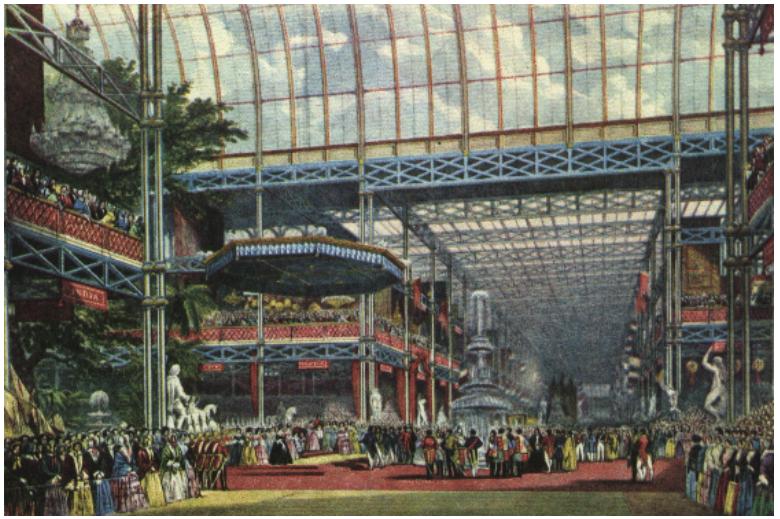
Shock, Vibration, Temperature, and Humidity

Mervin Richard, Chief of Conservation
National Gallery of Art
November 6, 2014

Art on the Move

14,000 exhibitors

6,200,000 visitors



Crystal Palace
Hyde Park, London,1851

The Big Question

Can the object be moved with Minimal risk?

Yes

Go for it!

No

Forget it!

Agents of Deterioration

- Vibration ✓
- Shock ✓
- Temperature ✓
- Relative Humidity ✓
- Light
- Pollutants ✓
- Water
- Pest ✓
- Fire
- Vandalism

Typical Causes of Damage During Shipment

Issue	How it causes damage
Fundamental problems	• Collision of loose object parts • Collision of loose objects • Collision of loose objects with the packing case • Abrasion • Deformation of packing case • Damage during handling prior to packing/shipping
Excessive force	• Inadequate shock protection • Inadequate vibration mitigation

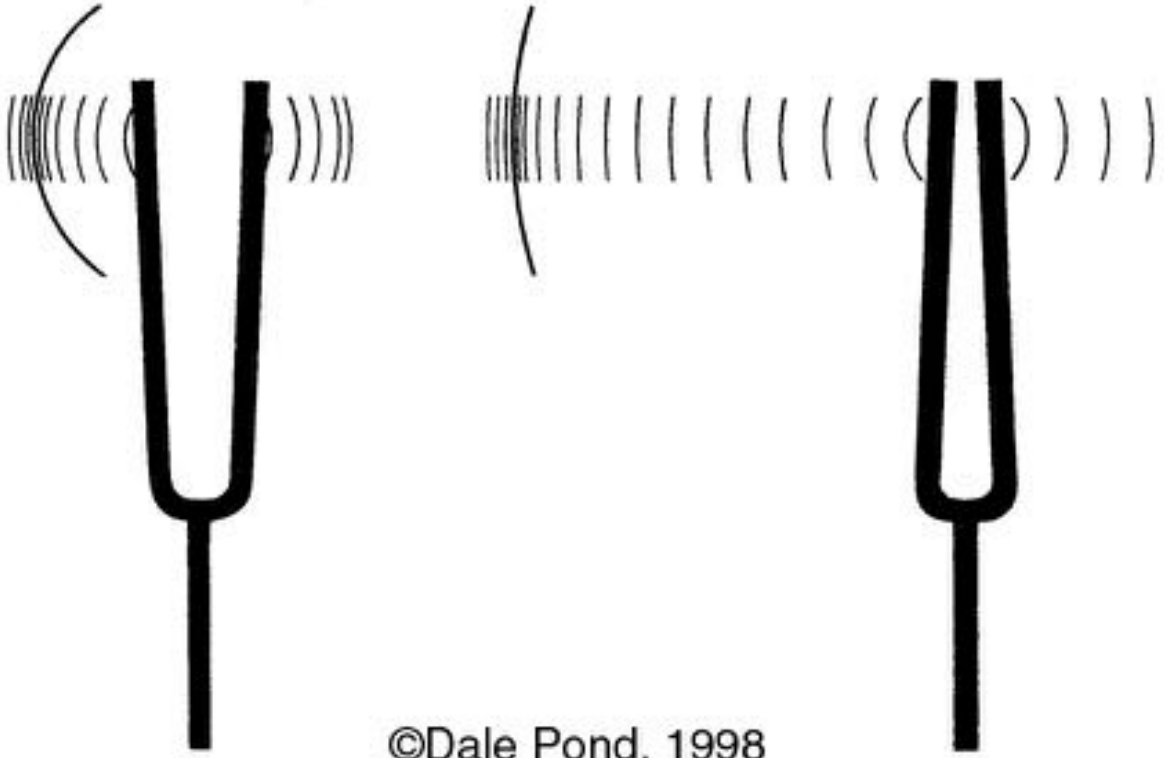
Based on information provided by Paul Marcon, CCI

Typical Causes of Damage During Shipment

Issue	How it causes damage
Lack of restraint in transit	• Repetitive bouncing of cargo • Stacked items falling in moving vehicles
Environmental hazards	• Extreme heat or cold • Extreme RH • Water (e.g. rain or snow). Pests. • Pollutants (poor quality packing materials)
Extreme hazards	• Intentional mishandling of packages. • Vehicle accidents

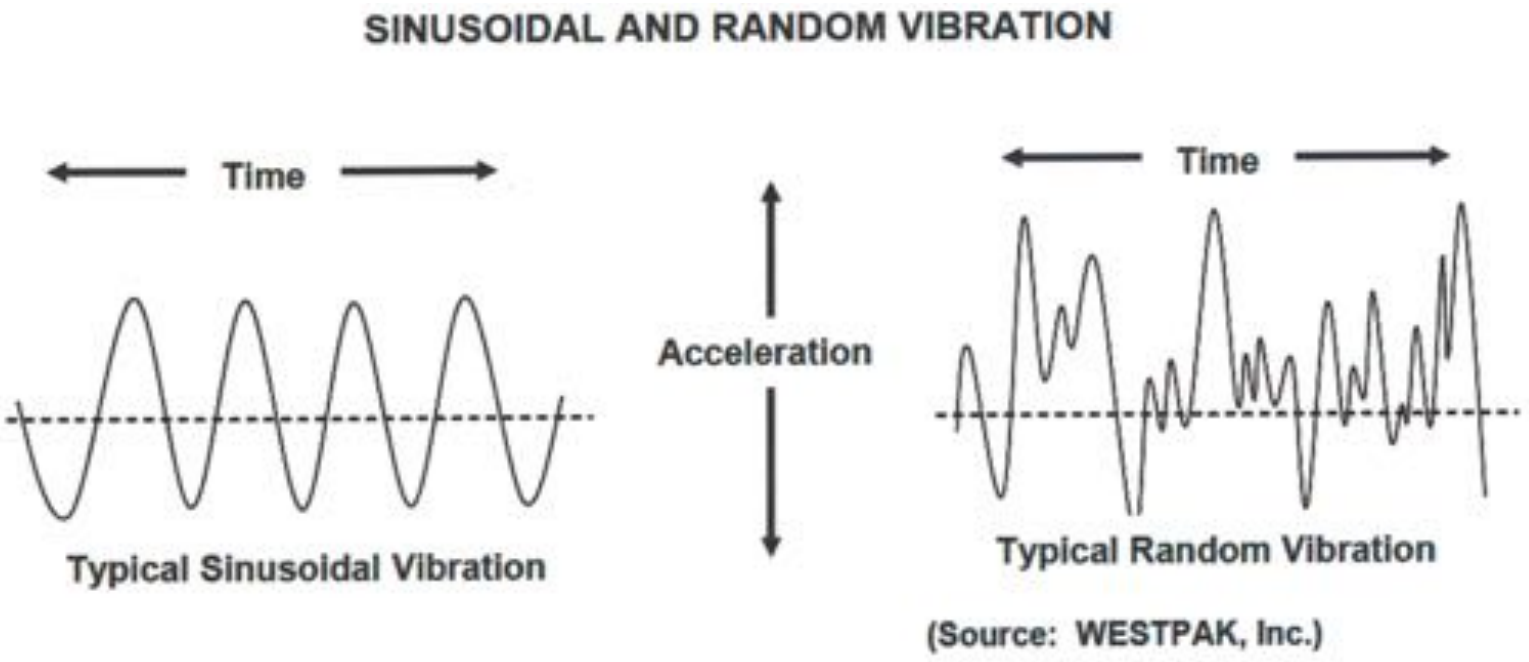
Based on information provided by Paul Marcon, CCI

Vibration

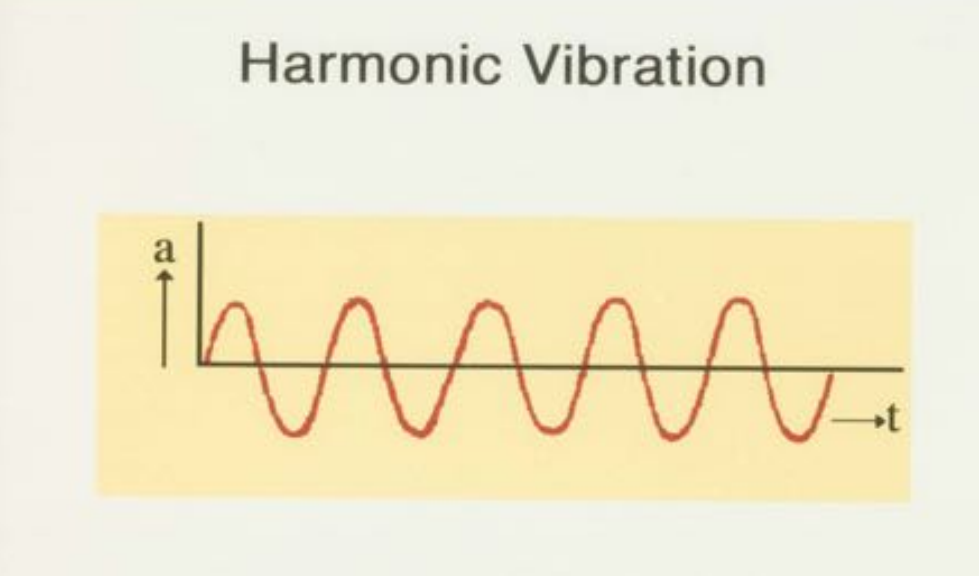


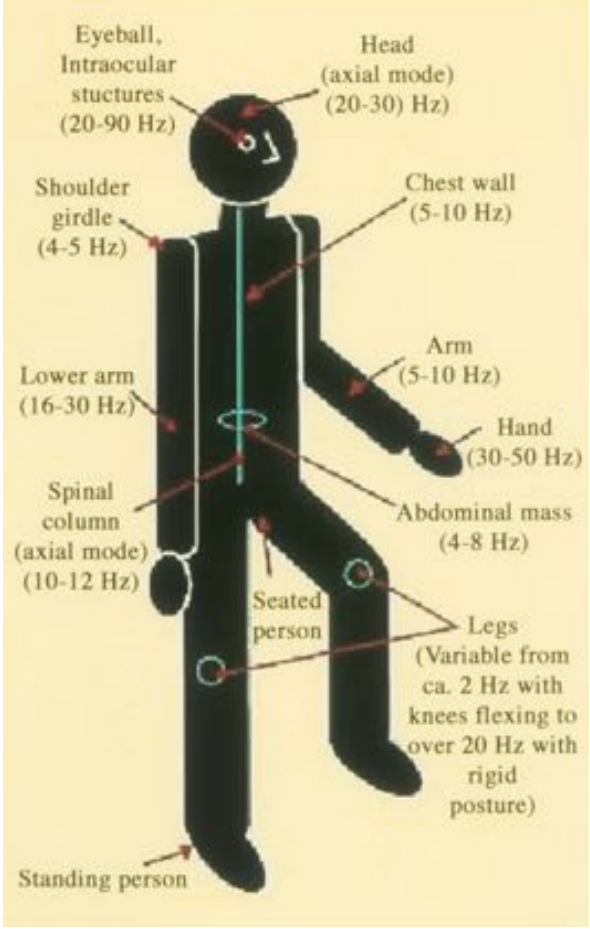
Vibration

Vibration


SINUSOIDAL AND RANDOM VIBRATION
Time
Acceleration
Time
Typical Sinusoidal Vibration
Typical Random Vibration
(Source: WESTPAK, Inc.)

