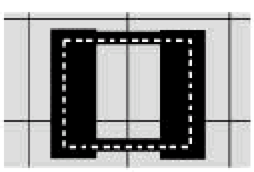
The *WorkSafe* TECHNOLOGIES® *IsoBase*™ SIP platform can be easily moved and easily transported with the equipment. The platform width can be adjusted to fit the plan dimensions of other equipment / cabinets

Shake Table Testing

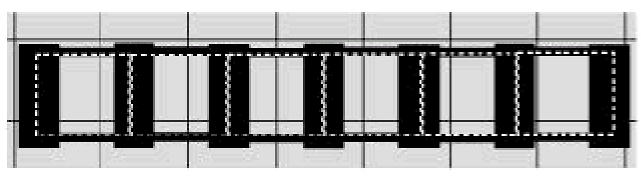
Our seismic-isolation products were independently tested at the University of British Columbia, Civil Engineering Laboratory in July, 1998 (http://www.civil.ubc.ca/home/eq_lab/). The test were conducted for PWGSC (Public Works & Government Services Canada) as part of their nonstructural fastening "standards" project

Performance

- **Table** - The "state-of -the-art" shake table performed tests on both the horizontal and vertical axis.
- **Bell Core Test** - The *WorkSafe* TECHNOLOGIES® *IsoBase*™, installed under LAN Racks, and Electronic Enclosures passed the rigorous Bell Core Synthetic Test (GR-63-Core), at 100% amplitude (a simulated magnitude 7.5 earthquake) for meeting UBC Seismic Zone 4 requirements.



single unit



ganged platform for multiple units

Disk Drives

Without the Seismic Isolation Platform - The data that has been gathered, indicates that during an earthquake with peak ground acceleration greater than 0.5g, the Disc Drives would be subjected to forces that would probably result in permanent damage, and possibly loss of data (see table below).

Manuf. - Model	**max. g operating**	**frequency**	max. g non-operating	frequency
Compaq - Alpha ES	**0.1g**	10-500 Hz		
Compaq - Alpha GS	**0.1g**	10-500Hz		
EMC Clarion	**0.25g**	5-500Hz		
HP- Model 20 Disc Drive	**0.25g**	5-2000Hz	0.5 - 1.0g	5-500Hz
HP – 9000 K Class	**0.21-0.50g**	5-500Hz		
SGI – Origin Fibre Vault	**0.25g**	5-2000Hz		
Sun - Class III Disc Drive	**0.25g** (all axis)	5-500Hz	1.0g (all axis)	5-500Hz

Manufacturers' Vibration Specification

Comments from engineers at Hewlett Packard:

- **Vibration Test Spectrum** - The lower part of the spectrum includes frequencies found in the upper part of the earthquake spectrum. The test was designed primarily to determine the destructive forces at higher frequencies.
- **Earthquake Spectrum** - The energy or "g forces" generated by an earthquake's seismic waves are more destructive than what is indicated by the table above. The reason is; seismic waves have longer periods and much larger amplitudes than found in the higher frequency test. *The above table should be considered as optimistic values.*

IsoBase™ – Example Installations

IsoBase™ – Example Installations

Sample Design

Ref: 1998 California Building Code, Chap. 16B, Div. IV., Earthquake Regulations for Seismic-Isolated Structures [for OSHPD 1 and DSA/SS]

This code is similar and virtually identical to UBC 1997 and all other code regulations (including FEMA 356 and ASCE) used in the USA and worldwide (including the Japanese code) applied for seismically isolated structures. These codes consider building contents, such as computers (even if their market value far exceeds the building's value) sacrificial and thus beyond scope. It is conservative and prudent, however, as these codes specifically allow for, applying these structural seismic design procedures to building contents too. Facility owners are free to accept limited damage potential for economic reasons and provide for seismic isolation accordingly. For instance, it is prudent to limit lateral seismic forces on main frame computers to 0.1g, but allow one or a few impact forces, not to exceed 0.5g. Published studies by IBM indicate that that level of forcing have only 10% chance to damage such computers or to halt their operation. See http://www.worksafetech.com/pages/isotest.html .

