TRICK shock isolation analysis

Shawn Callahan, Hector Rodriquez

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What is the required displacement and natural frequency to keep the accelerations from transportation shocks below 2g using foam and Keck's shock requirement for shipping instruments?

References: http://www.deltaflex.com/lord_pdfs/engineering_guide_ip.pdf

Environmental Conditions for instrumentation November 17, 2009 by Sean Adkins

Assume half sine input at 15g for 0.015 seconds

$G_{in} := 15 \cdot g \qquad t_0 := .015 \cdot sec$

Calculate delta V

$$\Delta V := \frac{2 \cdot G_{in} \cdot t_0}{\pi} = 1.405 \frac{m}{s}$$

Now calculate the frequency for a given fragility factor of 2 g's.
Note: KCWI is designed to withstand 4 g's in all axes.

$G_{fragility} := 2 \cdot g$ TRICK: assume more fragile instrument

Calculate the natural frequency of the isolators to achieve the desired fragility factor.

$$f_{n\_max} := \frac{G_{fragility}}{2 \cdot \pi \cdot \Delta V} = 2.222 \, Hz$$

Static deflection from f=(1/2π)(k/m)^.5

$$\delta_{static} := \frac{g}{\left(2 \cdot \pi \cdot f_{n\_max}\right)^2} = 50.302 \, mm$$

Dynamic deflection

$$\delta_{dynamic} := \frac{\Delta V}{2 \cdot \pi \cdot f_{n\_max}} = 100.604 \, mm$$

Assume weight of instrument is 150 lbs.

$$Wt_{dewar} := 100\cdot lbf = 444.822\,N$$

$$Wt_{pedestal} := 35\cdot lbf = 155.688\,N$$

$$Wt_{shipping} := 150\cdot lbf = 667.233\,N$$

Calculate the maximum stiffness of the foam/isolator

$$k_{max\_isolator} := \frac{Wt_{shipping}}{\delta_{static}} = 75.742\,\frac{lbf}{in}$$

Investigate using **anti-static foam** from the Foam Factory .

http://www.thefoamfactory.com/tech/AntiStaticTech.html

Select an IFD is:

$$IFD := 35\cdot lbf$$

From the definition of IFD, for a strain of .25 the force is 35 lbs/ 50 in^2:

$$thickness_{foam} := 3\cdot in$$

$$\sigma_{foam} := \frac{IFD}{50\cdot in^2} = 4.826\times 10^3\,Pa$$

$$\varepsilon_{foam} := 0.25$$

Calculate the effective modulus of the foam:

$$E_{foam} := \frac{\sigma_{foam}}{\varepsilon_{foam}} = 2.8\,psi$$

Determine the stiffness of using two sheets of foam for the bottom and top of the shipping container.

$$diameter_{bottom} := 15\cdot in \qquad no_{bottom\_layers} := 3$$

$$Area_{anti\_static\_bottom} := \frac{\pi \cdot diameter_{bottom}^{2}}{4}$$

$$thickness_{anti\_static.bottom} := thickness_{foam} \cdot no_{bottom\_layers}$$

$$k_{foam\_anti\_static} := \frac{E_{foam} \cdot Area_{anti\_static\_bottom}}{thickness_{anti\_static.bottom}} = 54.978 \frac{lbf}{in}$$

Conclusion: two layers is adeuquate to support the bottom and top of the instrument.

Use three 3" thick foam 27" accross with a 12.75 inch hole to constrain side-side.

$diameter := 12.75 \cdot in$

$Height := 27 \cdot in$

$thickness_{foam\_side} := 3 \cdot in$

$width_{sides} := 6 \cdot in$

$Area_{side\_side} := diameter \cdot thickness_{foam\_side}$

$no_{side\_side} := 3$

$$k_{side\_side} := \frac{E_{foam} \cdot Area_{side\_side}}{width_{sides}} \cdot no_{side\_side} = 53.55 \frac{lbf}{in}$$

$$k_{max\_isolator} = 75.742 \frac{lbf}{in}$$

Conclusion: three radial foam supports provides adequate radial isolation.