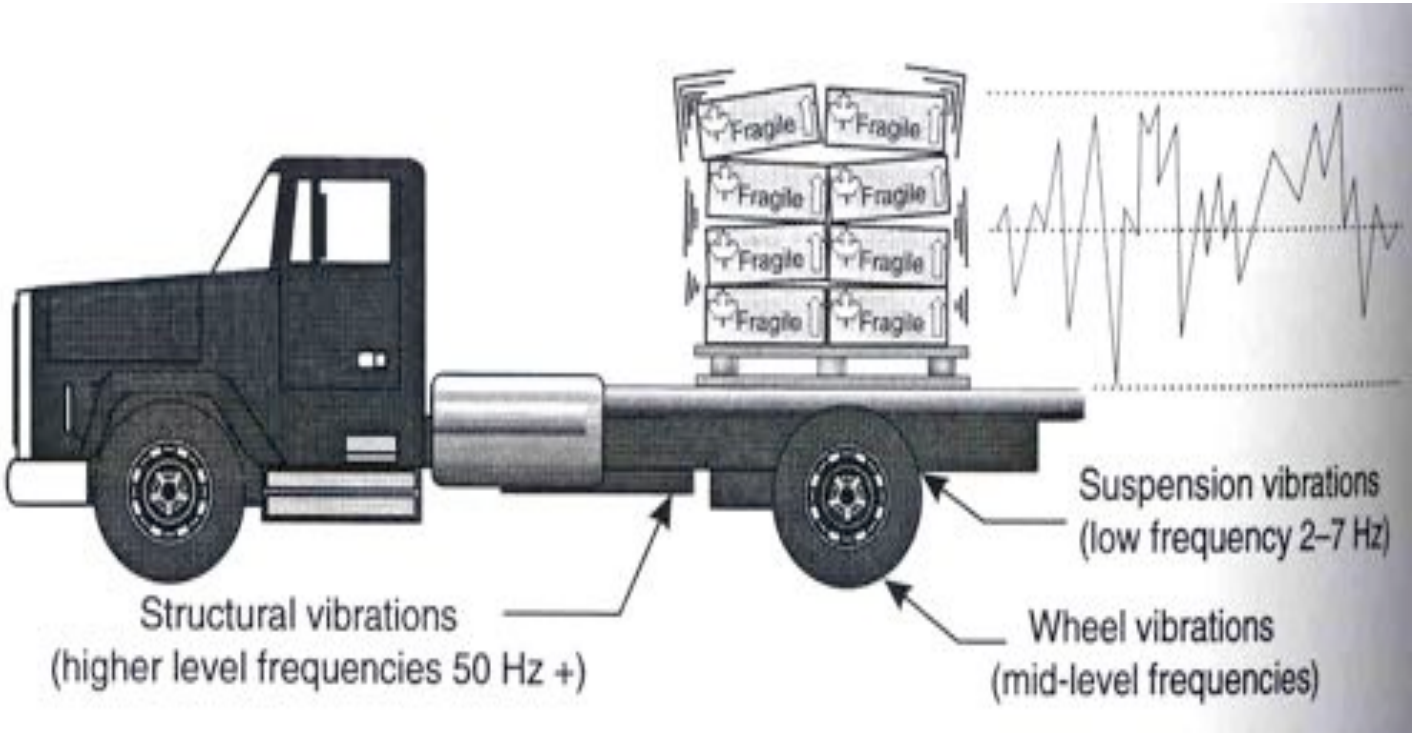
Vehicle Vibration





Vibration

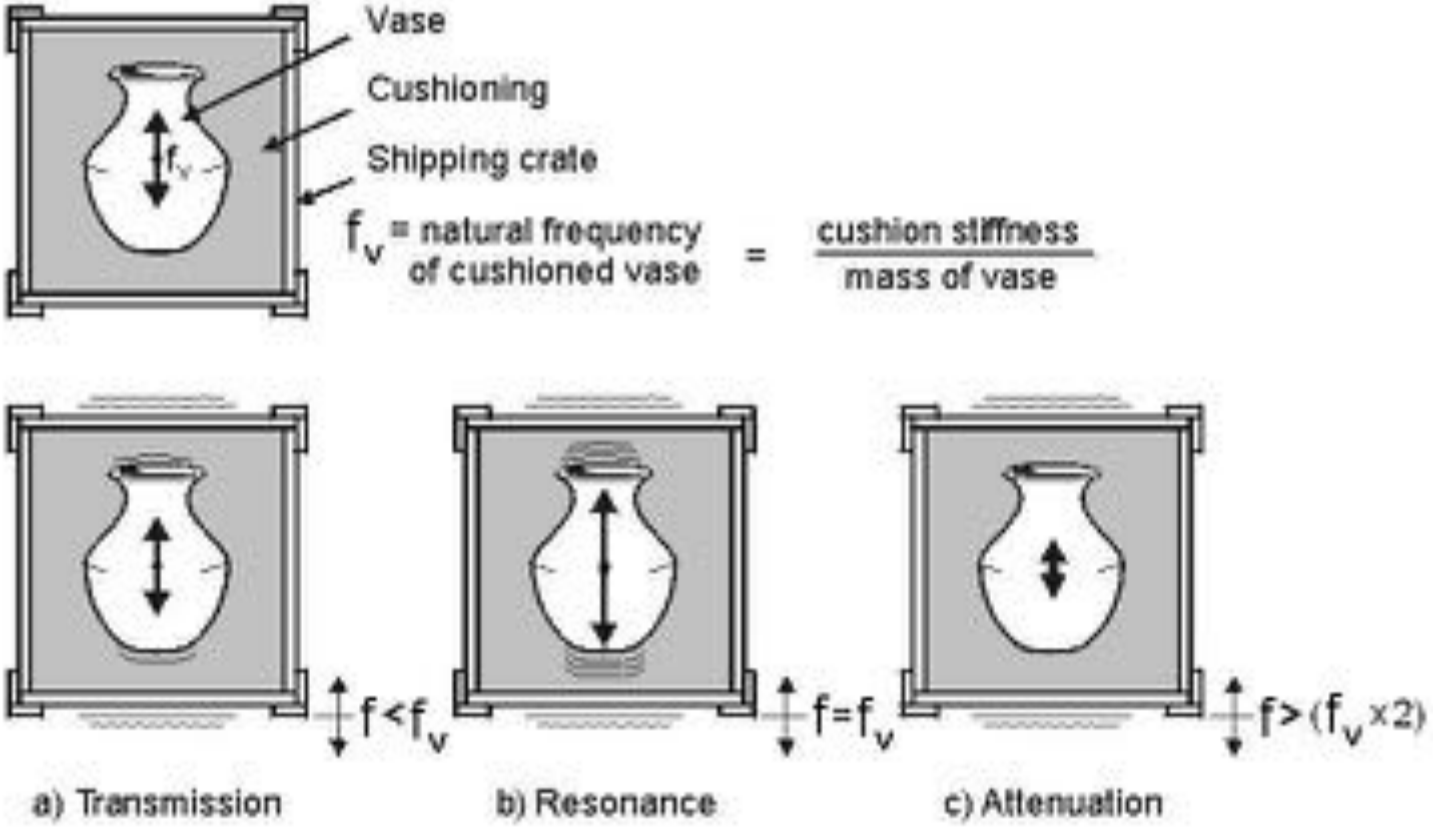
Vibration


Fragile
Fragile
Fragile
Fragile
Fragile
Fragile
Fragile
Fragile
Suspension vibrations
(low frequency 2–7 Hz)
Structural vibrations
(higher level frequencies 50 Hz +)
Wheel vibrations
(mid-level frequencies)

Air-Ride Suspension

Vibration

Vibration



Paul Marcon, Canadian Conservation Institute

Vibration

Paul Marcon, Canadian Conservation Institute

Vibration

Vibration Testing (Data Physics, Corp.)

Truck Vibration Environment

- Typically random vibration
- Higher vibration levels than aircraft
- Air-Ride Suspension is recommended
- Greatest concern
  - Low frequency vibrations with large displacements

Shock

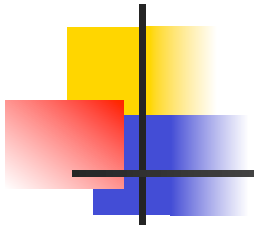
A mechanical or physical **shock** is a sudden acceleration or deceleration caused, for example, by impact, drop, kick, earthquake, or explosion

Shock

Force

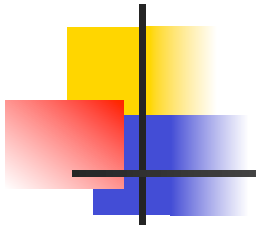
- That which causes an object with mass to change shape, direction, or speed
- Force = mass x acceleration

Force



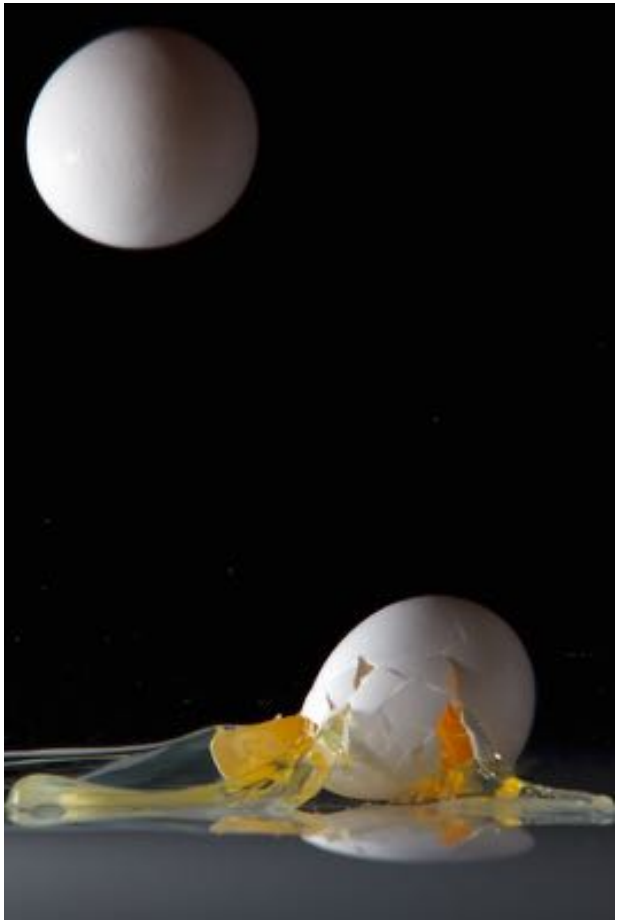
- Poundal
  - English unit of force
  - Force to accelerate one pound at a rate of one foot per second squared
  - pdl = lb ft/s^2