The ISO-Base™ Seismic Isolation Platform manufactured by WorkSafe Technologies™ meets the above stated voluntary design criteria. It had passed the intense UBC-Bellcore Engineering Test (R7.5) in Canada and were proven to exceed worldwide Seismic Zone 4 requirements. It relies on Tekton's Ball-'N'-Cone® Seismic Isolators manufactured by WorkSafe Technologies™ and covered by U.S. Patent # 5,599,106 (international patents pending & insured). See more about it in http://www.worksafetech.com/pages/isobase.html address.

The sample calculation below is made for an HP "N" Class Cabinet Ganged in over 60 ft row, but is representative to typical EMC, SGI, SUN and DEC Cabinets.

Design Problem:

Check adequacy of the ISO-Base™ Seismic Isolation Platform for isolating an HP "N" Class Cabinet ganged in a single row with or without anti-tip feet as shown below. Size: 23.5"W x 29.5"D x 73.5"H. Feet: Rigid threaded levelers spaced at 20.5"W x 26.5"D c/c. Weight: Unknown. Weight distribution: Unknown. Location: Fourth floor, concrete floor in Braced Framed Building. Site: Central Los Angeles, 10 miles from active seismic fault line capable to erupt in larger than magnitude 8.0 earthquake measured on the Richter scale. Soil: Stiff, bedrock, meets S_A or S_1 soil profile as per Table 16B-J of the referenced code. Hook up: Electronic cables, no piping, meets 11% damping criteria as per Table 16B-E of the referenced code. Platform: plan size matches cabinet, displacement capacity 8 1/8", ball size 1 1/2", weight rating exceeds actual weight as assured by WorkSafe Technologies™. The platform's sizing is the manufacturer's responsibility, thus to be omitted here. These design parameters are representative to typical applications.

1) displacement per Sect. 165B.3.1.

$D = 10ZNS_IT_I/B$ (54-1) where D = seismic Displacement in inches,
Z = seismic Zone base shear in g/g,
S_I = site Soil profile coefficient,
T_I = period of isolation system in sec., and
B = damping coefficient of hook-up.

Note that 10 were obtained by rounding up π^2.

Where

$T_I = 2\pi\sqrt{W/k_{min}g}$ (54-2) where W = Weight of cabinet in lbs,
k_{min} = min. effective isolator stiffness in lb/in,
g = gravity acceleration = 386 in/sec^2.