g- force

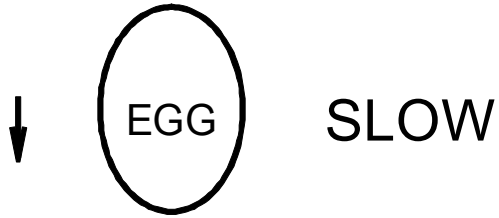


- Acceleration relative to free-fall
- Unit-less
- Easier to use

Shock

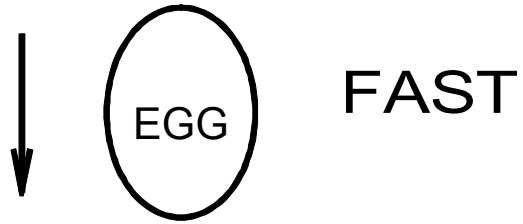


Shock



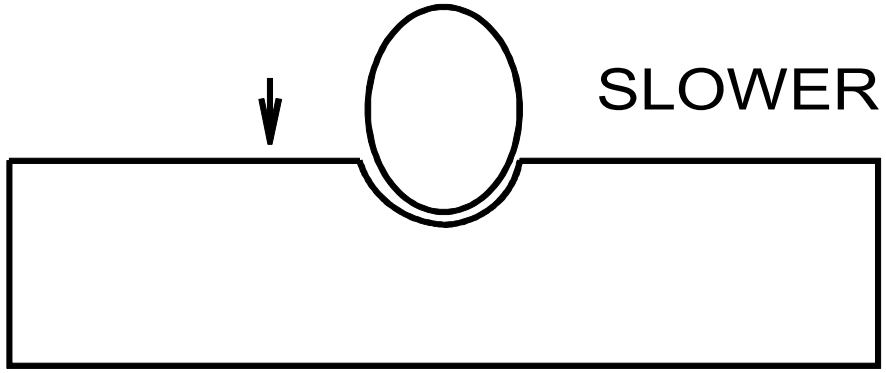
FOAM

Shock

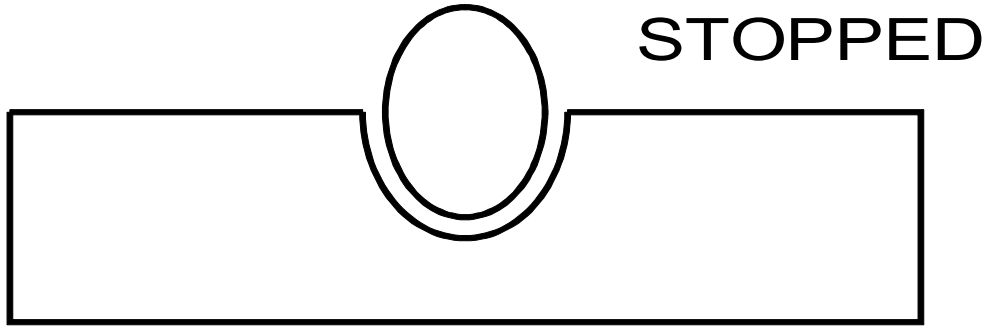


FOAM

Shock



Shock



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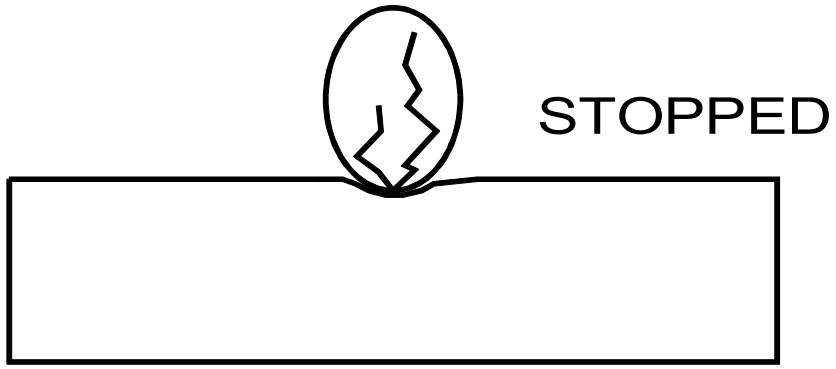
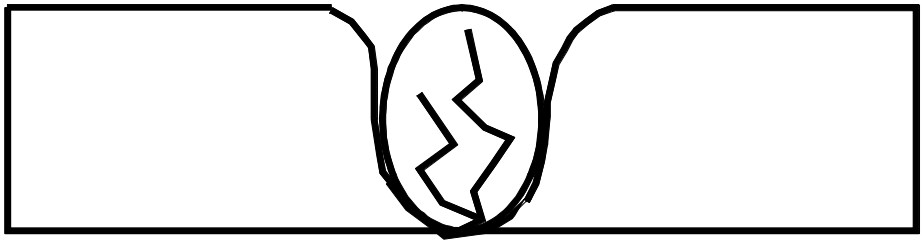


Shock

EGG STRIKES BOTTOM



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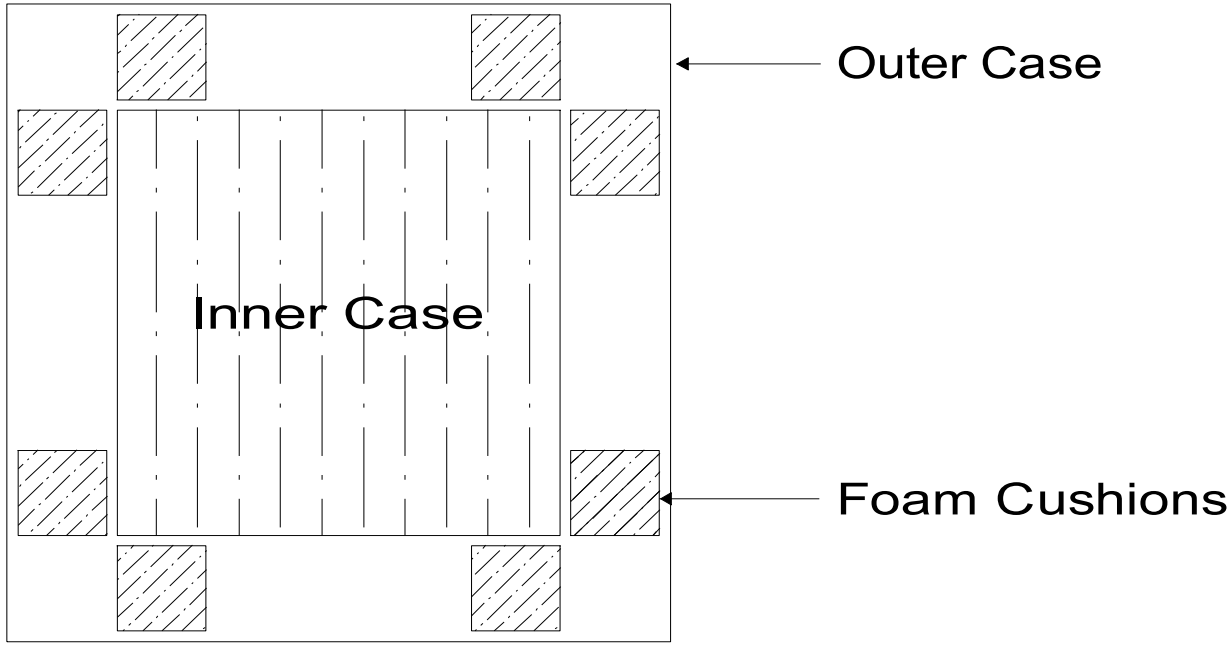
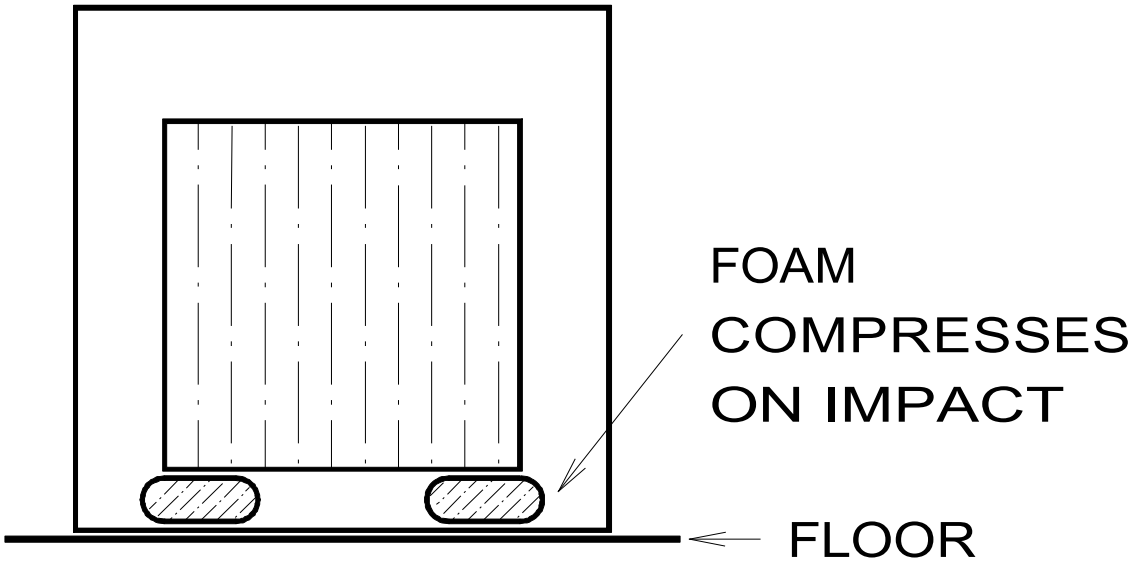


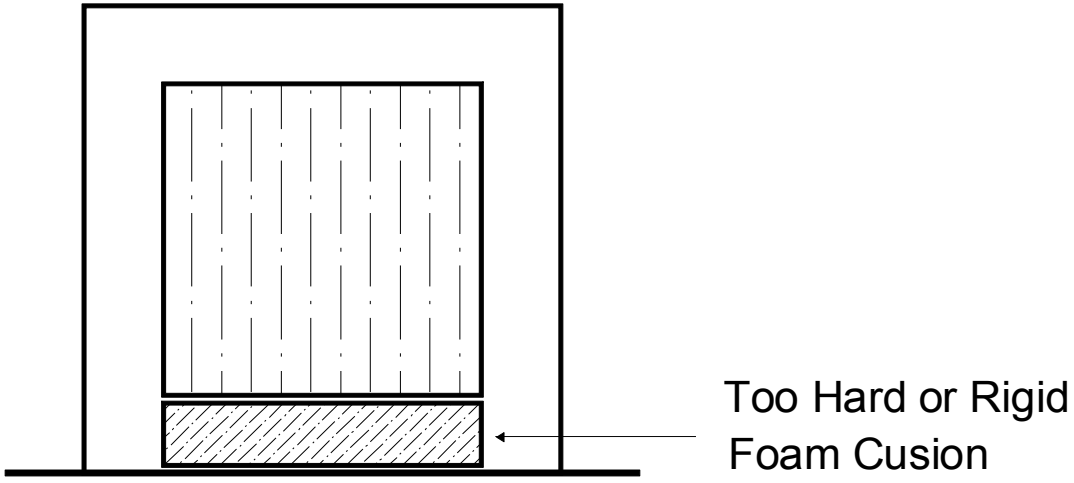
Shock

PROPER STATIC LOADING

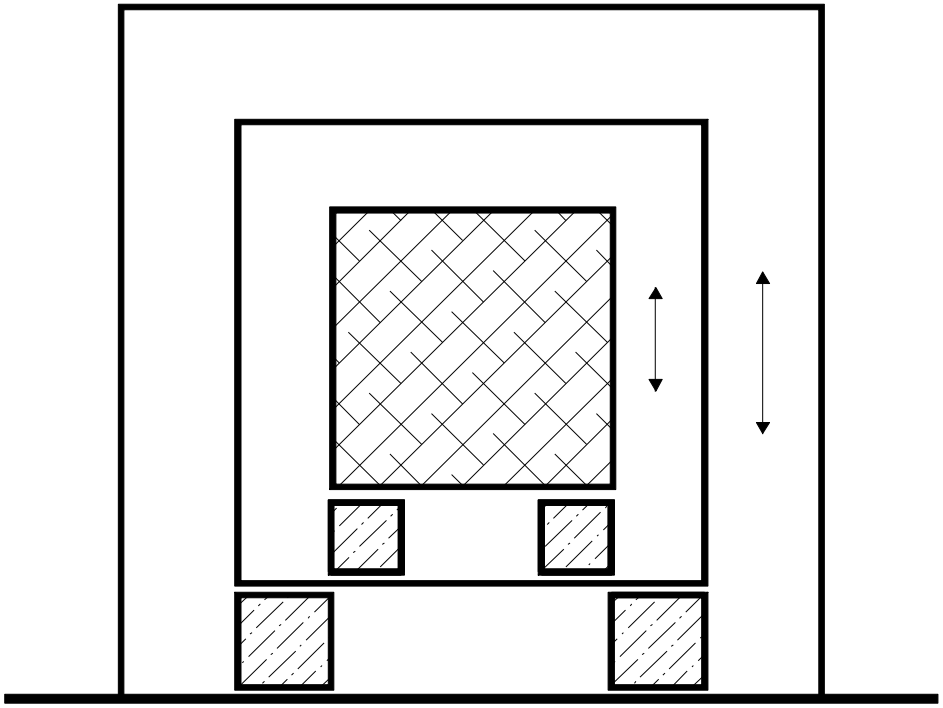


Shock

Improper Static Load

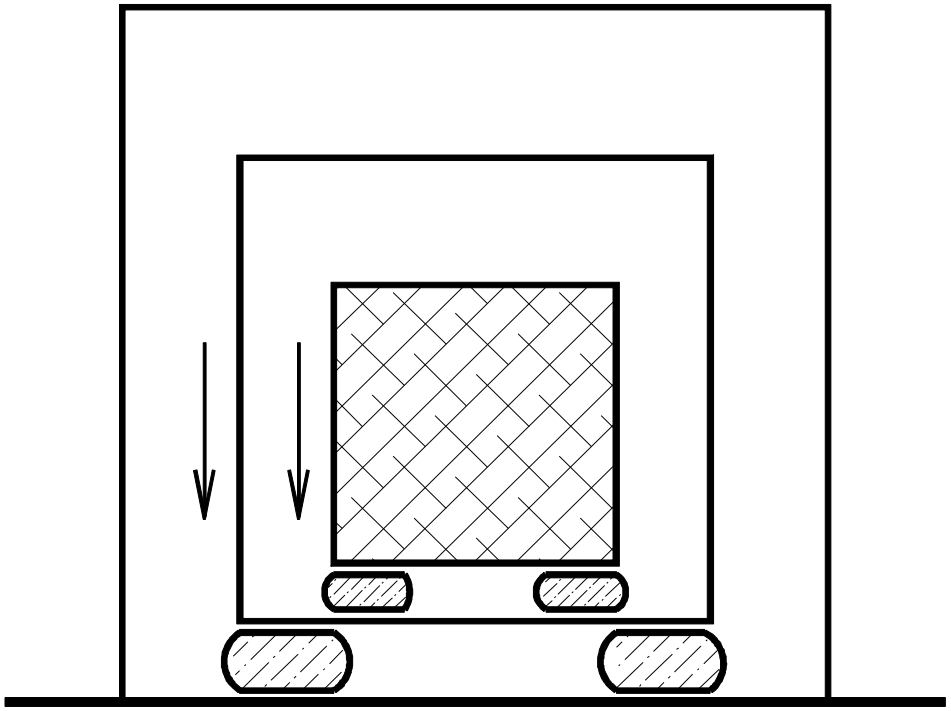


Shock



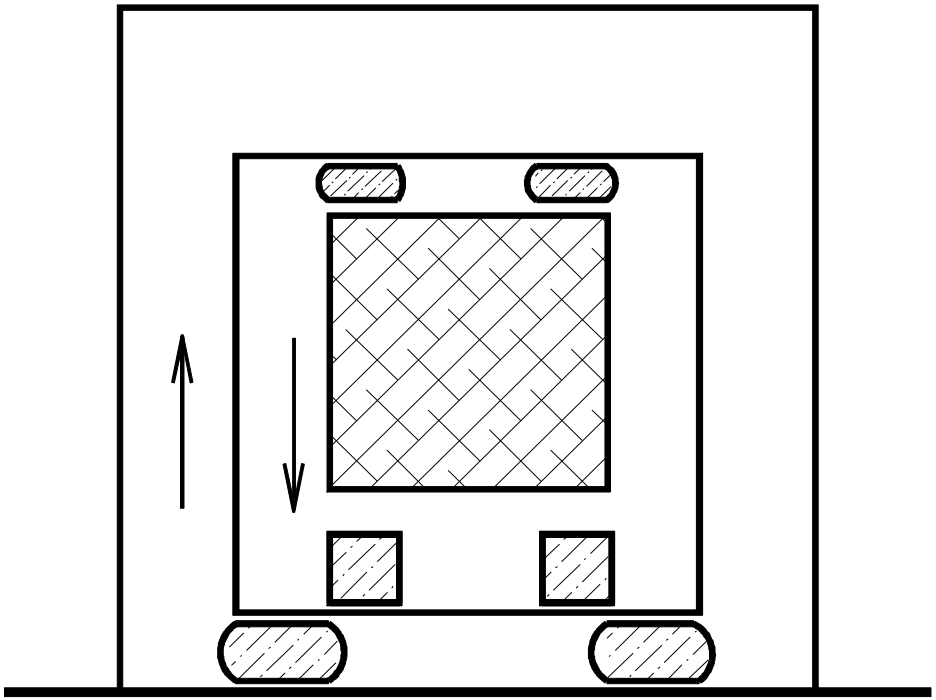
Tandem Cushioning

Shock



Tandem Cushioning

Shock



Tandem Cushioning

Fragility

Extremely Fragile	15-25 g's	Missile guidance systems, precision aligned test instruments, plaster sculpture
Very Fragile	25-40 g's	Mechanically shock-mounted instruments and electronic equipment, scientific instruments, x-ray equipment, some unfired clay , fragile glassware
Fragile	40-60 g's	Aircraft accessories, printers, most solid state electronic equipment, low-fired clay, some plaster, some glassware, some ceramics
Moderately Fragile	60-85 g's	Aircraft accessories, computer displays, unfired clay, low-fired clay, some plaster, some glassware, some ceramics
Moderately Rugged	85-110 g's	Major appliances, furniture, un-cracked, brittle, canvas painting
Rugged	110 + g's	Table saws, machinery

Fragility

Package Weight (lb)	Type of Handling	Drop Height (in.)
0-20	1 Person Throwing	42
21-50	1 Person Carrying	36
51-250	2 Persons Carrying	30
251-500	Light Equipment Handling	24
501-1000	Medium Equipment Handling	18
1000	Heavy Equipment Handling	12

Drop Height Generalizations

According to Fred Ostram and W. D. Godshall

- The probability of a package being dropped from a higher height is minimal.
- Most packages receive many drops at low heights while relatively few receive more than one drop from higher heights.

Drop Height Generalizations

According to Fred Ostram and W. D. Godshall

- Unitized loads are subjected to fewer and lower drops than are individual packages.
- Most packages are dropped on their bases. In most studies, base drops have averaged over 50% of the total number of drops.
- The heavier the package, the lower the drop height.

Drop Height Generalizations

According to Fred Ostram and W. D. Godshall

- The larger the package, the lower the drop height.
- Handholds reduce the drop height by lowering the container relative to the floor during handling.
- Labels such as *fragile* and *handle with care* have some effect but can be considered minor.