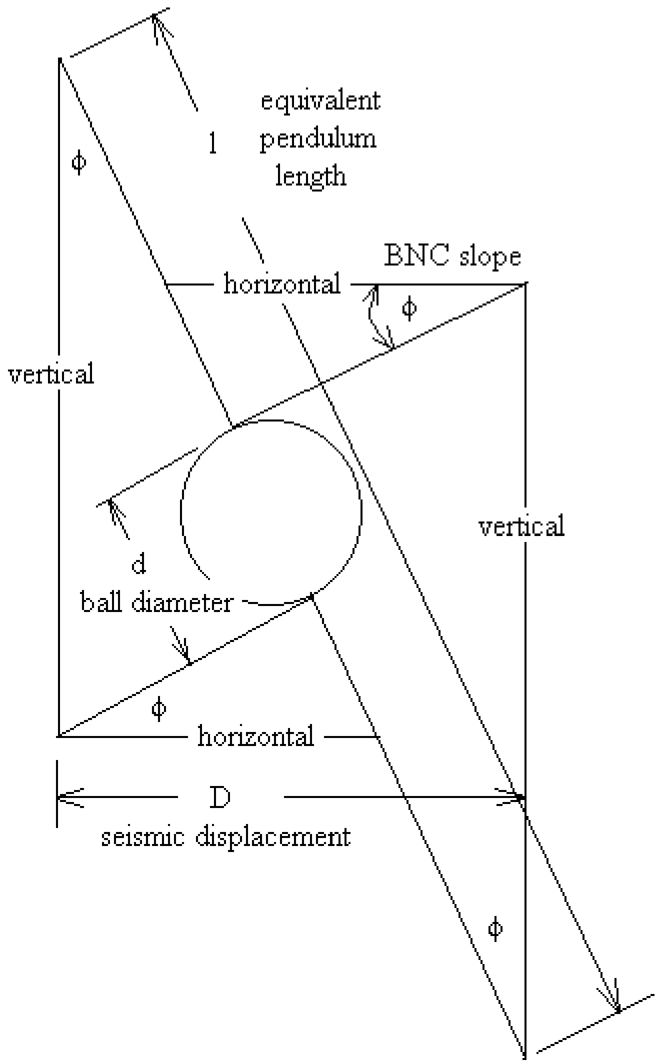
Let us substitute

$A = 10ZNS_IT_I/B\pi^2 = ZNS_I/B$ [1]

And thus simplify (54-1) as

$D = \pi^2AT_I$ [2].

Note that A is the base acceleration normalized to g, which acts on the computer floor.
The Ball-‘N’-Cone® Seismic Isolator (BNC) works like a pendulum of length l measured in inches as explained below:



That is, l is a function of D and computed as

$l = (D-d)/\cos\phi\tan\phi \approx (D-d)/\phi$ [3] where ϕ is in radian and small ($\ll 1$).

Using this, we obtain the stiffness as a function of displacement as

$k_{min} = W/l = W\phi/(D-d)$ [4] which need to be substituted back to (54-2).

$T_I = 2\pi\sqrt{W/[W\phi/(D-d)]g} = 2\pi\sqrt{(D-d)/\phi g}$ and this substituted back to [2],

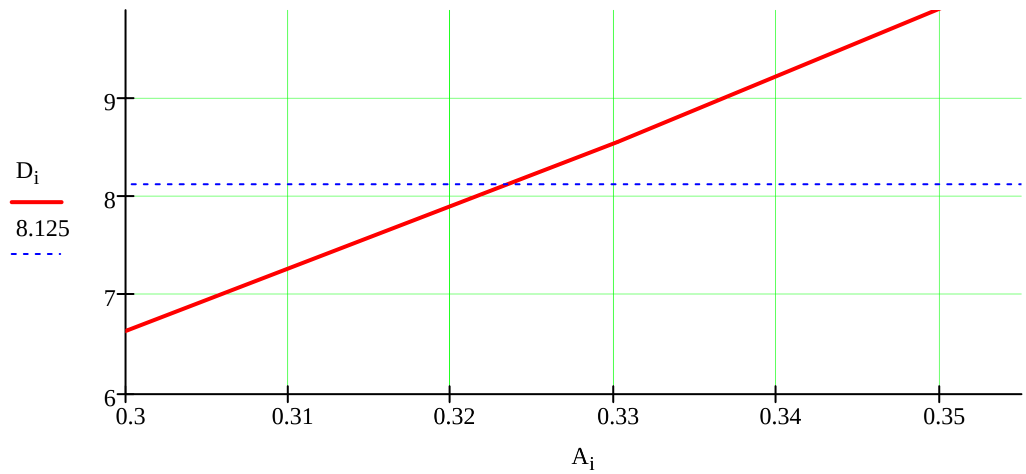
$D = \pi^2 A 2\pi\sqrt{(D-d)/\phi g}$ [5] which is to be solved for D as:

$D = 5A^2/\phi + \sqrt{25A^4/\phi^2 - 10A^2 d/\phi}$ [6] where we rounded up $4\pi^6/g$ to 10 sec^2/in.