Drop Height Generalizations

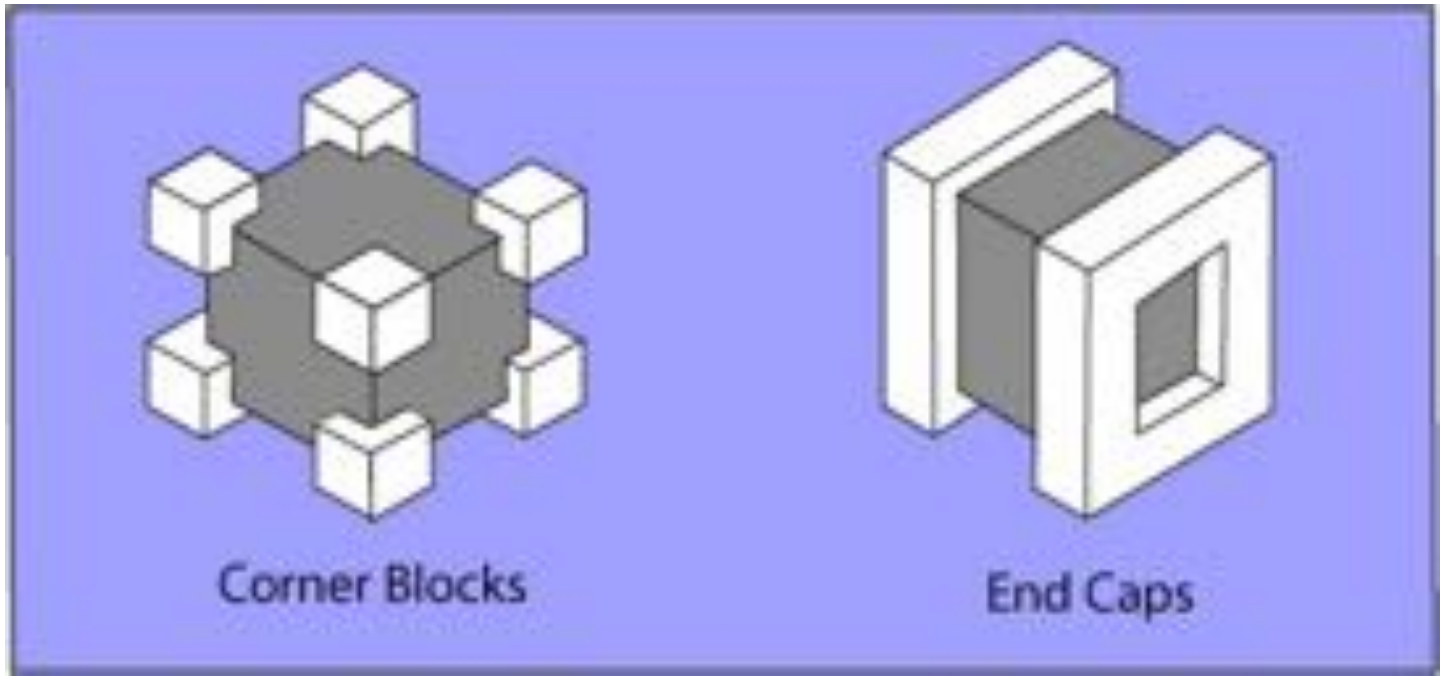
Drop Height Generalizations

Static Load

$$\text{Static Load} = \frac{\text{Mass}}{\text{Surface Area}}$$

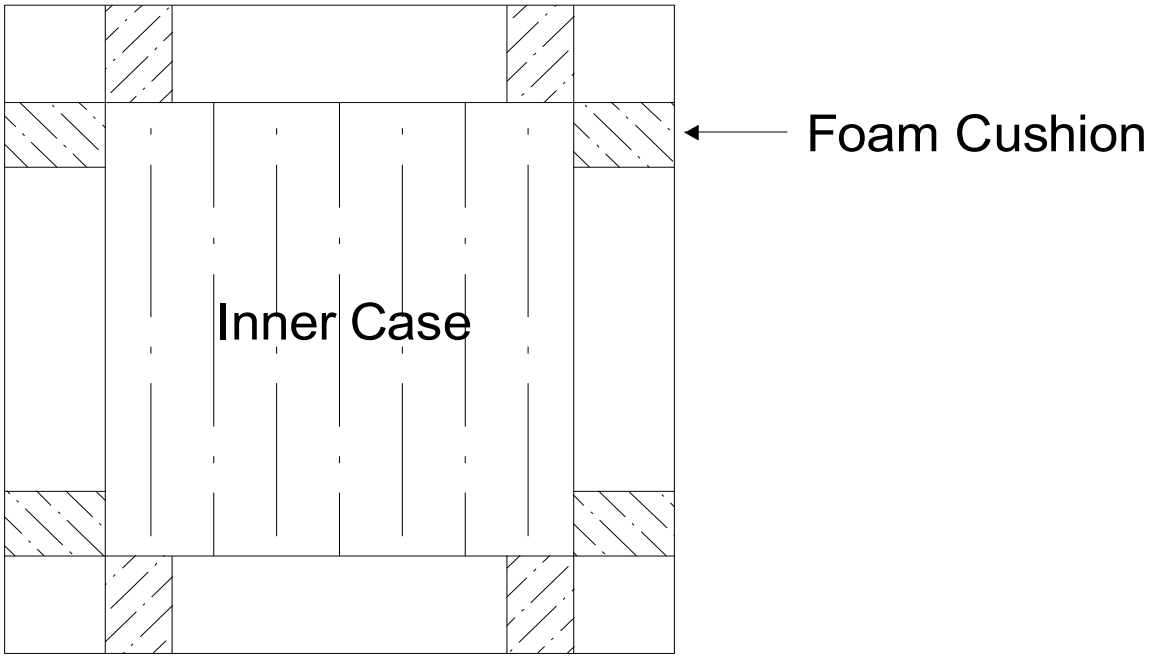
Static Load

Static Load

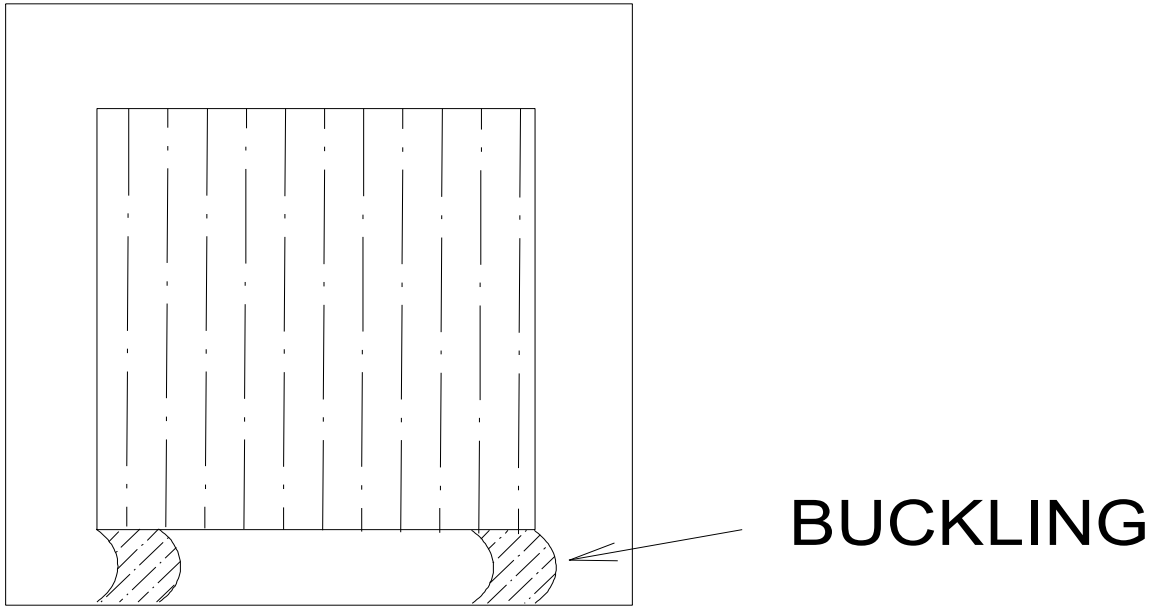


Cushion shape not important
If load is stable

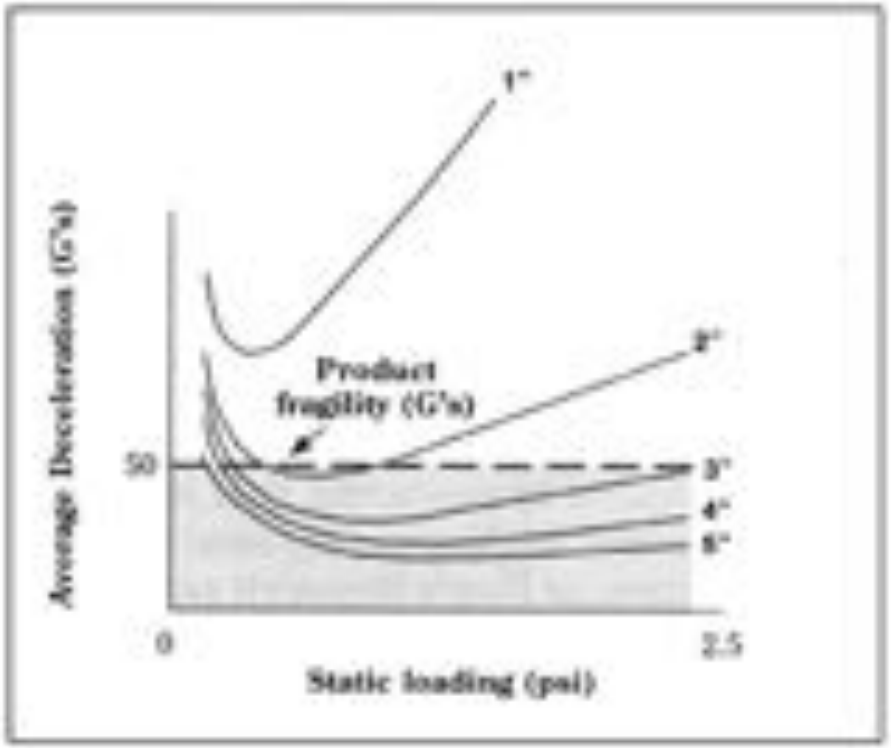
Cushion Buckling



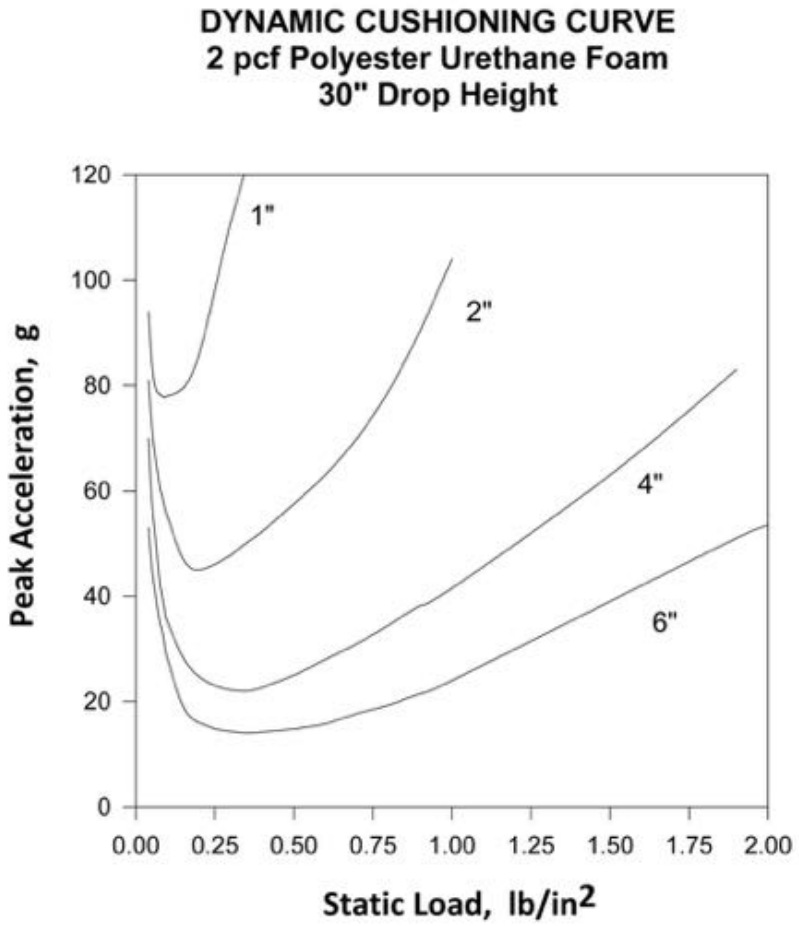
Cushion Buckling

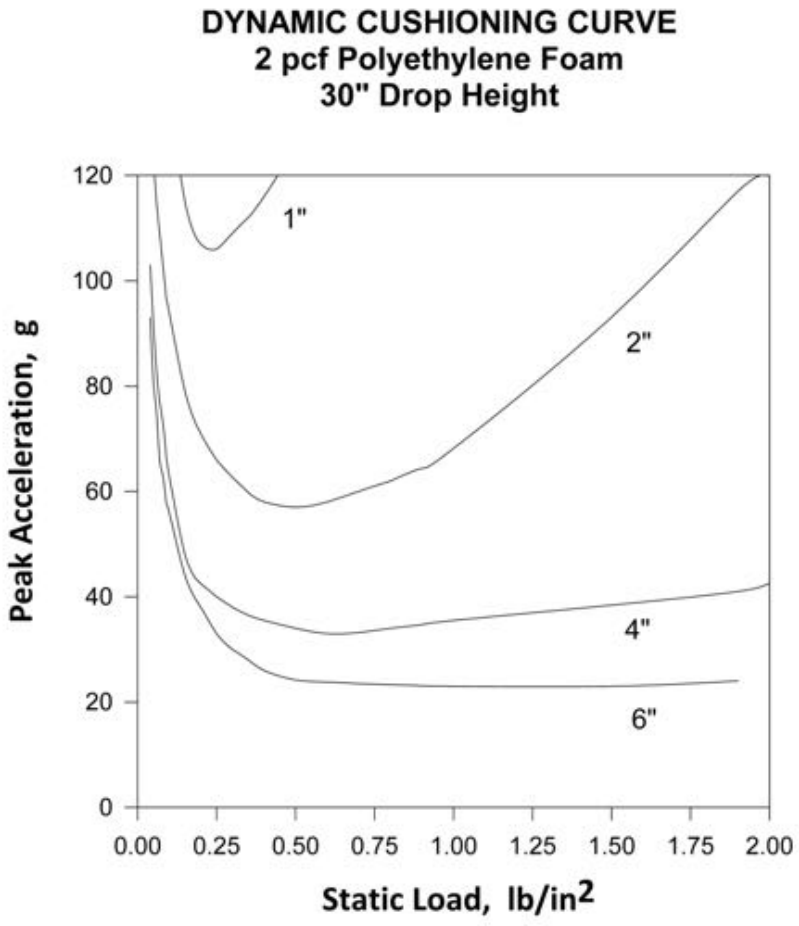


Dynamic Cushioning Curves



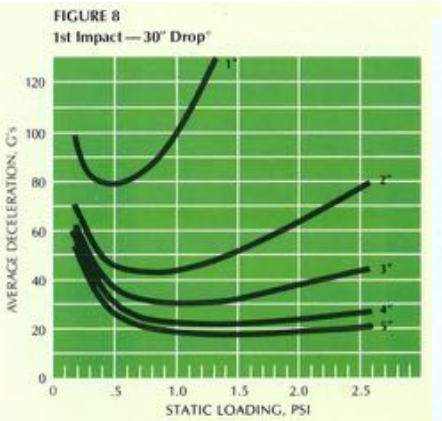
Dynamic Cushioning Curves

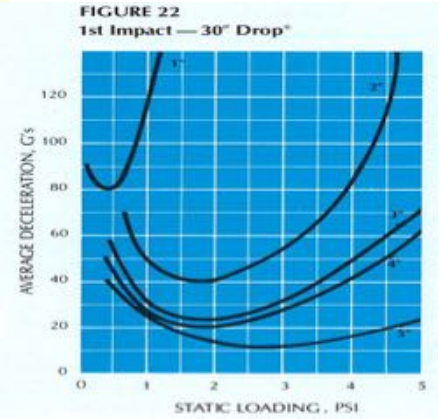


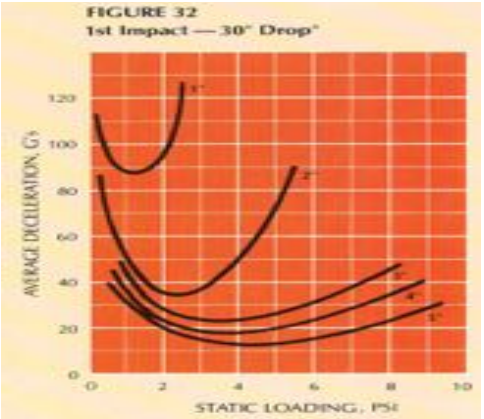


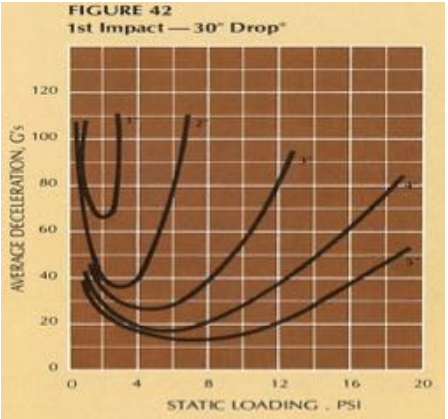
Dynamic Cushioning Curves

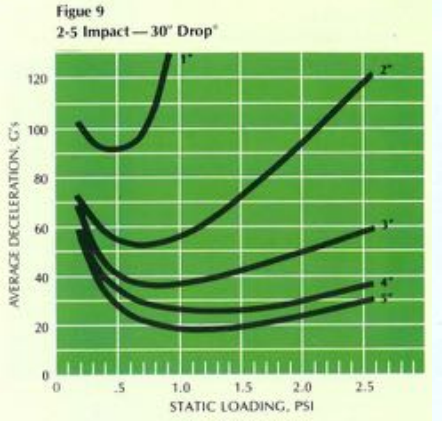
Ethafoam 220, 400, 600, 900

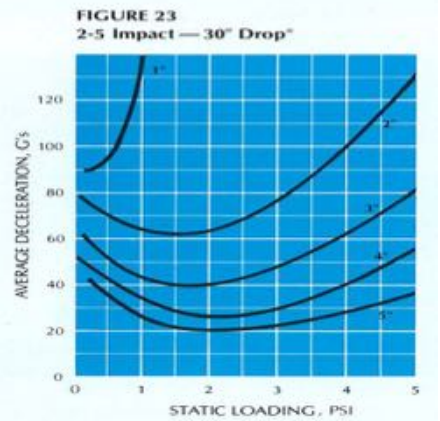


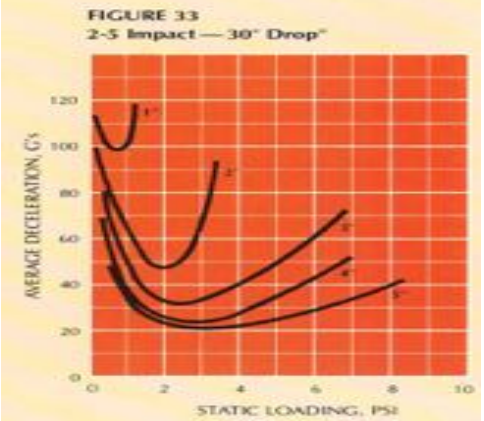


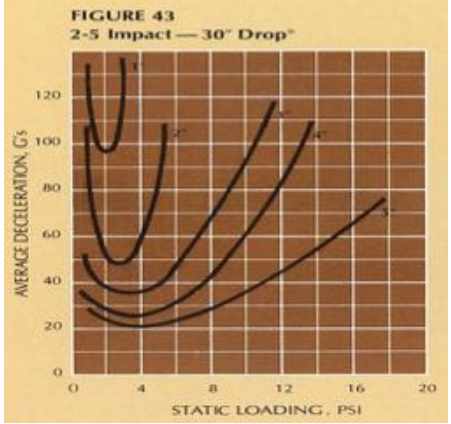








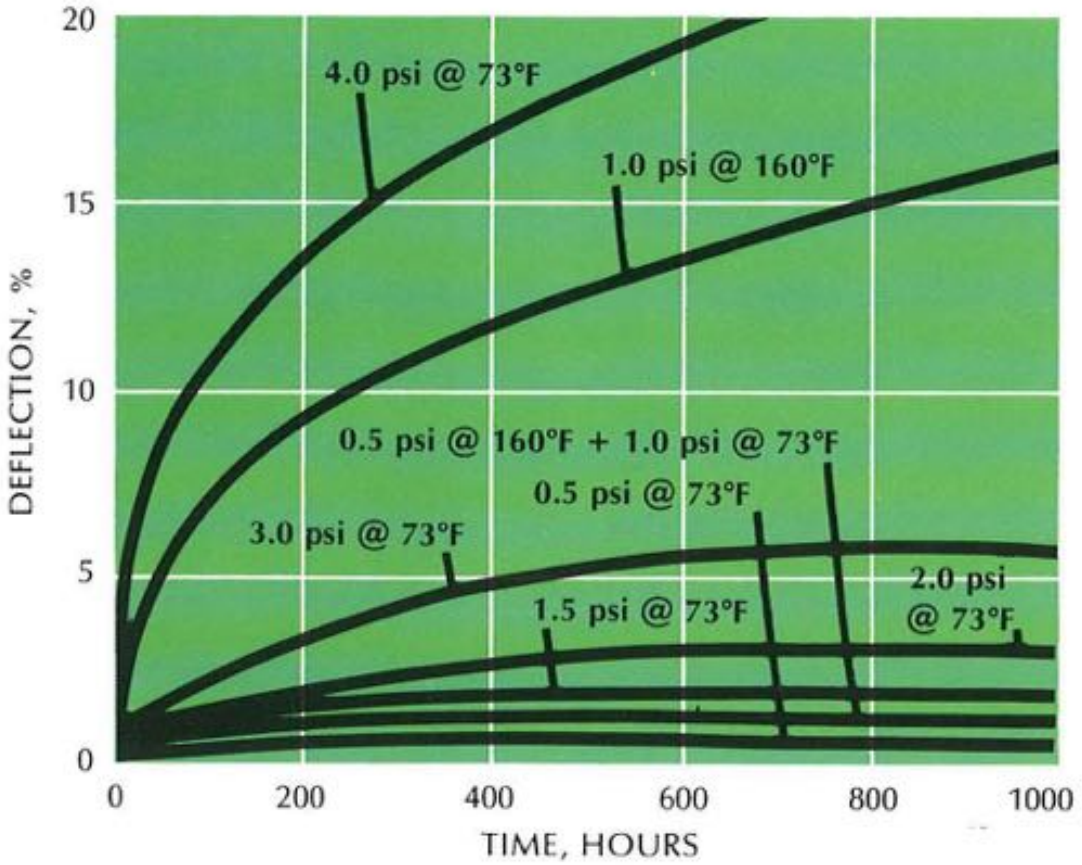




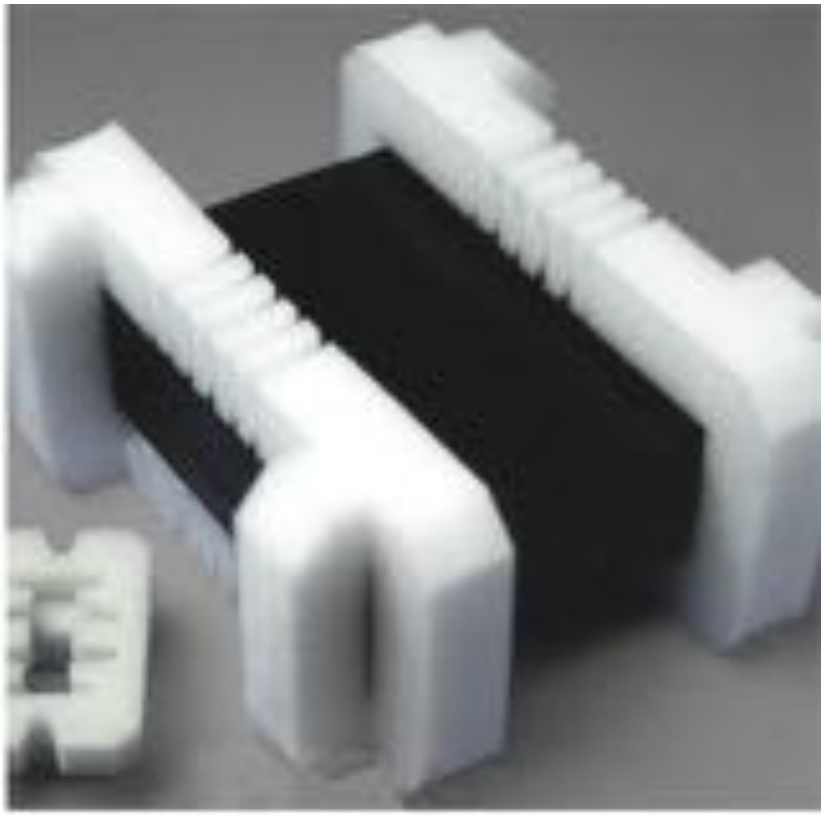
Compression Creep

FIGURE 65

Compressive Creep of ETHAFOAM 220 Plastic Foam 4″ x 4″ x 2″ Sample*



Shock



Polystyrene

Shock

Risk in Handling

Temperature in Transit

Temperature in Transit

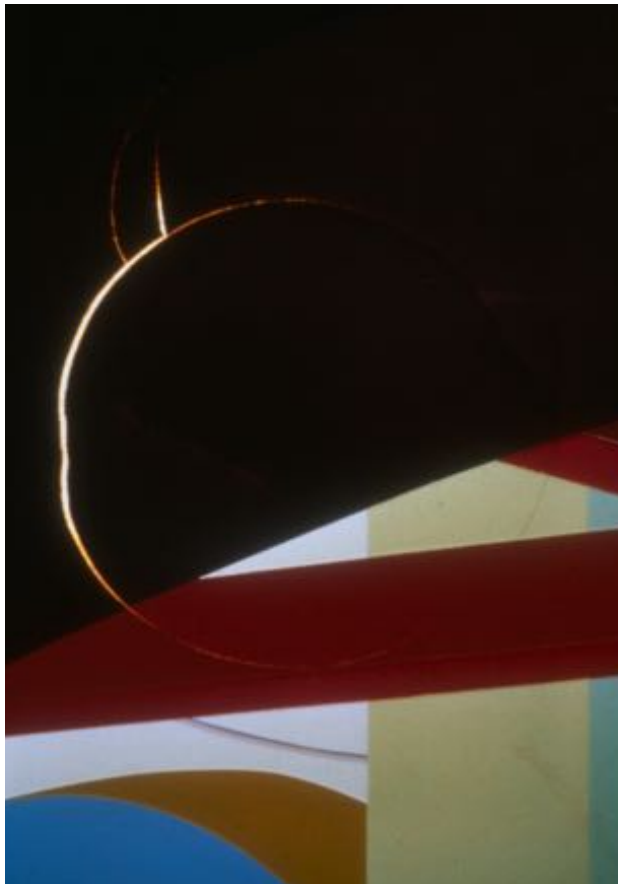
Temperature in Transit

Temperature in Transit

- Some materials become more brittle at lower temperatures
- Some materials become tacky at higher temperatures

Temperature-Related Damage

Temperature-Related Damage

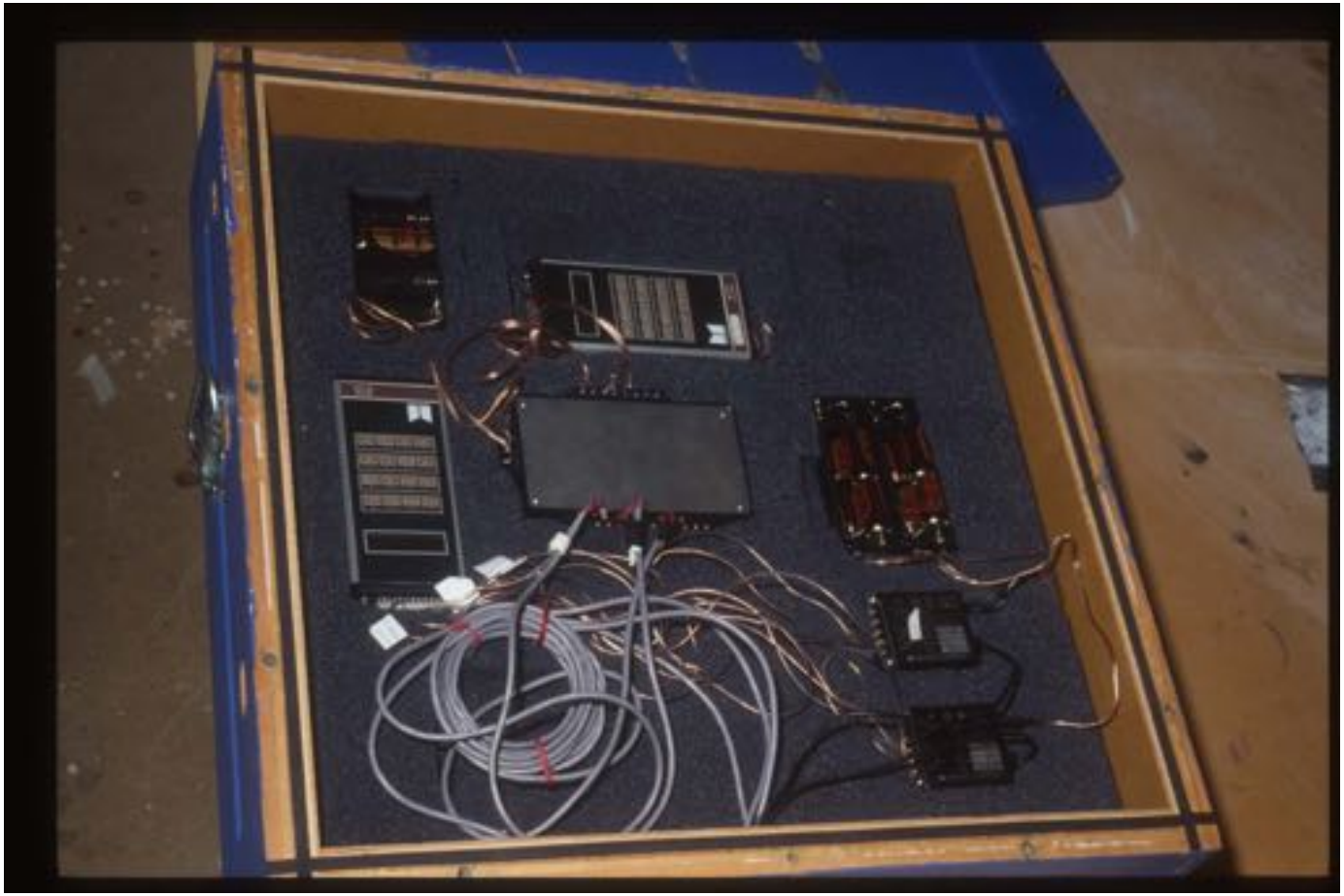


Temperature-Related Damage

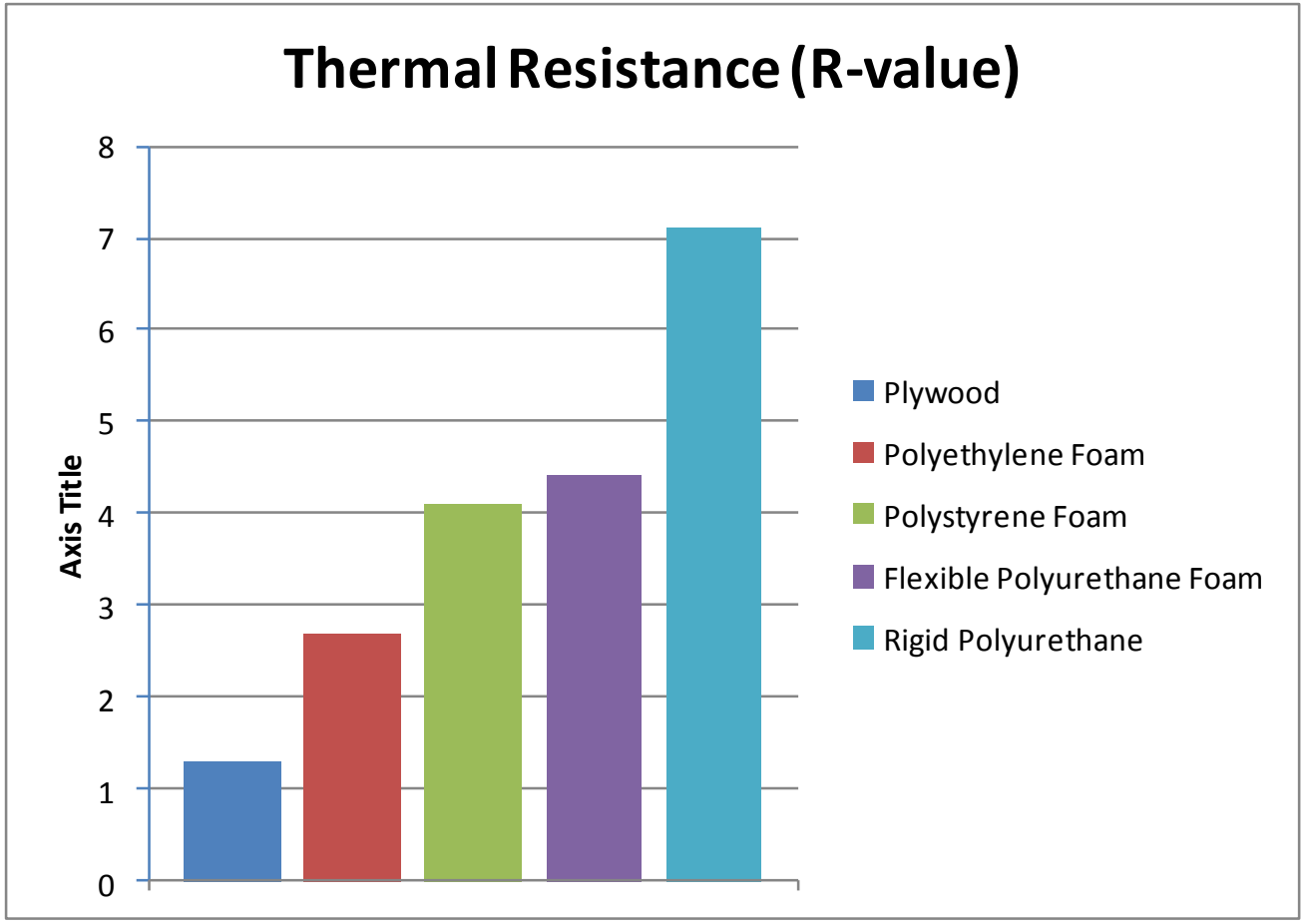
Environmental Chamber

-40° to 400° F, 10% to 85% RH (from approximately 40° to 200° F)