Below, for the range of interest, a simple Mathcad® program plotted the BNC performance in question using [6] and the applicable parameters as $\phi = 0.105$ (for 168° cone or 6° slope angle) and $d = 1.5$”:

$$i := 1, 2 .. 12 \qquad A_i := 0.03 \cdot i + 0.0001 \qquad \phi := 0.105 \qquad d := 1.5$$

$$D_i := \frac{5 \cdot (A_i)^2}{\phi} + \sqrt{\left[\frac{25 (A_i)^4}{\phi^2} - \frac{10 (A_i)^2 \cdot d}{\phi}\right]}$$



Now, let us finalize our checking: $Z = 0.4$, $N = 1.0$, $S_I = 1.0$ and $B = 1.35$. Note that the unlined (bare steel) BNC has 4% damping ($B = 0.9$) and the hook-up adds 11%. Thus

A = 0.4(1.0)1.0/1.35 = 0.296 < 0.500 OK, no impact on the Cabinet.

For curiosity, let us examine how much impact would receive the cabinet if the building would be less than 3 miles from fault line:

A = 0.4(1.0)1.5/1.35-0.323 = 0.444-0.323 = 0.121 < 0.500 OK with one or few impacts of less than or equal to 0.121g.

Further on, would this still work on soft soil of Soil Profile S_E or S_3:

A = 0.4(1.0)2.7/1.35-0.323 = 0.800-0.323 = 0.477 < 0.500 OK.

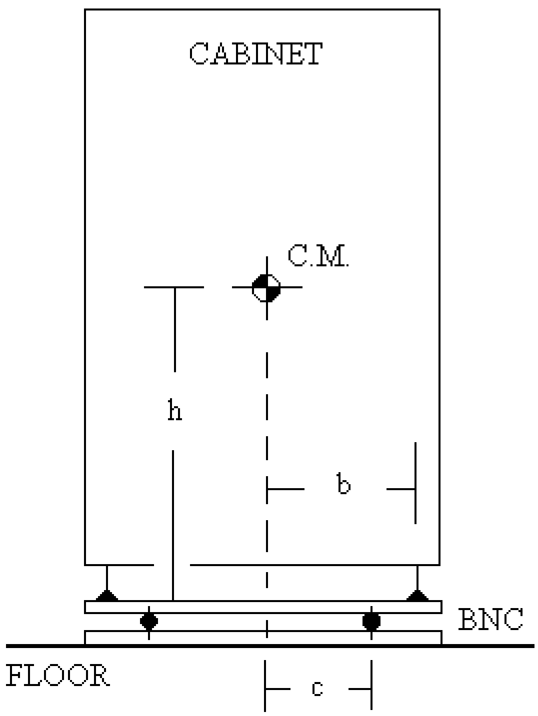
Notice, that W canceled out of [6], that is the Cabinet weight is irrelevant for this seismic design.

Lining the BNC dishes with 1/16” to1/8” rubber or poyurethane adds about 2 to 6% damping. Additionally -- in lieu of more data -- based on Tekton’s experiences and calculations, the following hook-up damping values assumed to be conservative:

- Light hook-up with few small wires 1 to 3%
- Light hook-up with many small wires bounded 3 to 9%
- Common hook-up with many assorted wires bounded 9 to 16%
- Extensive hook-up with many assorted wires bounded 16 to 21%
- Large scale hook-up with heavy wires 21 to 27%.

2) Check overturning.

Due to ganging, governs the Cabinet depth of the Cabinet without the anti-tip feet.



The cabinet will not overturn if

$c \geq b\text{-}\phi h$ [7] and if

$b/h \geq \phi$ [8]

Thus, h = (73.5 + 1.5)/2 = 37.5” and c = (29.5 – 10.5)/2 = 9.5” actual, c = 13.25 – 0.105(37.5) = 9.5” required, OK. (Note that we assumed 1 1/2” leg height.)

End Sample Calculation.

WorkSafe™ TECHNOLOGIES

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