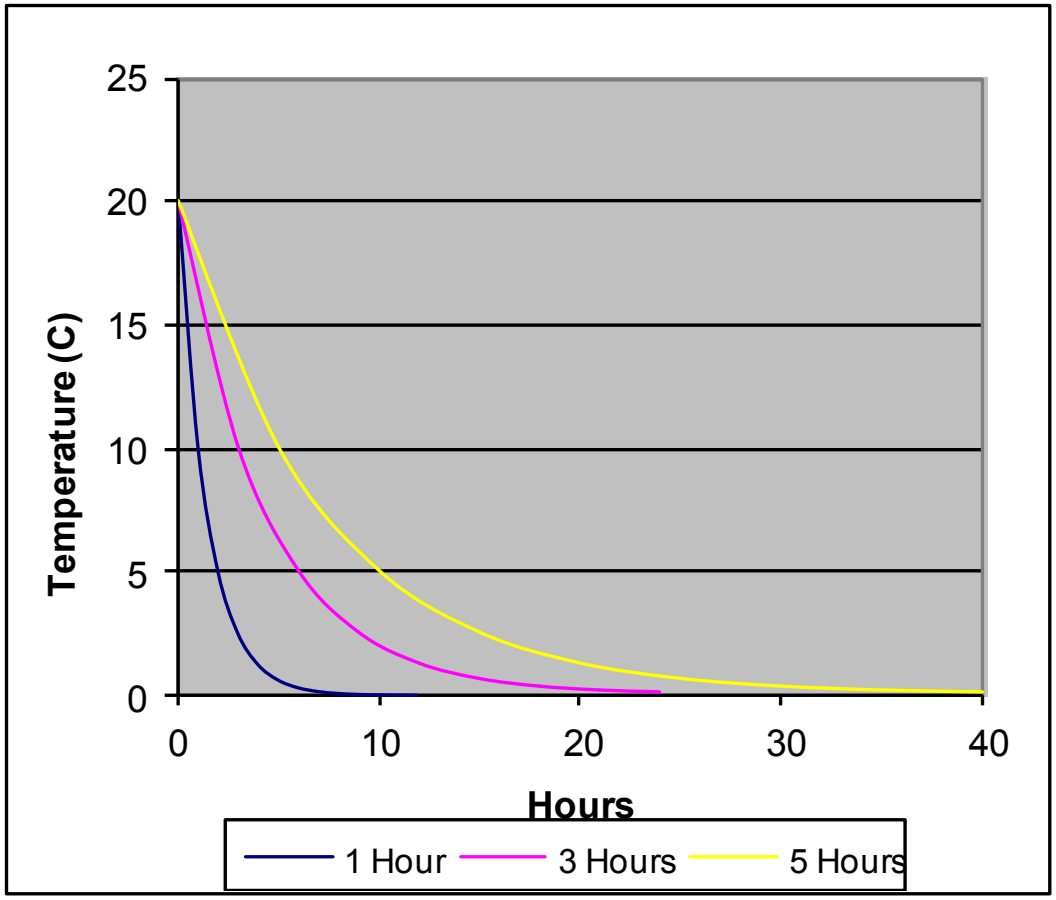
What Would TSA Say?



Insulating Value Of Packing Foams



Thermal Half Times Packing Cases



Relative Humidity

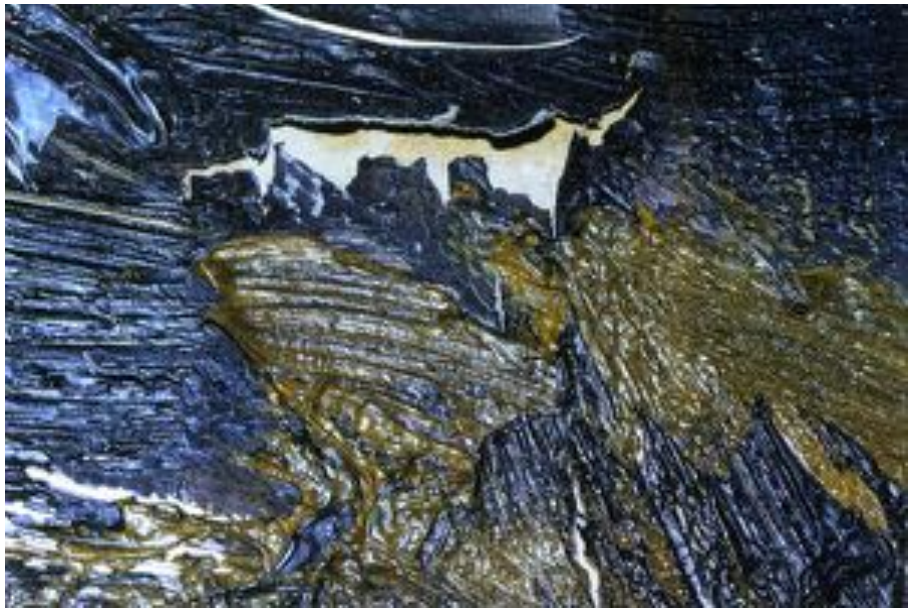
Relative Humidity

The ratio of the amount of water vapor in the air at a specific temperature to the maximum amount that the air could hold at that temperature, expressed as a percentage

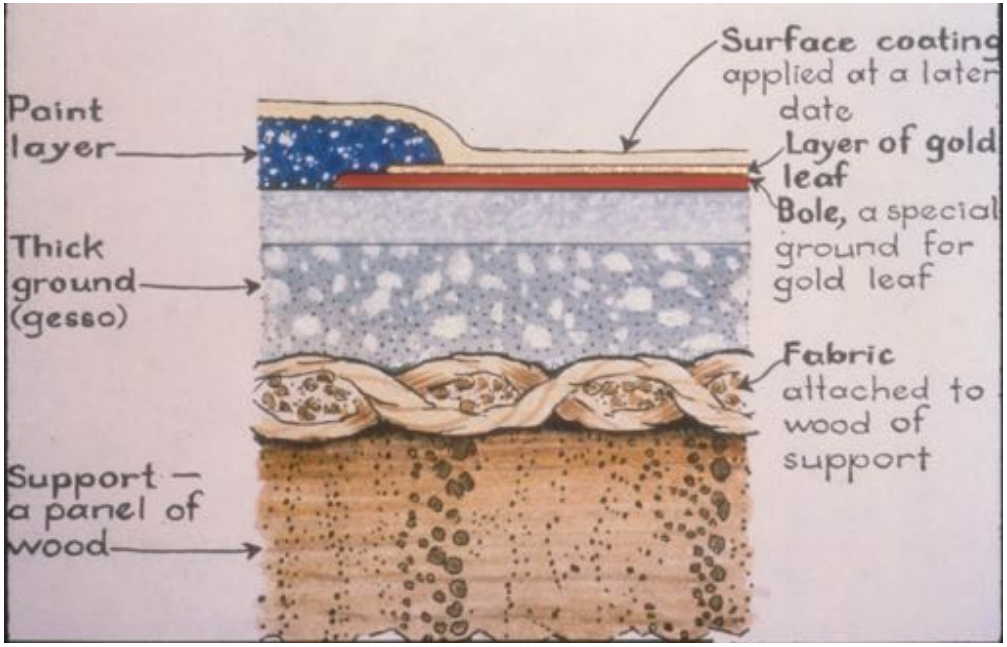
Free Dictionary Online

Relative Humidity

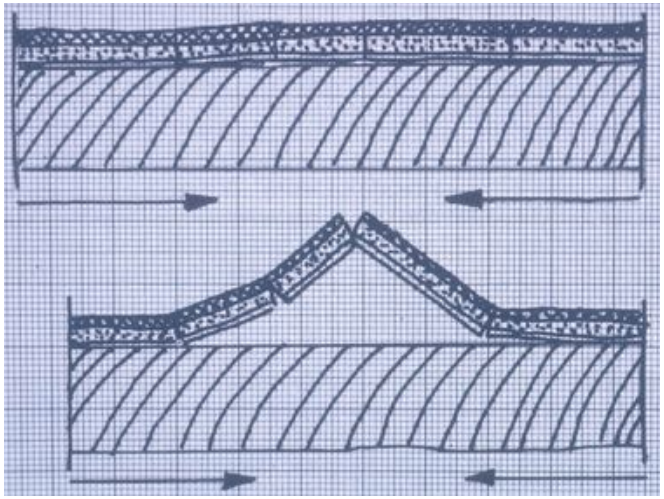
Flaking Paint



Relative Humidity



Flaking Paint



Relative Humidity

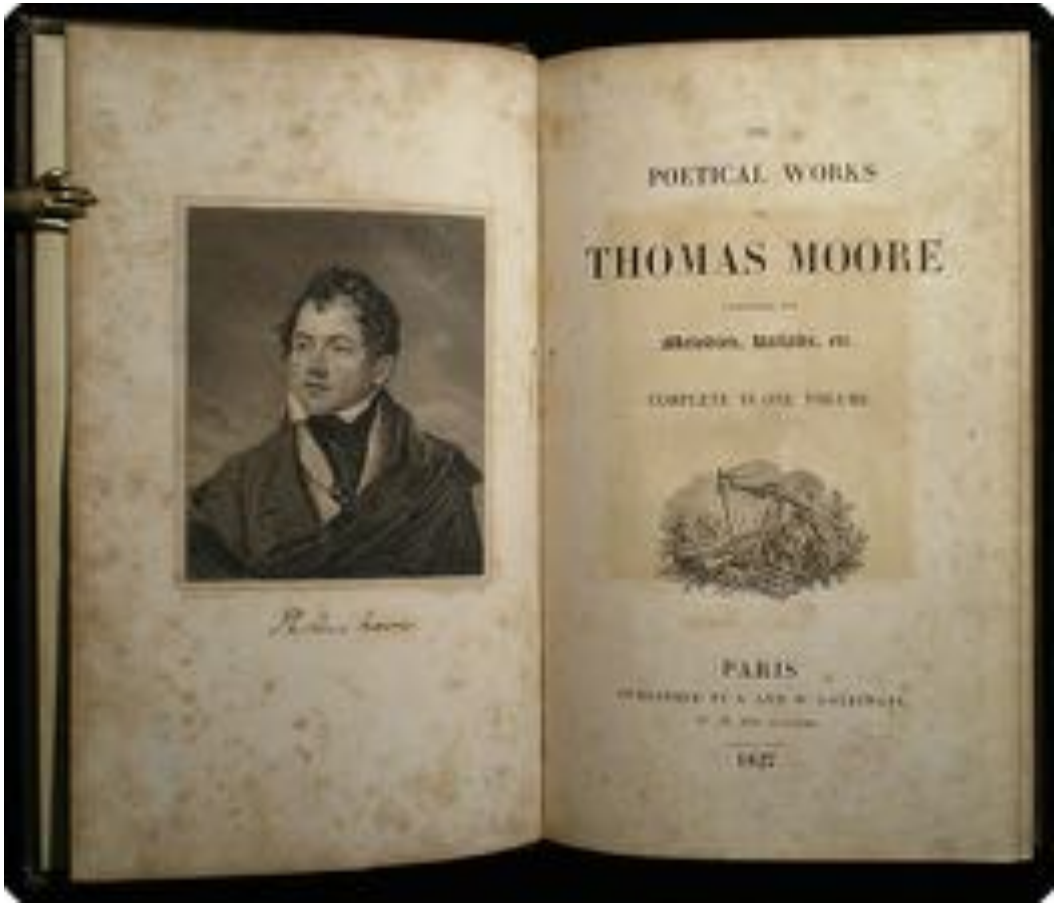
Varnish Bloom

John Singleton Copley
Portrait of Eleazer Tyng
1772, Oil on Canvas
National Gallery of Art

Relative Humidity

Corrosion

Relative Humidity



Mold

Environmental Specifications
National Gallery of Art

Temperature

70° F ± 5° F (21° C ± 2.5° C)

Relative Humidity

50% ± 5%

Environmental Specifications

Relative Humidity
45% ± 5%

Relative Humidity
55% ± 2%

Relative Humidity
50% ± 5%

Relative Humidity
55% ± 5%

Relative Humidity
50% ± 5% (summer)
45% ± 5% (winter)

Relative Humidity in Transit

Proper packing can minimize variations in relative humidity

Wrap in Plastic

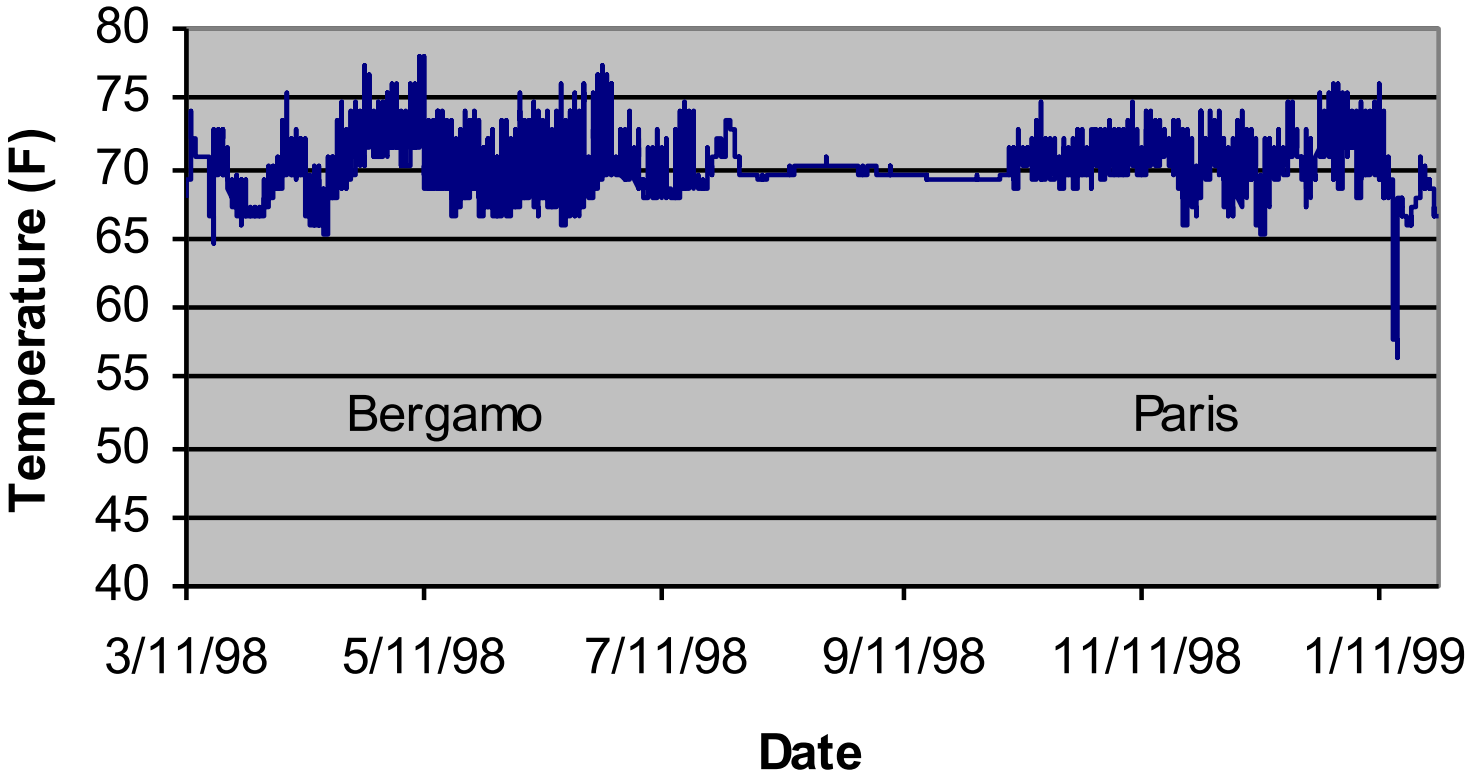
When Painting Equilibrated to a
Relative Humidity Below 65%

Microclimate Packages

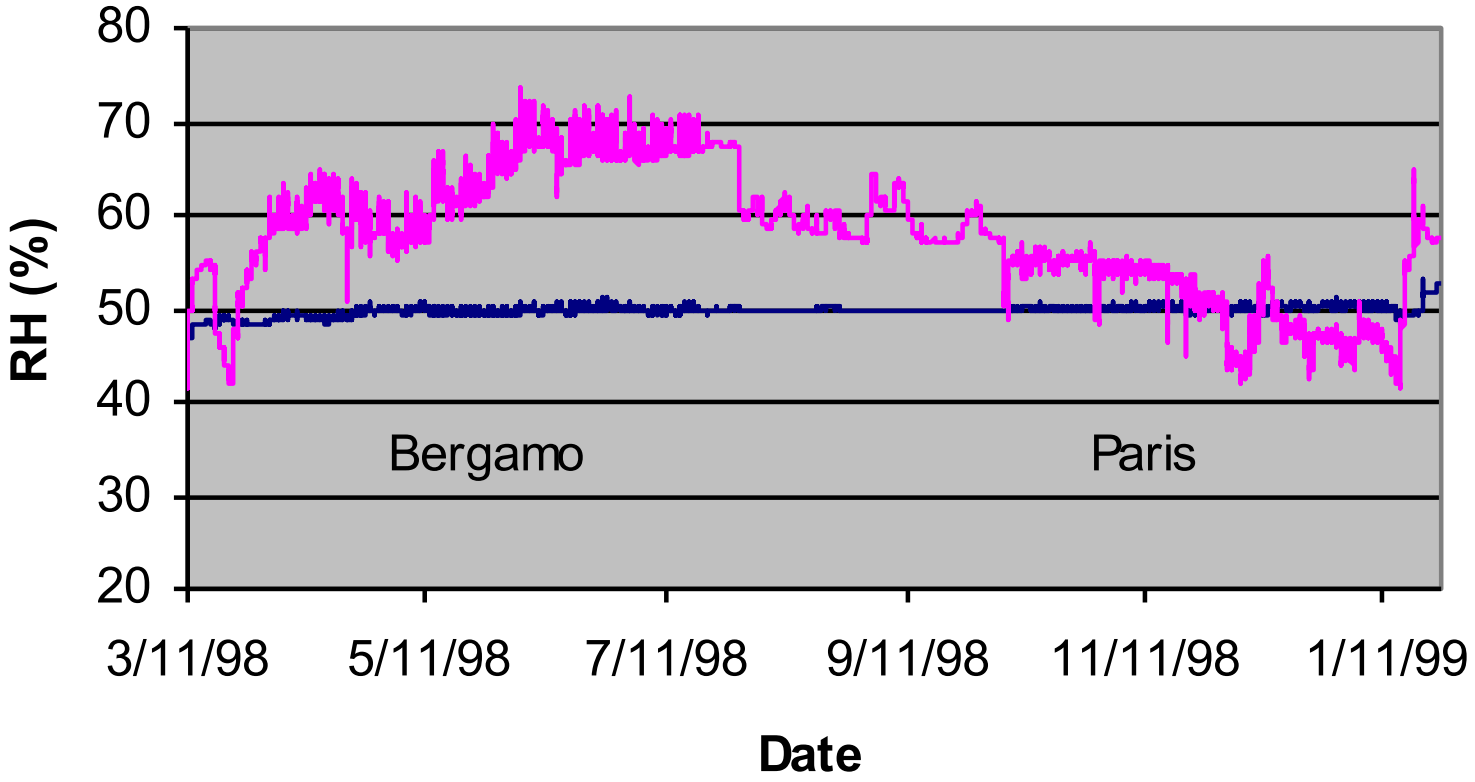
Titian
Italian, c. 1490 - 1576
Cardinal Pietro Bembo
c. 1540, oil on canvas
Samuel H. Kress Collection,
1952.5.28

Microclimate Packages

Lorenzo Lotto - St. Catherine on Loan in Microclimte Case



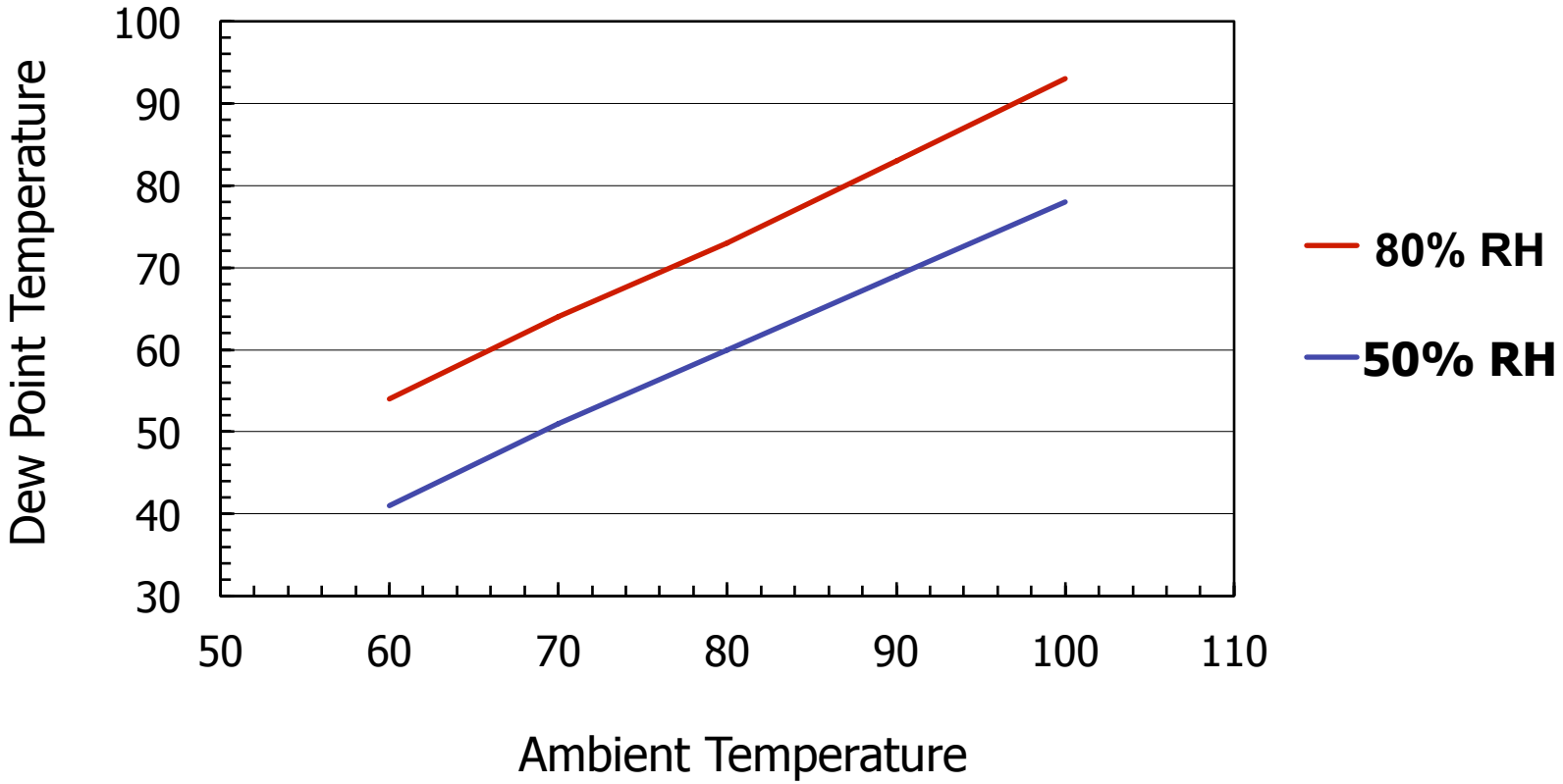
Lorenzo Lotto - St. Catherine on Loan in Microclimte Case



Dew Point Temperature

Temperature	50% RH	80% RH
60° F	41° F	54° F
70° F	51° F	64° F
80° F	60° F	73° F
90° F	69° F	83° F

Dew Point Temperature



Dew Point Temperature

Pollutants

Pest

Thank You for Listening